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PHYSICS | Class 12

- Chapterwise Summary
- Knowledge Boosters
- Objective Format as per the Latest Examination Pattern
- Tips and Tricks
- Common Errors
- Important NCERT Textbook/Exemplar Questions
- 2 Sample Question Papers with Specimen O.M.R Sheet

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TIPS AND TRICKS

How to PREPARE EFFECTIVELY TO SCORE WELL in the CBSE BOARD EXAMINATIONS

All learners wish to score well in the exams, and all of them are capable of doing so. What separates those who actually score well from those who do not is not hard to see. Below are a few important tips and tricks we have collected from speaking with and observing thousands of students who have done well in their board exams.

GIRD UP YOUR LOINS

In the present testing times due to Covid-19, you must be feeling a little short of confidence; concepts may not be as clear as they should be and you might be feeling not-ready to take the exams. Don't worry, all students are in the same boat. Focus hard on your studies, practise regularly and feel confident. Gird up your loins—it's time for action.

MAKE A SCHEDULE

Make a schedule for your studies and follow it earnestly. Decide the total number of hours you should devote to your studies and further divide them subjectwise. Try to get up early and utilise the morning hours as much as you can.

LEARN CONSTRUCTIVELY

You must utilise your time in a productive and beneficial way. Mere reading the textbook and making notes will not do much good. Try to understand the concepts and absorb them thoroughly. Summarise the topics and go through them every now and then.

Understanding the concepts and absorbing the key points will make you achieve the desired result.

MNEMONICS

Try to remember various concepts using the mnemonics like:

FANBOYS	:	(Coordinating conjunctions)—For, And, Nor, But, Or, Yet, So
PEMDAS	:	(Order of Maths operations)—Parentheses, Exponents, Multiplication, Division, Addition, Subtraction
ROY G. BIV	:	(The spectrum of colours)—Red, Orange, Yellow, Green, Blue, Indigo, Violet
PVT TIM HALL	:	(Essential Amino Acids)—Phenylalanine, Valine, Threonine, Tryptophan, Isoleucine, Methionine, Histidine, Arginine, Leucine, Lysine

You can also make your own mnemonics that will help you in absorbing the key points.

ADAPT YOURSELF TO THE CHANGE IN LEARNING

The last two years has seen a sudden change in the traditional way of learning. There has been a rapid rise in the need for online classes and self-study. You should adapt yourself to this sudden and rapid change in learning. You must get prepared and sharpen your skills as you have to work hard more on your own.

PRACTICE OBJECTIVE QUESTIONS DILIGENTLY AND REGULARLY

As you know 'Practice Makes Us Perfect'. A diligent and regular practice becomes necessary to attempt objective questions as one has to be quick in answering them within the prescribed time limit. There is no internal distribution of marks as well as no choice of step-marking in such questions i.e. either student will get full marks or no mark. So regular practice is the central theme in this pattern.

RECOGNISE THE PATTERN

Keep yourself updated with the latest pattern and format of the question paper. Through regular practice, you may be able to compose your own objective questions and answer them. Time management should be adhered with while attempting such questions else many of the questions may be left unanswered.

STAY COMPOSED

Try to keep calm and be in control of your feelings. Don't let the anxiety, fear, stress or despair come anywhere near you. Take a balanced diet, sleep well and do some physical exercise regularly. Spend some time doing the things which you like. Stay fit, calm and composed. It will help you immensely in your preparations and will lead you to success.

PREPARE FOR THE BIG DAY

The examination day holds a great significance for the learners. Most of the learners try and assimilate as much as they can, just before the examination. This stressful, last minute preparation should be avoided, as much as possible. The preparation should end a night before the examination. A sound sleep is important for a fresh start in the morning. Avoid over-stressing just before the examination.

MINDSET DURING EXAM

In the examination hall, ensure that you have filled your particulars in the answer sheets correctly. Mark your answers while reading the questions and attempt as according to the given direction. If you have a little time left in the end and many of the questions unanswered, provide quick answer to each question and don't waste your time in thinking. This will help you attempt all the questions within time limit.

EFFECTIVE USE OF TIME

In case, you have solved the paper before time, don't leave the examination hall. Revise your attempted answers and re-think about those not answered. Mark the correct or incorrect answers to unattempted questions as you will attain full marks for each correct answer but no mark will be deducted for wrong ones.

Gear up yourself with these sure shot arrows and hit the desired target.

All The Best!

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CHAPTER 1

Scan the **QR Code** and get instant access to Video Lecture of this Chapter

Electric Charges and Fields

Fastrack REVISION

- **Electric Charge:** It is a basic property of matter due to which it produces and experiences electric and magnetic effects.
  - It is a scalar quantity.
  - Its S.I. unit is Coulomb (C).
  - Like charges repel each other and unlike charges attract each other.
  - Charge on glass rod or cat's fur is called positive/vitreous charge.
  - Charge on plastic rod or silk is called negative/resinous charge.
- **Electrostatic Induction:** The redistribution of charges takes place in the uncharged body due to the presence of a charged body near it. This is called electrostatic induction.
- **Additive Property:** Total charge on a body is equal to the algebraic sum of all the charges placed on different parts of the body.

  Consider a system which consists of three charges namely $q_1, -q_2$ and q_3.

  Net charge $\quad q = q_1 + (-q_2) + q_3$
- **Quantisation of Charge:** It is the property by virtue of which all free charges exist in integral multiple of an elementary charge *i.e.,* electron.

  $q = \pm ne$ where, n is an integer

  and $e = 1.6 \times 10^{-19}$ C
- **Conservation of Charge:** The net charge on an isolated system remains constant. However, charge may be transferred from one part of the system to another.
- **Coulomb's Law:** It states that the force between two point like stationary charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them.

$$F \propto \frac{q_1 q_2}{r^2}$$

$$F = k\frac{q_1 q_2}{r^2}$$

where, $\quad k = \frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ N-m}^2/\text{C}^2$

ε_0 is called the permittivity of free space.

- **Principle of Superposition:** The net force on any charge due to number of other charges is the vector sum of all the forces exerted on the given charge by all other charges individually.

  Thus net force on q_1 due to charges $q_2, q_3, q_4, \ldots$ is given by

$$\vec{F}_1 = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14} + \ldots$$

- **Electric Field:** The region or space around a charge in which an another charge 'q_0' experiences a force is called electric field.
  - It is a vector quantity.
  - Its S.I. unit is N/C.
  - Its dimensions are $MLT^{-2}/AT = [MLT^{-3}A^{-1}]$
  - Electric field does not exert any force on the charge which produces it.
  - Electric field exerts a force on any other charge placed in it.
  - The direction of a force on positive charge is the direction of electric field.
- **Electric Field Intensity:** Electric Field intensity at a point is defined as the force experienced by a unit positive test charge placed at that point.

$$\vec{E} = \frac{\vec{F}}{q_0}$$

- **Electric Field due to a Point Charge q:**

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$$

- **Electric Field Lines:** Electric field lines are smooth curves such that a tangent drawn at any point on the curve gives the direction of electric field at that point.
- **Characteristics of Field Lines:**
  - Electric field lines originate at positive charge and terminate at negative charge. They do not form closed loop.
  - Electric field lines do not exist inside conductors *i.e.,* $E = 0$ inside a conductor.
  - Electric field lines do not cross each other. If they do, it means two directions of electric field at a single point which is absurd.
  - Electric field lines originate and terminate normally from the surface of a conductor.
  - 'E' is stronger where electric field lines are crowded and 'E' is weaker where they are farther apart.
  - Number of electric field lines drawn are proportional to magnitude of the charge.
- **Electric Dipole:** A pair of equal and opposite charges separated by small distance constitute a dipole.

  Example: NaCl, H_2O.
- **Electric Dipole Moment (p):** Electric dipole moment is defined as the product of magnitude of either charge and distance between the two charges.

  i.e., $\quad \vec{p} = q(2a)$
  - Its S.I. unit is coulomb-metre (C-m).
  - It is a vector quantity.
  - Direction of p is from $-q$ to $+q$.
- **Torque on a Dipole in a Uniform Electric Field:**

  τ = One force × perpendicular distance between the forces

  $\tau = qE \times 2a\sin\theta$ or $\tau = pE\sin\theta \quad (\because p = q(2a))$
  - Torque rotates the dipole and aligns it's axis in the direction of $\vec{E}$.
- **Electric Field Intensity of an Electric Dipole:**

  (i) For points on the axis:

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{2\vec{p}}{(r)^3}$$

  (ii) For point on equatorial plane:

  Net electric field, $E = -\frac{1}{4\pi\varepsilon_0}\frac{p}{(r^2 + l^2)^{3/2}}\hat{p}$

  If $r >>> l$ then, $\quad \vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{\vec{p}}{r^3}$

- **Electric Flux (ϕ_E):** The number of electric field lines passing through any surface area held in the electric field is called electric flux (ϕ_E).
  - It is a scalar quantity.
  - Its S.I. unit is Nm^2C^{-1}.
  - $\phi_E = \oint E \cdot dS$
- **Gauss's Theorem:** The total electric flux passing through a closed surface is $\frac{1}{\varepsilon_0}$ times the total charge enclosed in the surface.

i.e., $$\phi_E = \frac{q_{enclosed}}{\varepsilon_0}$$

- **Applications of Gauss's Law**

(a) Electric field due to an infinitely long straight uniformly charged wire

$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

(b) Electric field due to a uniformly charged infinite plane sheet

$$E = \frac{\sigma}{2\varepsilon_0}$$

(c) Electric field intensity due to two equally and oppositely charged parallel plane sheet of charge at any point

$E = \frac{\sigma}{\varepsilon_0}$ (between the two plates)

$E = 0$ (outside the plates)

Objective TYPE QUESTIONS

Multiple Choice Questions

Q 1. Electricity produced on rubbing is:

a. static electricity

b. electromagnetic

c. current electricity

d. None of these

Ans. (a) static electricity

Q 2. When a person combs his hair, static electricity is sometimes generated by what process?

a. Contact between the comb and hair results in a charge

b. Friction between the comb and hair results in the transfer of electrons

c. Conduction between the comb and hair

d. Induction between the comb and hair

Ans. (b) Friction between the comb and hair results in the transfer of electrons

Q 3. During the process of rubbing of two bodies, which charged particle transfer during the process:

a. Electron b. Proton c. Neutron d. Positron

Ans. (a) Electron

Q 4. The quantity whose unit is kilo ampere hour:

a. current b. potential difference

c. power d. charge

Ans. (d) charge

Q 5. A body is positively charged, it implies that:

a. there is only positive charge in the body

b. there is positive as well as negative charge in the body but the positive charge is more than negative charge

c. there is equal positive and negative charge in the body but the positive charge lies in the outer regions

d. negative charge is displaced from its position

Ans. (b) there is positive as well as negative charge in the body but the positive charge is more than negative charge

Q 6. A body can be negatively charged:

a. by adding some electrons to it

b. by adding some protons to it

c. by removing some electrons from it

d. by removing some protons from it

Ans. (a) by adding some electrons to it

Q 7. There are two types of electric charge-positive charges and negative charges. The property which differentiates the two types of charges is:

a. field of charge b. amount of charge

c. strength of charge d. polarity of charge

Ans. (d) polarity of charge

Q 8. Object may acquire an excess or deficiency of charge by:

a. hammering b. heating

c. shaking d. rubbing

Ans. (d) rubbing

Q 9. What will happen when we rub a glass rod with silk cloth?

a. Some of the electrons from the glass rod are transferred to the silk cloth

b. The glass rod gets positive charge and silk cloth gets negative charge

c. New charges are created in the process of rubbing

d. Both a. and b. are correct

Ans. (d) Both a. and b. are correct.

Q 10. When two bodies are rubbed against each other, they acquire:

a. equal and similar charges

b. equal and opposite charges

c. unequal and similar charges

d. unequal and opposite charges

Ans. (b) equal and opposite charges

Q 11. Charge is the property associated with matter due to which it produces and experiences:

a. electric effects only

b. magnetic effects only

c. both electric and magnetic effects

d. None of the above

Ans. (c) both electric and magnetic effects

Q 12. In general, metallic ropes are suspended on the carriers taking inflammable materials. The reason is:

a. to control the speed of the carrier

b. to keep the centre of gravity of the carrier nearer to the earth

c. to keep the body of the carrier in contact with the earth

d. None of the above

Ans. (c) to keep the body of the carrier in contact with the earth

Q 13. When 10^{19} electrons are removed from a neutral plate, the electric charge on it is:

a. –1.6 C b. +1.6 C c. 10^{19} C d. 10^{-19} C

Ans. (b) +1.6 C

Charge of one electron, $e = -1.6 \times 10^{-19}$ C

So, total charge removed from neutral plate, $Q = ne$

$= 10^{19} \times (-1.6 \times 10^{-19})$

$= -1.6$ C

Since, charge on neutral plate is zero and –1.6 C charge is removed from it. Thus, now it has +1.6 C charge.

Q 14. When some charge is transferred to 'A', it readily gets distributed over the entire surface of 'A'. If some charge is put on 'B', it stays at the same place. Here, A and B refer to:

a. insulator, conductor

b. conductor, insulator

c. insulator, insulator

d. conductor, conductor

Ans. (b) conductor, insulator

Q 15. Which of the following is responsible for the conduction of electricity in solids?

a. Free electrons b. Anion and Cation

c. Electron-hole pair d. Ionised particles

Ans. (a) Free electrons

Q 16. What is responsible for the conduction of electricity in liquids?

a. Free electrons b. Anion and Cation

c. Electron-hole pair d. Ionised particles

Ans. (b) Anion and Cation

Q 17. Which of the following materials is the best conductor of electricity?

a. Platinum b. Gold c. Silicon d. Copper

Ans. (d) Copper

Q 18. Which of the following is not an insulator?

a. Dry air b. Diamond

c. Ebonite d. Human body

Ans. (d) Human body

Q 19. The dielectric constant of an insulator cannot be:

a. 3.5 b. 2

c. 4.2 d. ∞

Ans. (d) ∞

T!P

The dielectric constant of a conductor (metal) is infinity.

Q 20. Which of the following phenomenon is responsible for attracting bits of paper with a help of charged comb:

a. Electrostatic shielding b. Electrostatic induction

c. Electrostatic potential d. Electric field

Ans. (b) Electrostatic induction

Q 21. A method of charging a conductor without bringing a charged body in contact with it is called:

a. magnetisation b. electrification

c. electrostatic induction d. electromagnetic induction

Ans. (c) electrostatic induction

Q 22. When a body is charged by induction, then the body:

a. becomes neutral

b. loses whole of the charge on it

c. does not lose any charge

d. loses part of the charge on it

Ans. (c) does not lose any charge

Q 23. A cylindrical conductor is placed near another positively charged conductor. The net charge acquired by the cylindrical conductor will be:

a. positive only

b. negative only

c. zero

d. either positive or negative

Ans. (c) zero

Q 24. A conducting sphere is negatively charged. Which of the following statements is true?

a. The charge is uniformly distributed throughout the entire volume

b. The charge is located at the center of the sphere

c. The charge is located at the bottom of the sphere because of gravity

d. The charge is uniformly distributed on the surface of the sphere

Ans. (d) The charge is uniformly distributed on the surface of the sphere

Q 25. What would happen, if 2 identical bodies of opposite charge come in contact?

a. Charge is exchanged

b. Charge is neutralised

c. Positive and negative charge is induced in both bodies

d. Depends on the duration of contact

Ans. (b) Charge is neutralised

Q 26. Which of the following is not a property of electric charge?

a. Additivity of charge b. Quantisation of charge

c. Conservation of charge d. Superposition of charge

Ans. (d) Superposition of charge

Q 27. Which of the following has the same charge as the basic unit of charge?

a. Electron b. Proton

c. Positron d. Both a. and b.

Ans. (d) Both a. and b.

Q 28. Charge on a body is integral multiple of $\pm e$. It implies the law of:

a. Conversation of charge b. Conversation of mass

c. Conversation of energy d. Quantisation of charge

Ans. (d) Quantisation of charge

Q 29. A polythene piece rubbed with wool is found to have a negative charge of 6×10^{-7} C. The number of electrons transferred to polythene from wool is:

a. 3.75×10^{10} b. 9.6×10^{10}

c. 9.6×10^{12} d. 3.75×10^{12}

Ans. (d) 3.75×10^{12}

Here, $q = -6 \times 10^{-7}$ C

∴ Number of electrons transferred from wool to polythene,

$$n = \frac{q}{e} = \frac{-6 \times 10^{-7}}{-1.6 \times 10^{-19}} = 3.75 \times 10^{12}$$

Q 30. If 10^9 electrons move out of a body to another body every second, then the time required to get a total charge of 1 C on the other body is:

a. 250 years b. 100 years
c. 198 years d. 150 years

Ans. (c) 198 years

The charge given out in one second

$$= 1.6 \times 10^{-19}\ C \times 10^9 = 1.6 \times 10^{-10}\ C$$

Time required to accumulate a charge of 1 C

$$= \frac{1}{1.6 \times 10^{-10}} = 6.25 \times 10^9\ s = 198 \text{ years}$$

Q 31. The number of electrons that must be removed from an electrically neutral silver dollar to give it a charge of +2.4 C is:

a. 2.5×10^{19} b. 1.5×10^{19}
c. 1.5×10^{-19} d. 2.5×10^{-19}

Ans. (b) 1.5×10^{19}

Total charge, $q = +2.4$ C

Then by quantisation of charge, $q = ne$

$\therefore$ Number of electrons, $n = \frac{q}{e}$

$$= \frac{2.4\ C}{1.6 \times 10^{-19}\ C} = 1.5 \times 10^{19}$$

Q 32. If a charge on the body is 1 nC, then how many electrons are present on the body?

a. 1.6×10^{19} b. 6.25×10^9
c. 6.25×10^{27} d. 6.25×10^{28}

Ans. (b) 6.25×10^9

Given, $q = 1\text{nC} = 1 \times 1 \times 10^{-9}$ C

and $e = 1.6 \times 10^{-19}$

From the property of quantisation charge,

$$q = ne$$

$$\Rightarrow n = \frac{q}{e} = \frac{1 \times 10^{-9}}{1.6 \times 10^{-19}}$$

$$= 0.625 \times 10^{-9} \times 10^{19} = 6.25 \times 10^9$$

Q 33. An object of mass 1 kg contains 4×10^{20} atoms. If one electron is removed from every atom of the solid, the charge gained by the solid in 1 g is:

a. 2.8 C b. 6.4×10^{-2} C
c. 3.6×10^{-3} C d. 9.2×10^{-4} C

Ans. (b) 6.4×10^{-2} C

Here,

Number of electrons removed = Number of atoms in 1 g

or $n = \frac{4 \times 10^{20}}{10^3} = 4 \times 10^{17}$

$\therefore$ Charge, $q = ne$

$$= 4 \times 10^{17} \times 1.6 \times 10^{-19}\ C$$

$$= 6.4 \times 10^{-2}\ C$$

Q 34. Coulomb's law relates two charges and distance between them describing the electric force as being:

a. proportional to the sum of the charges
b. inversely proportional to the distance between charges
c. proportional to the product of the charges and inversely proportional to the distance
d. proportional to the product of the charges and inversely proportional to the square of distance

Ans. (d) proportional to the product of the charges and inversely proportional to the square of distance

Q 35. Which of the following statements is true about electric forces?

a. Electric forces are produced by electric charges
b. Like charges attract, unlike charges repel
c. Electric forces are weaker than gravitational forces
d. Positive and negative charges can combine to produce a third type of charge

Ans. (a) Electric forces are produced by electric charges

Q 36. In case of Coulomb's law, which quantity has to be measured accurately so that force due to the charges is more accurate:

a. Magnitude of one of the charge
b. Distance between charges
c. Permittivity
d. None of the above

Ans. (b) Distance between charges

Q 37. What is the SI unit of permittivity of free space:

a. Wb b. F
c. $C^2 N^{-1} m^{-2}$ d. $C^2 N^1 m^2$

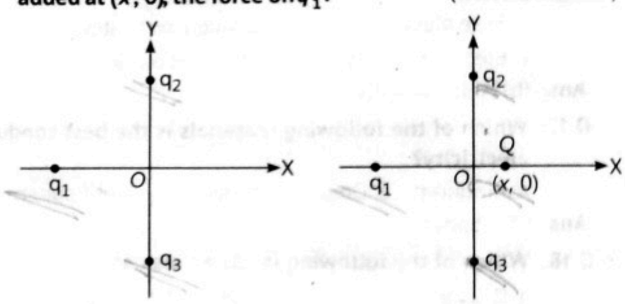
Ans. (c) $C^2 N^{-1} m^{-2}$

Q 38. The constant k in Coulomb's law depends on:

a. nature of medium b. system of units
c. intensity of charge d. Both a. and b.

Ans. (d) Both a. and b.

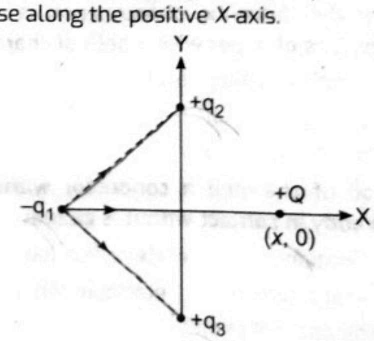
Q 39. In figure, two positive charges, q_2 and q_3 fixed along the Y-axis, exert a net electric force in the +x direction on a charge q_1 fixed along the X-axis. If a positive charge Q is added at (x, 0), the force on q_1: *(NCERT EXEMPLAR)*



a. shall increase along the positive X-axis
b. shall decrease along the positive X-axis
c. shall point along the negative X-axis
d. shall increase but the direction changes because of the intersection of Q with q_2 and q_3

Ans. (a) shall increase along the positive X-axis

Since, positive charge q_2 and q_3 exert a net force in the + x-direction on the charge q_1 fixed along the X-axis, the charge q_1 is negative as shown in figure. Obviously, due to addition of positive charge Q at (x, 0), the force on $-q$ shall increase along the positive X-axis.



Q 40. Which of the following statement is not a similarity between electrostatic and gravitational forces?

a. Both the forces obey inverse square law

b. Both the forces operate over very large distances

c. Both the forces are conservative in nature

d. Both the forces are always attractive in nature

Ans. (d) Both the forces are always attractive in nature

Q 41. The force between two small charged sphere having charges of 1×10^{-7} C and 2×10^{-7} C placed 20 cm apart in air is:

a. 4.5×10^{-2} N b. 4.5×10^{-3} N

c. 5.4×10^{-2} N d. 5.4×10^{-3} N

Ans. (b) 4.5×10^{-3} N

Here, $q_1 = 1 \times 10^{-7}$ C, $q_2 = 2 \times 10^{-7}$ C,

$r = 20$ cm $= 20 \times 10^{-2}$ m

As
$$F = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2} = \frac{9 \times 10^9 \times 1 \times 10^{-7} \times 2 \times 10^{-7}}{(20 \times 10^{-2})^2} = 4.5 \times 10^{-3} \text{ N}$$

Q 42. The nucleus of helium atom contains two protons that are separated by a distance 3.0×10^{-15} m. The magnitude of the electrostatic force that each proton exerts on the other is:

a. 20.6 N b. 25.6 N c. 15.6 N d. 12.6 N

Ans. (b) 25.6 N

Charge of proton is, $q_p = 1.6 \times 10^{-19}$ C

Distance between the protons is, $r = 3 \times 10^{-15}$ m

The magnitude of electrostatic force between protons is
$$F_e = \frac{q_p q_p}{4\pi\varepsilon_0 r^2} = \frac{9 \times 10^9 \times 1.6 \times 10^{-19} \times 1.6 \times 10^{-19}}{(3 \times 10^{-15})^2} = 25.6 \text{ N}$$

Q 43. Two insulated charged metallic spheres P and Q have their centres separated by a distance of 60 cm. The radii of P and Q are negligible compared to the distance of separation. The mutual force of electrostatic repulsion, if the charge on each is 3.2×10^{-7} C is:

a. 5.2×10^{-4} N b. 2.5×10^{-3} N

c. 1.5×10^{-3} N d. 3.5×10^{-4} N

Ans. (b) 2.5×10^{-3} N

Here, $q_1 = q_2 = 3.2 \times 10^{-7}$, $r = 60\text{cm} = 0.6\text{m}$

Electrostatic force,
$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2} = \frac{(9 \times 10^9)(3.2 \times 10^{-7})^2}{(0.6)^2} = 2.56 \times 10^{-3} \text{ N}$$

Q 44. Two point charges of $+3\mu$C and $+4\mu$C repel each other with a force of 10 N. If each is given an additional charge of -6μC, the new force is:

a. 2 N b. 4 N

c. 5 N d. 7.5 N

Ans. (c) 5 N

Here, $q_1 = +3\,\mu$C, $q_2 = +4\,\mu$C, $F = 10$ N

$q'_1 = +3 - 6 = -3\,\mu$C

$q'_2 = +4 - 6 = -2\,\mu$C

$$\therefore \quad \frac{F'}{F} = \frac{(q'_1)(q'_2)}{q_1 q_2} = \frac{(-3) \times (-2)}{3 \times 4} = \frac{6}{12} = \frac{1}{2}$$

$$\therefore \quad F' = \frac{1}{2} \times F = \frac{1}{2} \times 10 = 5 \text{ N}$$

Q 45. The ratio of magnitude of electrostatic force and gravitational force for an electron and a proton is:

a. 6.6×10^{39} b. 2.4×10^{39}

c. 6.6×10^{29} d. 2.4×10^{29}

Ans. (b) 2.4×10^{39}

For an electron and a proton:

Electrostatic force, $|F_e| = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$

Gravitational force, $|F_g| = \frac{Gm_e m_p}{r^2}$

$$\therefore \quad \frac{|F_e|}{|F_g|} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{Gm_e m_p} = \frac{9 \times 10^9 \times (1.6 \times 10^{-19})^2}{6.67 \times 10^{-11} \times 9 \times 10^{-31} \times 1.66 \times 10^{-27}} = 2.4 \times 10^{39}$$

Q 46. The electrostatic attracting force on a small sphere of charge 0.2 μC due to another small sphere of charge −0.4μC in air is 0.4 N. The distance between the two sphere is:

a. 43.2×10^{-6} m b. 42.4×10^{-3} m

c. 18.1×10^{-3} m d. 19.2×10^{-6} m

Ans. (b) 42.4×10^{-3} m

Here, $q_1 = 0.2\,\mu\text{C} = 0.2 \times 10^{-6}$ C

$q_2 = -0.4\,\mu\text{C} = -0.4 \times 10^{-6}$ C, $F = -0.4$ N

As $F = \frac{q_1 q_2}{4\pi\varepsilon_0 r^2}$

$$\therefore \quad r^2 = \frac{q_1 q_2}{4\pi\varepsilon_0 F} = \frac{0.2 \times 10^{-6} \times 0.4 \times 10^{-6} \times 9 \times 10^9}{0.4}$$

$\Rightarrow \quad r^2 = 1.8 \times 10^{-3}$

$\therefore \quad r = (1.8 \times 10^{-3})^{1/2} = 0.0424 \text{ m} = 42.4 \times 10^{-3}$ m

Q 47. An electron enters uniform electric field maintained by parallel plates and of value E Vm^{-1} with a velocity v ms^{-1}, the plates are separated by a distance d metre, then acceleration of the electron in the field is:

a. $\frac{Ee}{m}$ b. $\frac{-Ee}{m}$

c. $\frac{Ee}{md}$ d. $Ee\frac{d}{m}$

Ans. (a) $\frac{Ee}{m}$

We know that, $F = eE$

Therefore, acceleration in electron due to force F
$$a = \frac{F}{m} = \frac{eE}{m}$$

Q 48. Under the action of a given coulombic force the acceleration of an electron is 2.5×10^{22} ms^{-2}. Then the magnitude of the acceleration a proton under the action of same force is nearly:

a. 1.6×10^{-19} ms^2 b. 9.1×10^{31} ms^{-2}
c. 1.4×10^{19} ms^{-2} d. 1.6×10^{27} ms^{-2}

Ans. (c) 1.4×10^{19} ms^{-2}

The acceleration due to given coulombic force F is

$$a = \frac{F}{m} \text{ or } a \propto \frac{1}{m}$$

$$\therefore \quad \frac{a_p}{a_e} = \frac{m_e}{m_p}$$

where m_e and m_p are masses of electron and proton respectively.

$$a_p = \frac{a_e m_e}{m_p}$$

$$= \frac{(2.5 \times 10^{22} \text{ ms}^{-2})(9.1 \times 10^{-31} \text{ kg})}{(1.67 \times 10^{-27} \text{ kg})}$$

$$= 13.6 \times 10^{18} \text{ ms}^{-2} \approx 1.4 \times 10^{19} \text{ ms}^{-2}$$

Q 49. The acceleration for electron and proton due to electrical force of their mutual attraction when they are 1 Å apart is:

a. 3.1×10^{22} ms^{-2}, 1.3×10^{19} ms^{-2}
b. 3.3×10^{18} ms^{-2}, 3.2×10^{16} ms^{-2}
c. 2.5×10^{22} ms^{-2}, 1.4×10^{19} ms^{-2}
d. 2.5×10^{18} ms^{-2}, 1.3×10^{16} ms^{-2}.

Ans. (c) 2.5×10^{22} ms^{-2}, 1.4×10^{19} ms^{-2}

Force of mutual attraction between an electron and a proton

$$F = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$

$$= \frac{(9 \times 10^9)(1.6 \times 10^{-19})^2}{(10^{-10})^2} = 2.3 \times 10^{-8} \text{ N}$$

$$\text{Acceleration of electron} = \frac{F}{m_e}$$

$$= \frac{2.3 \times 10^{-8}}{9 \times 10^{-31}} = 2.5 \times 10^{22} \text{ ms}^{-2}$$

$$\text{Acceleration of proton} = \frac{F}{m_p}$$

$$= \frac{2.3 \times 10^{-8}}{1.66 \times 10^{-27}} = 1.4 \times 10^{19} \text{ ms}^{-2}$$

Q 50. In superposition principle, the force acting on the given charge by other charges is:

a. proportional to the given number charges
b. inversely proportional to the given number charges
c. unaffected by other charges
d. None of the above

Ans. (c) unaffected by other charges

Q 51. Each of the two points charges are doubled and their distance is halved. Force of interaction becomes *n* times, where *n* is:

a. 4 b. 1 c. 1/16 d. 16

Ans. (d) 16

From the formula, $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$

$$F' = \frac{1}{4\pi\varepsilon_0}\frac{2q_1 \times 2q_2}{(r/2)^2} = \frac{4}{1/4}F = 16F$$

$$\Rightarrow \quad nF = 16F \Rightarrow n = 16$$

Q 52. A charge 'q' is placed at the centre of the line joining of two equal +ve charge 'Q'. The system of the three charges will be in equilibrium, if q =

a. $-\frac{Q}{2}$ b. $-\frac{Q}{4}$ c. $\frac{Q}{4}$ d. $\frac{Q}{2}$

Ans. (b) $-\frac{Q}{4}$

At equilibrium, net force will be zero

$$\therefore \frac{1}{4\pi\varepsilon_0} \times \frac{Qq}{(r/2)^2} + \frac{1}{4\pi\varepsilon_0} \times \frac{Q^2}{r^2} = 0$$

$$4q = -Q$$

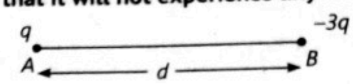
$$\text{or} \quad q = \frac{-Q}{4}$$

Q 53. Two spheres having charges +Q and $-Q$ is kept at a certain distance from each other. A force F acts between the two spheres. If a third sphere with charge Q is kept between then it experiences a force in magnitude and direction as:

a. 8 F towards +Q charge
b. 8 F towards $-Q$ charge
c. Zero having no direction
d. 4 F towards +Q charge

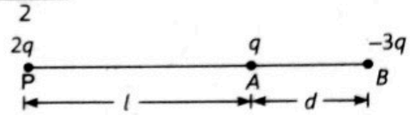
Ans. (b) 8 F towards $-Q$ charges

Q 54. Two charges q and $-3q$ are fixed on X-axis separated by distance d. Where should a third charge $2q$ be placed from A such that it will not experience any force?



a. $\frac{d - \sqrt{3}\,d}{2}$ b. $\frac{d + \sqrt{3}d}{2}$ c. $\frac{d + 3d}{2}$ d. $\frac{d - 3d}{2}$

Ans. (b) $\frac{d + \sqrt{3}\,d}{2}$



Let a charge $2q$ be placed at point P, at a distance l from A, where charge q is placed, as shown in figure.
The charge $2q$ will not experience any force, when force of repulsion on it due to q is balanced by force of attraction on it due to $3q$ at B, where $AB = d$.

$$\frac{(2q)(q)}{4\pi\varepsilon_0 l^2} = \frac{(2q)(3q)}{4\pi\varepsilon_0(l + d)^2}$$

$$(l + d)^2 = 3l^2$$

$$\text{or} \quad 2l^2 - 2ld - d^2 = 0$$

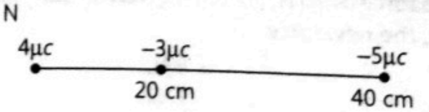
$$l = \frac{2d \pm \sqrt{4d^2 + 8d^2}}{4} = \frac{d}{2} \pm \frac{\sqrt{3}\,d}{2}$$

$$\Rightarrow \quad l = \frac{d + \sqrt{3}\,d}{2}$$

Q 55. Three point charges are placed on the following points along the X-axis: 4μC at $x = 0$, -3μC at $x = 20$ cm; and -5μC at $x = 40$ cm. What is the value of force on -3μC (approximately):

a. 6 N b. 4 N c. 3 N d. 5 N

Ans. (a) 6 N



$$F_1 = \left(\frac{1}{4\pi\varepsilon_0}\right)\frac{q_1 q_2}{r^2}$$

$$= \frac{9\times10^9 \times 3\times10^{-6}\times 4\times10^{-6}}{(20\times10^{-2})^2} = \frac{108\times10^{-3}}{4\times10^{-2}} = 2.7\text{ N}$$

$$F_2 = \frac{9\times10^9\times 3\times10^{-6}\times 5\times10^{-6}}{(20\times10^{-2})^2}$$

$$= \frac{105\times10^{-3}}{4\times10^{-2}} = 3.375\text{ N}$$

$$F_{net} = F_1 + F_2$$

$$= 2.7 + 3.375 = 6.075\text{ N} \cong 6\text{ N}$$

Q 56. Consider the charge q, q and $-q$ placed at the vertices of an equilateral triangle of each side l. The sum of forces acting on each charge is:

a. $\dfrac{q^2}{4\sqrt{2}\,\pi\varepsilon_0 l^2}$ b. $\dfrac{-q^2}{4\pi\varepsilon_0 l^2}$

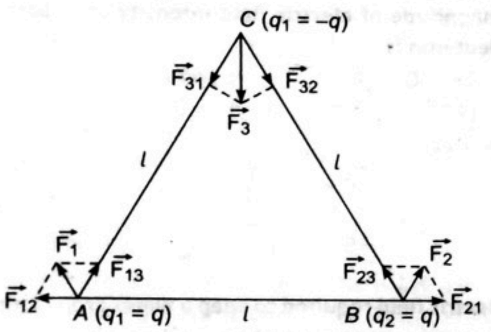
c. $\dfrac{q^2}{4\pi\varepsilon_0 l^2}$ d. zero

Ans. (d) zero

From diagram, force on $q_1 (= q)$ at A,

$$\vec{F}_1 = \vec{F}_{12} + \vec{F}_{13} = F\hat{r}_1$$

where, $F = \dfrac{q^2}{4\pi\varepsilon_0 l^2}$ and $\hat{r}_1$ is the unit vector along BC.



Force on $q_2 (= q)$ at B,

$$\vec{F}_2 = \vec{F}_{21} + \vec{F}_{23} = F\hat{r}_2$$

where, $\hat{r}_2$ is the unit vector along AC.

Force on $q_3 (= -q)$ at C,

$$\vec{F}_3 = \vec{F}_{31} + \vec{F}_{32}$$

$$= \left(\sqrt{F^2 + F^2 + 2F\cdot F\cos 60^\circ}\right)\hat{n} = \sqrt{3}\,F\,\hat{n}$$

where, $\hat{n}$ = unit vector along the direction bisecting $\angle BCA$.

$\therefore\ \vec{F}_1 + \vec{F}_2 + \vec{F}_3 = 0$

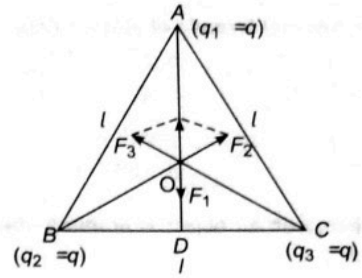
Q 57. Three charges of equal magnitude q are placed at the vertices of an equilateral triangle of side l. The force on a charge Q placed at the centroid of the triangle is:

a. $\dfrac{3Qq}{4\pi\varepsilon_0 l^2}$ b. $\dfrac{2Qq}{4\pi\varepsilon_0 l^2}$

c. $\dfrac{Qq}{2\pi\varepsilon_0 l^2}$ d. zero

Ans. (d) zero

As shown in figure, draw $AD \perp BC$.



$$\therefore \quad AD = AB\cos 30^\circ = \frac{l\sqrt{3}}{2}$$

Distance (AO) of the centroid O from A

$$\frac{2}{3}AD = \frac{2l}{3}\frac{\sqrt{3}}{2} = \frac{l}{\sqrt{3}}$$

$\therefore$ Force on Q at O due to charge, $q_1 = q$ at A,

$$\vec{F}_1 = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{(l/\sqrt{3})^2} = \frac{3Qq}{4\pi\varepsilon_0 l^2}, \text{ along } AO$$

Similarly, force on O due to charge, $q_2 = q$ at B,

$$\vec{F}_2 = \frac{3Qq}{4\pi\varepsilon_0 l^2}, \text{ along } BO$$

and force on Q due to charge, $q_3 = q$ at C

$$\vec{F}_3 = \frac{3Qq}{4\pi\varepsilon_0 l^2}, \text{ along } CO$$

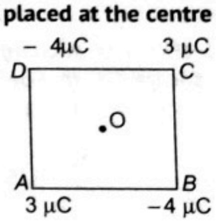
Angle between forces F_2 and $F_3 = 120^\circ$

By parallelogram law, resultant of forces $\vec{F}_2$ and $\vec{F}_3$

$$= \frac{3Qq}{4\pi\varepsilon_0 l^2}, \text{ along } OA$$

$$\therefore \text{Total force on } Q = \frac{3Qq}{4\pi\varepsilon_0 l^2} - \frac{3Qq}{4\pi\varepsilon_0 l^2} = 0$$

Q 58. Four point charges are placed at the corners of a square *ABCD* of side 10 cm, as shown in figure. The force on a charge of 1 μC placed at the centre of square is:



a. 7 N b. 8 N c. 2 N d. zero

Ans. (d) zero

Forces of repulsion on 1μC charge at O due to 3 μC charges, at A and C are equal and opposite. So, they cancel each other. Similarly, forces of attraction of 1μC charge at O due to −4 μC charges at B and D are also equal and opposite. So they also cancel each other.

Hence, the net force on the charge of 1μC at O is zero.

Q 59. V/m is the SI unit of which physical quantity:

a. Electric potential b. Electric field

c. Electrostatic force d. Electric dipole moment

Ans. (b) Electric field

Q 60. The electric field at a point is:

a. always continuous

b. continuous, if there is no charge at that point

c. discontinuous, if there is a charge at that point

d. Both b. and c. are correct

Ans. (d) Both b. and c. are correct

Q 61. The dimensional formula of electric field intensity is:

a. $[M^1L^1T^3A^{-1}]$ b. $[ML^{-1}T^{-3}A^1]$
c. $[M^1L^1T^{-3}A^{-1}]$ d. $[M^1L^2T^1A^1]$

Ans. (c) $[M^1L^1T^{-3}A^{-1}]$

Since, $E = \frac{F}{q}$, $[E] = \frac{[M^1L^1T^{-2}]}{[AT]} = [M^1L^1T^{-3}A^{-1}]$

Q 62. If the charge on an object is doubled, then electric field becomes:

a. half b. double c. unchanged d. thrice

Ans. (b) double

As $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$

If $q' = 2q$, then $E' = \frac{1}{4\pi\varepsilon_0}\frac{2q}{r^2}$ or $E' = 2E$

So, electric field is doubled.

Q 63. A charged particle is free to move in an electric field. It will travel:

a. always along a line of force
b. along a line of force, if its initial velocity is zero
c. along a line of force, if it has same initial velocity in the direction of an active angle with the line of force
d. None of the above

Ans. (b) along a line of force, if its initial velocity is zero

Because E point is along the tangent to the lines of force. If initial velocity is zero, then due to the force, it moves in the direction of E.

Q 64. Which of the charge will have an electric field directed radially outwards from the charge at any point in space?

a. Positive charge b. Negative charge
c. Dipole d. System of charges

Ans. (a) Positive charge

Q 65. A force of 2.25 N acts on a charge of 15×10^{-4} C. The intensity of electric field at that point is:

a. 150 NC^{-1} b. 15 NC^{-1} c. 1500 NC^{-1} d. 1.5 NC^{-1}

Ans. (c) 1500 NC^{-1}

Electric field, $E = \frac{F}{q} = \frac{2.25\ N}{15 \times 10^{-4}\ C} = 1500\ NC^{-1}$

Q 66. A particle of mass 10^{-3} kg and charge 5 μC is thrown at a speed of 20 ms^{-1} against a uniform electric field of strength 2×10^5 NC^{-1}. The distance travelled by particle before coming to rest is:

a. 0.1 m b. 0.2 m c. 0.3 m d. 0.4 m

Ans. (b) 0.2 m

$$F = qE = 5 \times 10^{-6} \times 2 \times 10^5 = 1\,N$$

Since, the particle is thrown against the field

$\therefore$ $a = -F/m = -\frac{1}{10^{-3}} = -10^3\ ms^{-2}$

As $v^2 - u^2 = 2as$

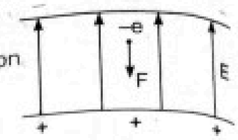
$\therefore$ $0^2 - (20)^2 = 2 \times (-10^3) \times s$

or $s = 0.2$ m

Q 67. An electron initially at rest falls a distance of 1.5 cm in a uniform electric field of magnitude 2×10^4 N/C. The time taken by the electron to fall this distance is:

a. 1.3×10^2 s b. 2.1×10^{-12} s
c. 1.6×10^{-10} s d. 2.9×10^{-9} s

Ans. (d) 2.9×10^{-9} s



Here, the direction of field upward. So, the negatively charged electron experiences a downward force.

$\therefore$ The acceleration of electron is

$$a_e = \frac{eE}{m_e} \quad ...(1)$$

The time required by the electron to fall through a distance h is

$$t_e = \sqrt{\frac{2h}{a_e}} = \sqrt{\frac{2hm_e}{eE}} \quad \text{[using eq.(1)]}$$

$$= \left[\frac{2 \times 1.5 \times 10^{-2} \times 9.11 \times 10^{-31}}{1.6 \times 10^{-19} \times 2 \times 10^4}\right]^{1/2} = 2.9 \times 10^{-9}\ s$$

Q 68. The electric field that can balance a charged particle of mass 3.2×10^{-27} kg is (Given that the charge on the particle is 1.6×10^{-19} C)

a. 19.6×10^{-8} NC^{-1} b. 20×10^{-6} NC^{-1}
c. 19.6×10^{8} NC^{-1} d. 20×10^{6} NC^{-1}

Ans. (a) 19.6×10^{-8} NC^{-1}

Here, $m = 3.2 \times 10^{-27}$ kg, $e = 1.6 \times 10^{-19}$ C, $g = 9.8\ ms^{-2}$

As $E = \frac{F}{q} = \frac{mg}{e} = \frac{3.2 \times 10^{-27} \times 9.8}{1.6 \times 10^{-19}} = 19.6 \times 10^{-8}\ NC^{-1}$

Q 69. Deuteron and α-particle in air are at separation 1 Å. The magnitude of electric field intensity on α-particle due to deuteron is:

a. 5.6×10^{11} N/C b. 1.44×10^{11} N/C
c. 2.828×10^{11} N/C d. zero

Ans. (b) 1.44×10^{11} N/C

$$E = 9 \times 10^9 \times \frac{q^2}{r^2}$$

$$= 9 \times 10^9 \times \frac{1.6 \times 10^{-19}}{(1 \times 10^{-10})^2} = 1.44 \times 10^{11}\ N/C$$

Q 70. Electric field required to keep a water drop of mass 'm' just to remain suspended when charged with 1 electron is:

a. mg b. $\frac{mg}{e}$ c. emg d. $\frac{em}{g}$

Ans. (b) $\frac{mg}{e}$

Mass of water drop = m

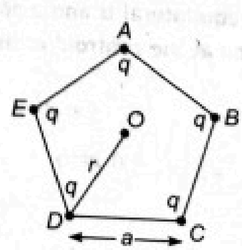
Weight of water drop = mg

$\because$ mg = electrostatic force applied by the field

$\therefore$ $mg = qE = eE$

$\Rightarrow$ $E = \frac{mg}{e}$

Directions (Q. Nos. 71-73): Refer to the given figure and answer the following questions.



Q 71. Five equal charges each of value q are placed at the corners of a regular pentagon of side a. The electric field at the centre of the pentagon is:

a. $\frac{q}{4\pi\varepsilon_0 r^2}$ b. $\frac{q^2}{4\pi\varepsilon_0 r^2}$

c. $\frac{2q}{4\pi\varepsilon_0 r^2}$ d. zero

Ans. (d) zero

The electric field at the centre of pentagon would be zero.

Q 72. What will be the electric field at centre O, if the charge from one of the corners (say A) is removed?

a. $\frac{q}{4\pi\varepsilon_0 r^2}$ along OA b. $\frac{2q}{4\pi\varepsilon_0 r^2}$ along OB

c. $\frac{q^2}{4\pi\varepsilon_0 r^2}$ along OC d. $\frac{2q}{4\pi\varepsilon_0 r^2}$ along OA

Ans. (a) $\frac{q}{4\pi\varepsilon_0 r^2}$ along OA

When a charge q from corner A is removed, electric field at O is $E_1 = \frac{q}{4\pi\varepsilon_0 r^2}$ along OA.

Q 73. What will be the electric field at O, if the charge q at A is replaced by $-q$?

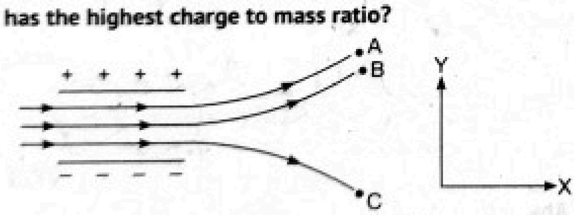
a. $\frac{q}{4\pi\varepsilon_0 r^2}$ along OB b. $\frac{2q}{4\pi\varepsilon_0 r^2}$ along OA

c. $\frac{4q}{4\pi\varepsilon_0 r^2}$ along OC d. zero

Ans. (b) $\frac{2q}{4\pi\varepsilon_0 r^2}$ along OA

If the charge q at A is replaced by $-q$, it is equivalent to adding charge $-2q$ at A. Therefore, electric field at O, $E_2 = \frac{2q}{4\pi\varepsilon_0 r^2}$ along OA.

Q 74. The tracks of three charged particles in a uniform electrostatic field are shown in the figure. Which particle has the highest charge to mass ratio?



a. A b. B c. C d. A and B

Ans. (c) C

Particles A and B have negative charges because they are being deflected towards the positive plate of the electrostatic field. Particle C has positive charge because it is being deflected towards the negative plate.

∴ Deflection of charged particle in time t in y-direction

$$h = 0 \times t + \frac{1}{2}at^2 = \frac{1}{2}\frac{qE}{m}t^2$$

i.e., $$h \propto \frac{q}{m}$$

As the particle C suffers maximum deflection in y-direction, so it has highest charge of mass (q/m) ratio.

Q 75. Electric field lines provide information about:

a. field strength b. direction

c. nature of charge d. All of these

Ans. (d) All of these

Q 76. Which of the following is true about electric field lines:

a. They start from positive charge and end at negative charge

b. Two field lines do not cross each other

c. They do not form closed loops

d. All of the above

Ans. (d) All of the above

Q 77. Electric field lines contract length wise, it shows:

a. repulsion between same charges

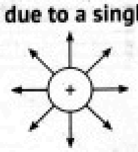
b. attraction between opposite charges

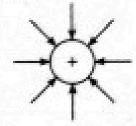
c. no relation between force and contraction

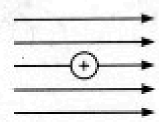
d. electric field lines do not move on straight path

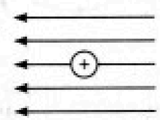
Ans. (b) attraction between opposite charges

Q 78. Which of the following figures represents the electric field lines due to a single positive charge?

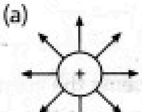
a.


b.


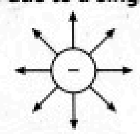
c.


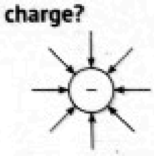
d.


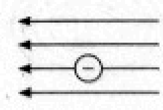
Ans. (a)

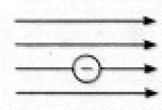


Q 79. Which of the following figures represents the electric field lines due to a single negative charge?

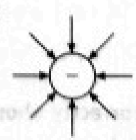
a.


b.


c.


d.


Ans. (b)



Q 80. Which of the following statements is not true about electric field lines?

a. Electric field lines start from positive charge and end at negative charge

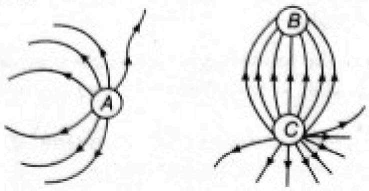
b. Two electric field lines can never cross each other

c. Electrostatic field lines do not form any closed loops

d. Electric field lines cannot be taken as continuous curve

Ans. (d) Electric field lines cannot be taken as continuous curve

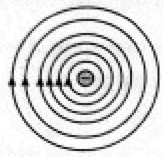
Q 81. Figures shows the electric field lines around three point charges *A*, *B* and *C*. Which of the following charges are positive?

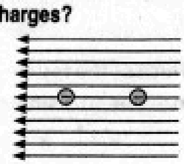


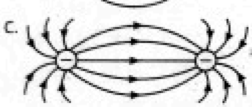
a. Only *A*
b. Only *C*
c. Both *A* and *C*
d. Both *B* and *C*

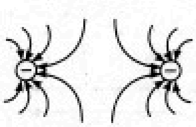
Ans. (c) Both *A* and *C*

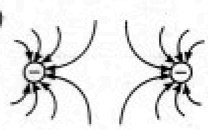
Q 82. Which of the following represents the electric field lines due to a combinations of two negative charges?

a.


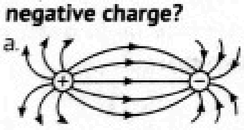
b.


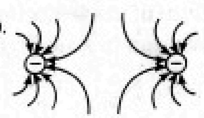
c.


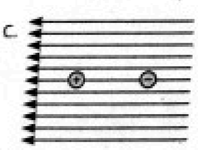
d.


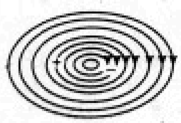
Ans. (d)


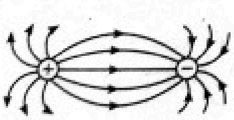
Q 83. Which of the following figure represents the electric field lines due to a combination of one positive and one negative charge?

a.


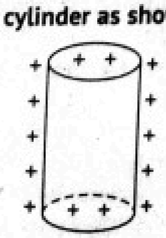
b.


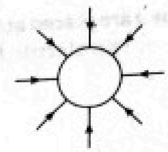
c.


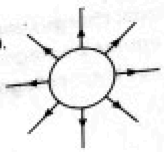
d.


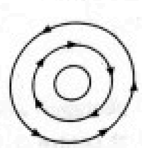
Ans. (a)


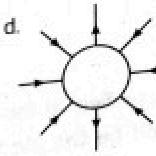
Q 84. Which of the following figures correctly shows the top view sketch of the electric field lines for a uniformly charged hollow cylinder as shown in figure?

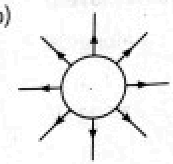


a.


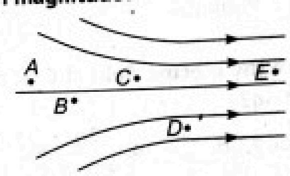
b.


c.


d.


Ans. (b)


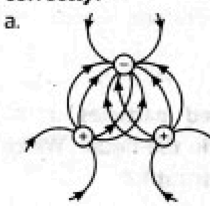
Q 85. A non-uniform electric field is represented by the diagram. At which of the following points the electric field is greatest in magnitude?

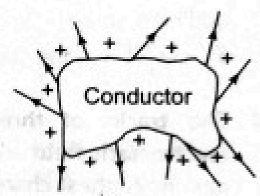


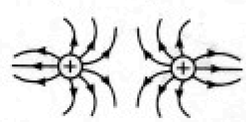
a. *A*
b. *B*
c. *C*
d. *D*

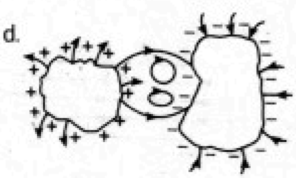
Ans. (d) *D*

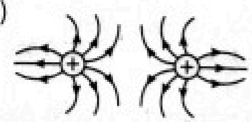
Q 86. Which of the following curves represent electric field lines correctly?

a.


b.


c.


d.


Ans. (c)


Q 87. For a dipole, electric field lines are dense at the point located at:

a. center of dipole
b. one of the charges
c. outside the dipole
d. perpendicular to dipole

Ans. (b) one of the charges

Q 88. The SI unit of electric flux is:

a. $NC^{-1}m^2$
b. NCm^{-2}
c. $NC^{-2}m^2$
d. $NC^{-1}m^{-2}$

Ans. (a) $NC^{-1}m^2$

Q 89. The dimensional formula of electric flux is:

a. $[M^1L^1T^{-2}]$ b. $[M^1L^3T^{-3}A^{-1}]$

c. $[M^2L^2T^{-2}A^{-2}]$ d. $[M^1L^{-3}T^3A^1]$

Ans. (b) $[M^1L^3T^{-3}A^{-1}]$

Q 90. Electric flux will be maximum when:

a. electric field and area are perpendicular to each other

b. electric field and area are parallel to each other

c. electric field and area are at an angle other than 0° and 90°

d. None of the above

Ans. (a) electric field and area are perpendicular to each other

Q 91. In case of a cube of 10 cm length, Electric flux is minimum for which of the case:

a. Charge of 2 C is placed at the intersection point of diagonals

b. Charge of 1 C is placed at the center of cube

c. Charge of 2 C is placed outside the sphere

d. Charge of 1 C is placed on one of the sides

Ans. (c) Charge of 2 C is placed outside the sphere

Q 92. A point charge q is placed at a distance $a/2$ directly above the centre of a square of side a. The electric flux through the square is:

a. $\frac{q}{\varepsilon_0}$ b. $\frac{q}{\pi\varepsilon_0}$ c. $\frac{q}{4\varepsilon_0}$ d. $\frac{q}{6\varepsilon_0}$

Ans. (d) $\frac{q}{6\varepsilon_0}$

An imaginary cube can be made by considering charge 'q' at the centre and given square is one of its face.

From Gauss law, $\phi = \frac{Q_{in}}{\varepsilon_0}$

This is the flux passing through all the six surfaces.

$\therefore \frac{1}{6}$ th of this flux would pass through one surface.

Q 93. A circular plane sheet of radius 10 cm is placed in a uniform electric field of 5×10^5 NC^{-1}, making an angle of 60° with the field. The electric flux through the sheet is:

a. 1.36×10^2 Nm^{2}C^{-1} b. 1.36×10^4 Nm^{2}C^{-1}

c. 0.515×10^2 Nm^{2}C^{-1} d. 0.515×10^4 Nm^{2}C^{-1}

Ans. (b) 1.36×10^4 Nm^{2}C^{-1}

Here, $r = 10$ cm $= 0.1$ m, $E = 5 \times 10^5$ NC^{-1}

As the angle between the plane sheet and the electric field is 60°, angle made by the normal to the plane sheet and the electric field is $\theta = 90° - 60° = 30°$

$$\phi_E = ES\cos\theta = E \times \pi r^2 \cos\theta$$
$$= 5 \times 10^5 \times 3.14 \times (0.1)^2 \cos 30°$$
$$= 1.36 \times 10^4 \text{ Nm}^2\text{C}^{-1}$$

Q 94. A uniform electric field $E = 2 \times 10^3$ NC^{-1} is acting along the positive X-axis. The flux of this field through a square of 10 cm on a side whose plane is parallel to the y-z plane is:

a. 20 NC^{-1}m^2 b. 30 NC^{-1}m^2

c. 10 NC^{-1}m^2 d. 40 NC^{-1}m^2

Ans. (a) 20 NC^{-1}m^2

Here, $E = 2 \times 10^3$ NC^{-1} is along + X-axis

Surface area, $S = (10 \text{ cm})^2$

$$= 10^2 \times 10^{-4} \text{ m}^2 = 10^{-2} \text{ m}^2$$

When plane is parallel to y-z plane, $\theta = 0°$

So, $\phi = ES\cos\theta = 2 \times 10^3 \times 10^{-2} \cos 0°$
$= 20$ NC^{-1}m^2

Q 95. In a region where intensity of electric field is 5 NC^{-1}, 40 electric field lines are crossing per square metre. The number of electric field lines crossing per square metre where intensity of electric field is 10 NC^{-1}, will be:

a. 20   b. 80   c. 100   d. 200

Ans. (b) 80

Number of lines of electric field crossing is equal to flux (ϕ).

We know that, $\phi = \int E \cdot dS$

By keeping area constant and doubling E, ϕ will also get doubled.

$\therefore$ No. of lines $= 2 \times 40 = 80$

Q 96. Which of the following is a property of electric dipole:

a. It is a vector quantity

b. Dipole moment is directed from negative charge to positive charge

c. Net charge of electric dipole is zero

d. All of the above

Ans. (d) All of the above

Q 97. Which of the following statements about dipole moment is not true?

a. The dimensions of dipole moment is [LTA]

b. The unit of dipole moment is Cm

c. Dipole moment is a vector quantity and directed from negative to positive charge

d. Dipole moment is a scalar quantity and has magnitude equal to the potential energy of the system of charges

Ans. (d) Dipole moment is a scalar quantity and has magnitude equal to the potential energy of the system of charges

Q 98. In case of dipole, which of the following quantity is inversely proportional to cube of distance between the charges:

a. Electric flux

b. Electric field

c. Force at the centre of dipole

d. Force at the point perpendicular to dipole

Ans. (b) Electric field

Q 99. What will be the value of electric field at the centre of the electric dipole?

a. Zero

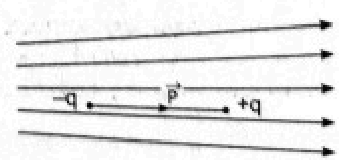
b. Equal to the electric field due to one charge at the centre

c. Twice the electric field due to one charge at the centre

d. Half the value of electric field due to one charge at the centre

Ans. (c) Twice the electric field due to one charge at the centre

Q 100. Figure shows electric field lines in which an electric dipole $\vec{p}$ is placed at shown. Which of the following statements is correct? *(NCERT EXEMPLAR)*



a. The dipole will not experience any force

b. The dipole will experience a force towards right

c. The dipole will experience a force towards left

d. The dipole will experience a force upwards

Ans. (c) The dipole will experience a force towards left

The spacing between electric lines of force increases from left to right. Therefore, E on left is greater than E on right. Force on $+q$ charge of dipole is smaller and to the right. Force on $-q$ charge of dipole is bigger and to the left. Hence, the dipole will experience a force towards the left.

Q 101. The necessary condition for the ratio of electric field intensity due to an electric dipole of dipole length $2a$ at its axial point to its equatorial point is 2 : 1 is:

a. $r >> a$, where r is the distance from the midpoint of the dipole to the concerned point

b. $r << a$, where r is the distance from the midpoint of the dipole to the concerned point

c. $r = a$, where r is the distance from the midpoint of the dipole to the concerned point

d. None of these

Ans. (a) $r >> a$, where r is the distance from the midpoint of the dipole to the concerned point.

Q 102. The ratio of electric field due to an electric dipole on its axis and on the perpendicular bisector of the dipole is:

a. 1 : 2 b. 2 : 1 c. 1 : 4 d. 4 : 1

Ans. (b) 2 : 1

Electric field due to dipole on its axis,

$$E_1 = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$$

Electric field due to dipole on its perpendicular bisector,

$$E_2 = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}$$

$$\frac{E_1}{E_2} = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3} \times 4\pi\varepsilon_0\frac{r^3}{p}$$

$$\frac{E_1}{E_2} = \frac{2}{1} \text{ or } 2:1$$

Q 103. A point charge is situated at an axial point of a small electric dipole at a large distance from it. The charge experiences a force F. If the distance of the charge is doubled, the force acting on the charge will become:

a. $2F$ b. $F/2$ c. $F/4$ d. $F/8$

Ans. (d) $F/8$

Let charge q is placed at a distance r from the dipole.

Electric field due to dipole at axial point,

$$E = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$$

Force on charge q, $F = qE$

$$= \frac{1}{4\pi\varepsilon_0}\frac{2pq}{r^3}$$

When we double the distance

$$F' = \frac{1}{4\pi\varepsilon_0}\frac{2pq}{(2r)^3}$$

$$F' = \frac{1}{4\pi\varepsilon_0}\frac{2pq}{r^3}\left(\frac{1}{8}\right)$$

$$F' = \frac{F}{8}$$

Q 104. An electric dipole of dipole moment 20×10^6 Cm is enclosed by a closed surface. The net flux coming out of the surface is:

a. 10×10^{-3} b. 20×10^{-6} c. $\frac{q}{2}$ d. 0

Ans. (d) 0

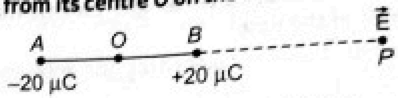
We know that, $\phi = \frac{q}{\varepsilon_0}$

Here, $q = 0$ because dipole has both positive and negative charge of equal magnitude.

$$\Rightarrow \quad \phi = \frac{0}{\varepsilon_0} = 0$$

$\therefore$ There will be no flux through the surface.

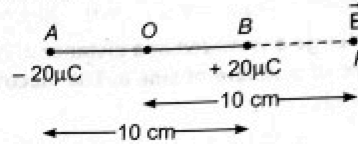
Q 105. Two charges $+20\mu C$ and $-20\mu C$ are placed 10 mm apart. The electric field at point P, on the axis of the dipole 10 cm away from its centre O on the side of the positive charge is:



a. 8.6×10^9 NC^{-1} b. 4.1×10^6 NC^{-1}

c. 3.6×10^6 NC^{-1} d. 4.6×10^5 NC^{-1}

Ans. (c) 3.6×10^6 NC^{-1}



Here, $q = \pm 20\,\mu C = \pm 20 \times 10^{-6}$ C, $2a = 10$ mm $= 10 \times 10^{-3}$ m, $r = OP = 10$ cm $= 10 \times 10^{-2}$ m

$$|\vec{p}| = q \times 2a = 20 \times 10^{-6} \times 10 \times 10^{-3}$$
$$= 2 \times 10^{-7} \text{ cm}$$

The electric field, along BP,

$$\vec{E} = \frac{2|\vec{p}|r}{4\pi\varepsilon_0(r^2 - a^2)^2}$$

As $a << r$,

$$\vec{E} = \frac{2|\vec{p}|}{4\pi\varepsilon_0 r^3} = \frac{2 \times 2 \times 10^{-7} \times 9 \times 10^9}{(10 \times 10^{-2})^3}$$
$$= 3.6 \times 10^6 \text{ NC}^{-1}$$

Q 106. Two points charges of $1\,\mu C$ and $-1\,\mu C$ are separated by a distance of 100 Å. A point P is at a distance of 10 cm from the midpoint and on the perpendicular bisector of the line joining the two charges. The electric field at P will be

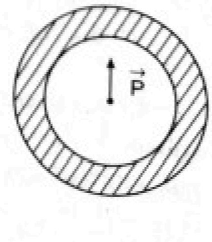
a. 9 NC^{-1} b. 0.9 NC^{-1} c. 90 NC^{-1} d. 0.09 NC^{-1}

Ans. (d) 0.09 NC^{-1}

The point lies on equatorial line of a short dipole.

$$\therefore \quad E = \frac{2ql}{4\pi\varepsilon_0 r^3} = \frac{9 \times 10^9 \times 10^{-6} \times 10^{-8}}{(10^{-1})^3}$$
$$= 0.09 \text{ NC}^{-1}$$

Q 107. Shown in the figure is a shell made of a conductor. It has inner radius a and outer radius b, and carries charge Q. At its centre is a dipole $\vec{p}$ as shown. In this case:



a. surface charge density on the inner surface of the shell is zero everywhere
b. surface charge density on the inner surface is uniform and equal to $\frac{(Q/2)}{4\pi a^2}$
c. electric field outside the shell is the same as that of a point charge at the centre of the shell
d. surface charge density on the outer surface depends on $|\vec{p}|$

Ans. (c) electric field outside the shell is the same as that of a point charge at the centre of the shell

Q 108. If an electric dipole is placed in a uniform electric field, it experiences:

a. torque only
b. net force only
c. both torque and net force
d. neither torque nor net force

Ans. (a) torque only

Q 109. Torque induced by an external electric field on a dipole is maximum when:

a. dipole moment and electric field are parallel
b. dipole moment and electric field are perpendicular
c. dipole moment and electric field are at angle of 180°
d. None of the above

Ans. (b) dipole moment and electric field are perpendicular

Q 110. In the case of dipole subjected to external electric field that gains torque, which of the following angle represents an unstable equilibrium:

a. 0° b. 45° c. 90° d. 180°

Ans. (d) 180°

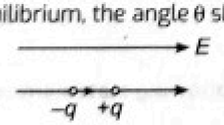
When angle between dipole and electric field $\theta = 180°$, the dipole is said to be in unstable equilibrium.

Q 111. An electric dipole is placed in an uniform electric field with the dipole axis making an angle θ with the direction of the electric field. The orientation of the dipole for stable equilibrium is:

a. $\frac{\pi}{6}$ b. $\frac{\pi}{3}$
c. 0 d. $\frac{\pi}{2}$

Ans. (c) 0

For stable equilibrium, the angle θ should be zero.



$\tau = pE \sin\theta = pE \sin\theta = 0$

Q 112. An electric dipole of dipole moment $\vec{p}$ is placed in a uniform external electric field $\vec{E}$. Then the:

a. torque experienced by the dipole is $\vec{E} \times \vec{p}$
b. torque is zero, if $\vec{p}$ is perpendicular to $\vec{E}$
c. torque is maximum, if $\vec{p}$ is perpendicular to $\vec{E}$
d. potential energy is maximum, if $\vec{p}$ is parallel to $\vec{E}$

Ans. (c) torque is maximum, if $\vec{p}$ is perpendicular to $\vec{E}$

Torque on dipole form $\tau = p \times E \sin\theta$

The direction of torque is perpendicular to the plane of paper inwards, *i.e.*, when the dipole is parallel or anti-parallel to $\vec{E}$ and maximum at $\theta = 90°$.

So, torque is maximum, if $\vec{p}$ is perpendicular to $\vec{E}$.

Q 113. An electric dipole placed in a non-uniform electric field can experience: *(CBSE 2020)*

a. a force but not a torque
b. a torque but not a force
c. always a force and a torque
d. neither a force nor a torque

Ans. (c) always a force and a torque

Q 114. Two equal and opposite charges 2×10^{-10} C are placed at a distance of 1 cm forming a dipole and are placed in an electric field 2×10^5 N/C, maximum torque on dipole is:

a. $2\sqrt{2} \times 10^{-6}$ Nm b. 8×10^{8} Nm
c. 4×10^{-9} Nm d. 4×10^{-7} Nm

Ans. (d) 4×10^{-7} Nm

Here, $q = 2 \times 10^{-10}$ C, $x = 1\text{cm} = 0.01\text{m}$

Dipole moment = Charge × Distance

$= 2 \times 10^{-10} \times 10^{-2} = 2 \times 10^{-12}$ cm

Maximum Torque = pE

$= 2 \times 10^{-12} \times 2 \times 10^{5} = 4 \times 10^{-7}$ Nm

Q 115. An electric dipole is placed at an angle of 30° with an electric field of intensity 2×10^5 NC^{-1}. It experiences a torque equal to 4 Nm. The charge on the dipole if the dipole length is 2 cm is:

a. 8 mC b. 4 mC c. 6 mC d. 2 mC

Ans. (d) 2 mC

Here, $E = 2 \times 10^5$ NC^{-1}, $l = 2$ cm, $\tau = 4$ Nm

Torque, $\vec{\tau} \times \vec{p} \times \vec{E}$; $\tau = pE \sin\theta$

∴ $4 = p \times 2 \times 10^5 \times \sin 30°$

or $p = 4 \times 10^{-5}$ Cm

∴ Charge, $q = \frac{p}{l} = \frac{4 \times 10^{-5}\text{ Cm}}{0.02\text{ m}}$

$= 2 \times 10^{-3}$ C = 2 mC

Q 116. Two small balls each having a positive charge Q Coulombs are suspended by two insulating strings of equal length L meters from a hook fixed to a stand. The whole setup is taken in a satellite into space, where there is no gravity. What is the angle between the string and tension in the string?

a. 180°, $\frac{1}{4\pi\varepsilon_0} \frac{Q^2}{(2L)^2}$ b. 90°, $\frac{1}{4\pi\varepsilon_0} \frac{Q^2}{L^2}$
c. 180°, $\frac{1}{4\pi\varepsilon_0} \frac{Q^2}{2L^2}$ d. 180°, $\frac{1}{4\pi\varepsilon_0} \frac{Q}{4L}$

Ans. (a) 180°, $\frac{1}{4\pi\varepsilon_0} \frac{Q^2}{(2L)^2}$

In a satellite, there is a condition of weightlessness.

∴ $mg = 0$

Due to electrostatic force of repulsion between the balls, the string would become horizontal.

∴ Angle between string = 180°

Tension in string = Force of repulsion

$= \frac{1}{4\pi\varepsilon_0} \frac{Q^2}{(2L)^2}$

Q 117. When a comb rubbed with dry hair attracts pieces of paper. This is because the:

a. comb polarises the piece of paper

b. comb induces a net dipole moment opposite to the direction of field

c. electric field due to the comb is uniform

d. comb induces a net dipole moment perpendicular to the direction of field

Ans. (a) comb polarises the piece of paper

Q 118. What is the dimension of volume charge density:

a. $[A^2L^{-3}T^2]$ b. $[AL^{-3}T]$ c. $[AL^{-2}T]$ d. $[A^2L^{-2}T^2]$

Ans. (b) $[AL^{-3}T]$

Q 119. What is the unit of linear charge density:

a. Unitless b. C/m c. C-m d. C

Ans. (b) C/m

Q 120. If σ = Surface charge density, ε = electric permittivity, then dimension of $\frac{\sigma}{\varepsilon}$:

a. electric force

b. electric field intensity

c. pressure

d. electric charge

Ans. (b) electric field intensity

Q 121. Match the following and find the correct option:

Column I	Column II
A. Linear charge density	p. $\frac{\text{Charge}}{\text{Volume}}$
B. Surface charge density	q. $\frac{\text{Charge}}{\text{Length}}$
C. Volume charge density	r. $\frac{\text{Charge}}{\text{Area}}$

a. A-q, B-r, C-p b. A-p, B-r, C-p

c. A-r, B-p, C-q d. A-r, B-q, C-p

Ans. (a) A-q, B-r, C-p

Q 122. Electric field at a point of distance r from a uniformly charged wire of infinite length having linear charge density λ is directly proportional to:

a. r^{-1} b. r c. r^2 d. r^{-2}

Ans. (a) r^{-1}

We know that, electric field at distance r from an infinitely long line charge is given by

$$E = \frac{\lambda}{2\pi\varepsilon_0 r} \Rightarrow \lambda = 2\pi\varepsilon_0 \cdot rE$$

$$E \propto r^{-1}$$

Q 123. The surface considered for Gauss's law is called:

a. closed surface b. spherical surface

c. Gaussian surface d. plane surface

Ans. (c) Guassian surface

Q 124. If $\oint_S \vec{E}\cdot d\vec{S} = 0$ over a surface, then:

a. the electric field inside the surface and on it is zero

b. the electric field inside the surface is necessarily uniform

c. all charges must be outside the surface

d. None of the above

Ans. (d) None of the above

Q 125. The electric flux through a closed Gaussian surface depends upon: *(CBSE 2020)*

a. net charge enclosed and permittivity of the medium

b. net charge enclosed, permittivity of the medium and the size of the Gaussian surface

c. net charge enclosed only

d. permittivity of the medium only

Ans. (a) net charge enclosed and permittivity of the medium

Q 126. If the net electric flux through a closed surface is zero, then we can infer that: *(CBSE 2020)*

a. no net charge is enclosed by the surface

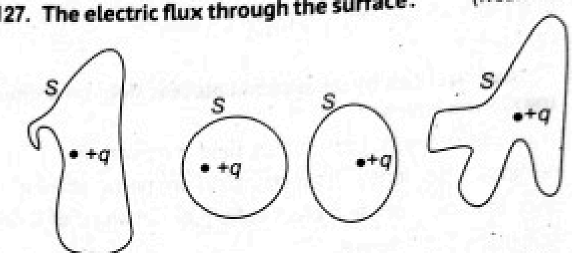
b. uniform electric field exists within the surface

c. electric potential varies from point to point inside the surface

d. charge is present inside the surface

Ans. (a) no net charge is enclosed by the surface

Q 127. The electric flux through the surface: *(NCERT EXEMPLAR)*



(i) (ii) (iii) (iv)

a. in figure (iv) is the largest

b. in figure (iii) is the least

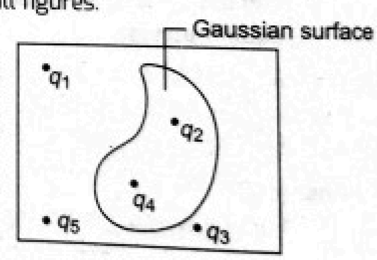
c. in figure (ii) is same as in figure (iii) but is smaller than figure (iv)

d. is the same for all the figures

Ans. (d) is the same for all the figures

As per Gauss's theorem in electrostatics, the electric flux through a surface depends only on the amount of charge enclosed by the surface. It does not depend on size and shape of the surface. Therefore, electric flux through the surface is the same for all figures.

Q 128. Five charges q_1, q_2, q_3, q_4 and q_5 are fixed at their positions as shown in figure, S is a Gaussian surface. The Gauss's law is given by $\oint_s \vec{E}\cdot d\vec{S} = \frac{q}{\varepsilon_0}$



Which of the following statement is correct? *(NCERT EXEMPLAR)*

a. $\vec{E}$ on the LHS of the above equation will have a contribution from q_1, q_5 and q_3 while q on the RHS will have a contribution from q_1 and q_4 only

b. $\vec{E}$ on the LHS of the above equation will have a contribution from all charges while q on the RHS will have a contribution from q_2 and q_4 only

c. $\vec{E}$ on the LHS of the above equation will have a contribution from all charges while q on the RHS will have a contribution from q_1, q_3 and q_5 only

d. Both $\vec{E}$ on the LHS and q on the RHS will have contribution from q_2 and q_4 only

Ans. (b) $\vec{E}$ on the LHS of the above equation will have a contribution from all charges while q on the RHS will have a contribution from q_2 and q_4 only.
When the point is on the diameter and away from the centre of hemisphere which is charged uniformly and positively, the component of electric field intensity parallel to the diameter cancel out. So, the electric field is perpendicular to the diameter.

Q 129. A sphere encloses an electric dipole within it. The total flux across the sphere is:

a. zero
b. half that due to a single charge
c. double that due to a single charge
d. dependent on the position of dipole

Ans. (a) zero

Q 130. Which of the following statements is not true about Gauss's law?

a. Gauss's law is true for any closed surface
b. The term q on the right side of Gauss's law includes the sum of all charges enclosed by the surface
c. Gauss's law is not much useful in calculating electrostatic field when the system has some symmetry
d. Gauss's law is based on the inverse square dependence on distance contained in the coulomb's law

Ans. (c) Gauss's law is not much useful in calculating electrostatic field when the system has some symmetry.

Q 131. The electric flux through a cube of side 1 cm which encloses an electric dipole is:

a. $\frac{q}{6\varepsilon_0}$ b. $\frac{3q}{\varepsilon_0}$ c. 0 d. $\frac{q}{3\varepsilon_0}$

Ans. (c) 0
Since, net charge enclosed in the surface by the cube is zero. According to Gauss law, net flux through the cube is zero.

Q 132. A point charge 4μC is at the centre of a cubic Gaussian surface 10 cm on edge. Net electric flux through the surface is:

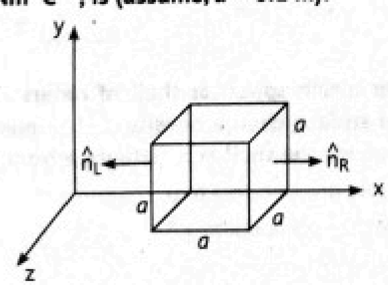
a. 2.5×10^5 Nm²C⁻¹ b. 4.5×10^5 Nm²C⁻¹
c. 4.5×10^6 Nm²C⁻¹ d. 2.5×10^6 Nm²C⁻¹

Ans. (b) $4.5 \times 10^5\ Nm^2C^{-1}$

Here, $q = 4\ \mu C = 4 \times 10^{-6}\ C,\ l = 10\ cm$

$$\phi = \frac{q}{\varepsilon_0} = \frac{4 \times 10^{-6}}{8.85 \times 10^{-12}} = 4.5 \times 10^5\ Nm^2C^{-1}$$

Q 133. The electric field components in the given figure are $E_x = \alpha x^{1/2}$, $E_y = E_z = 0$ in which $\alpha = 800\ NC^{-1}m^{-1/2}$. The charge within the cube, if net flux through the cube is $1.05\ Nm^2C^{-1}$, is (assume, $a = 0.1$ m):



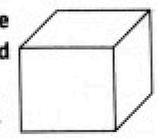
a. 9.27×10^{-12} C b. 9.27×10^{12} C
c. 6.97×10^{-12} C d. 6.97×10^{12} C

Ans. (a) 9.27×10^{-12} C

By Gauss's law, $\phi = \frac{q}{\varepsilon_0}$

or $q = \phi\varepsilon_0 = 1.05 \times 8.854 \times 10^{-12}$ C
$= 9.30 \times 10^{-12}$ C

Q 134. The total flux through the faces of the cube with side of length a, if a charge q is placed at corner A of the cube is:



a. $\frac{q}{8\varepsilon_0}$ b. $\frac{q}{4\varepsilon_0}$ c. $\frac{q}{2\varepsilon_0}$ d. $\frac{q}{\varepsilon_0}$

Ans. (a) $\frac{q}{8\varepsilon_0}$

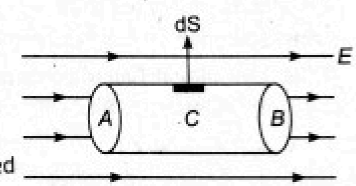
In the figure, when a charge q is placed at corner A of the cube, it is being shared equally by 8 cubes.

∴ The total flux through the faces of the given cube $= \frac{q}{8\varepsilon_0}$

Q 135. A cylinder of radius R and length L is placed in a uniform electric field E parallel to the cylinder axis. The total flux for the surface of the cylinder is given by:

a. $2\pi R^2 E$ b. $\frac{R^2}{E}$
c. $\frac{\pi R^2}{E}$ d. zero

Ans. (d) zero



Flux through surface A,
$\phi_A = E \times \pi R^2$
Flux through surface B,
$\phi_B = -E \times \pi R^2$
Flux through curved surface, $C = \int E \cdot dS$
$= \int E\ dS \cos 90° = 0$

∴ Total flux through cylinder $= \phi_A + \phi_B + \phi_C = 0$

Q 136. The number of electric line of forces that radiated outward from 2 C of charge in vacuum is:

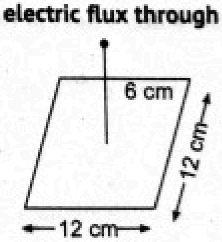
a. 1.13×10^{11} b. 1.13×10^{13}
c. 2.26×10^{11} d. 2.26×10^{13}

Ans. (c) 2.26×10^{11}

Number of electric lines $\phi = \frac{q}{\varepsilon_0}$

$$= \frac{2}{8.854 \times 10^{-12}} = 0.226 \times 10^{12} = 2.26 \times 10^{11}$$

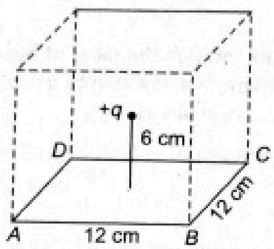
Q 137. A point charge + 20μC is at a distance 6 cm directly above the centre of a square of side 12 cm as shown in figure. The magnitude of electric flux through the square is:



a. 2.5×10^6 Nm²C⁻¹ b. 3.8×10^5 Nm²C⁻¹
c. 4.2×10^5 Nm²C⁻¹ d. 2.9×10^6 Nm²C⁻¹

Ans. (b) $3.8 \times 10^5\ Nm^2C^{-1}$

From figure, it is clear that square $ABCD$ is one of the six faces of a cube of side 12 cm. By Gauss's theorem, total electric flux through all the six faces of the cube $= \frac{q}{\varepsilon_0}$



$\therefore$ Electric flux through the square

$$\phi = \frac{1}{6}\frac{q}{\varepsilon_0} = \frac{1}{6} \times \frac{20 \times 10^{-6}}{8.85 \times 10^{-12}}$$

$$= 3.8 \times 10^5 \ \text{Nm}^2\text{C}^{-1}$$

Q 138. Electric field is independent of distance of the given surface and charge in which of the case:

a. Infinitely long uniformly charged wire
b. infinitely large uniformly charged plane sheet
c. Uniformly charged spherical shell
d. None of the above

Ans. (b) infinitely large uniformly charged plane sheet

Q 139. Cylindrical Gaussian surface is used to calculate electric field intensity for:

a. point charge b. hollow sphere
c. infinitely plane sheet d. infinitely long charged wire

Ans. (d) infinitely long charged wire

Q 140. According to Gauss law electric field on infinitely long straight wire is proportional to:

a. r b. $\frac{1}{r^2}$ c. $\frac{1}{r^3}$ d. $\frac{1}{r}$

Ans. (d) $\frac{1}{r}$

T!P

Electric field due to an infinitely long straight wire is

$$E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

Q 141. Two infinitely long parallel conducting plates having surface charge densities $+\sigma$ and $-\sigma$ respectively, are separated by a small distance. The medium between the plates is vacuum. If ε_0 is the dielectric permittivity of vacuum, then the electric field in the region between the plates:

a. 0 v/m b. $\frac{\sigma}{2\varepsilon_0}$ v/m c. $\frac{\sigma}{\varepsilon_0}$ v/m d. $\frac{2\sigma}{\varepsilon_0}$ v/m

Ans. (c) $\frac{\sigma}{\varepsilon_0}$ v/m

From Gauss law, electric field due to charged infinite plane sheet, $E_1 = \frac{\sigma}{2\varepsilon_0}$

Here, the field between the plates $E = E_1 + E_2$

$$= \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0} \text{ v/m}$$

Q 142. Above an infinitely large plane carrying a charge density σ' an electric field points up and is equal to $\frac{\sigma}{2\varepsilon_0}$. What is the magnitude and direction of electric field below the plane?

a. $\frac{\sigma}{2\varepsilon_0}$ downwards b. $\frac{\sigma}{2\varepsilon_0}$ upwards
c. $\frac{\sigma}{\varepsilon_0}$ downwards d. $\frac{\sigma}{\varepsilon_0}$ upwards

Ans. (a) $\frac{\sigma}{2\varepsilon_0}$ downwards

Using Gauss law, electric field due to an infinite plane sheet can be obtained.

$\therefore$ $$2E\, dS = \sigma \frac{dS}{\varepsilon_0}$$

or $$E = \frac{\sigma}{2\varepsilon_0}$$

Hence, electric field is $\frac{\sigma}{2\varepsilon_0}$ downwards.

Q 143. Two large, thin metal plates are parallel and close to each other. On their inner faces, the plates have surface charge densities of opposite signs and of magnitude 16×10^{-22} Cm^{-2}. The electric field between the plate is:

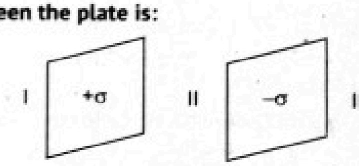
a. 1.8×10^{-10} NC^{-1} b. 1.9×10^{-10} NC^{-1}
c. 1.6×10^{-10} NC^{-1} d. 1.5×10^{-10} NC^{-1}

Ans. (a) 1.8×10^{-10} NC^{-1}

Here, $$E = \frac{\sigma}{\varepsilon_0} = \frac{16 \times 10^{-22}}{8.854 \times 10^{-12}}$$

$$= 1.8 \times 10^{-10} \ \text{NC}^{-1}$$

Q 144. Two large thin metal plates are parallel and close to each other. On their inner faces, the plates have surface charge densities of opposite signs and magnitude 27×10^{-22} Cm^{-2}. The electric field $\vec{E}$ in region II in between the plate is:



a. 4.25×10^{-8} NC^{-1} b. 6.28×10^{-10} NC^{-1}
c. 3.05×10^{-10} NC^{-1} d. 5.03×10^{-10} NC^{-1}

Ans. (c) 3.05×10^{-10} NC^{-1}

The value of $\vec{E}$ in the region II, in between the plates $= \frac{\sigma}{\varepsilon_0}$

$$= \frac{27 \times 10^{-22}}{8.85 \times 10^{-12}} = 3.05 \times 10^{-10} \ \text{NC}^{-1}$$

Q 145. Consider a thin spherical shell of radius R consisting of uniform surface charge density σ. The electric field at a point outside the shell at a distance x from its centre is:

a. inversely proportional to σ
b. directly proportional to x^2
c. directly proportional to R
d. inversely proportional to x^2

Ans. (d) inversely proportional to x^2

Q 146. The electric field at a distance R due to charge q is E. If the same charge is placed on the copper spherical shell of radius R, the electric field strength at the surface of the conductor will be:

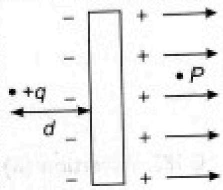
a. $\frac{E}{4}$ b. $\frac{E}{2}$ c. E d. $2E$

Ans. (c) E

Q 147. A point charge $+q$, is placed at a distance d from an isolated conducting plane. The field at a point P on the other side of the plane is: *(NCERT EXEMPLAR)*

a. directed perpendicular to the plane and away from the plane
b. directed perpendicular to the plane but towards the plane
c. directed radially away from the point charge
d. directed radially towards the point charge

Ans. (a) directed perpendicular to the plane and away from the plane



When a point charge $+q$ is placed at a distance d from an isolated conducting plane, some negative charge develops on the surface of the plane towards the charge and an equal positive charge develops on opposite side of the plane. Hence, the field at a point P on the other side of the plane is directed perpendicular to the plane and away from the plane as shown in figure.

Assertion and Reason Type Questions

Directions (Q.Nos. 148 to 173): In the following questions, astatement of Assertion (A) is followed by a statement of Reason (R). Mark the correct choice as:

a. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A)
b. Both Assertion (A) and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A)
c. Assertion (A) is true but Reason (R) is false
d. Assertion (A) is false and Reason (R) is also false

Q 148. Assertion (A): When we rub a glass rod with silk, the rod gets positively charged and the silk gets negatively charged.

Reason (R): On rubbing, electrons from silk cloth move to the glass rod.

Ans. (c) When we rub a glass rod with silk cloth, electrons from the glass rod are transferred to the silk cloth. Thus the rod gets positively charged and the silk gets negatively charged.

Q 149. Assertion (A): Charge is quantized.

Reason (R): Charge, which is less than 1 C is not possible.

Ans. (c) $Q = \pm ne$ and charge lesser than 1C is possible.

Q 150. Assertion (A): Charging is due to transfer of electrons.

Reason (R): Mass of a body decreases slightly when it is negatively charged.

Ans. (c) A body becomes negatively charged only when some electrons are transferred to the body *i.e.*, the body gains some electrons. Hence, its mass increases slightly. Mass of a body decreases only when body gives some electrons to some other body.

Q 151. Assertion (A): When bodies are charged through friction, there is a transfer of electric charge from one body to another, but no creation or destruction of charge.

Reason (R): This follows from conservation of electric charges.

Ans. (a) Conservation of electric charges states that the total charge of an isolated system remains unchanged with time.

Q 152. Assertion (A): The charge on a body can be increased or decreased in terms of electronic charge e.

Reason (R): Quantisation of charge means that the charge on a body is the integral multiple of electronic charge e.

Ans. (a) All the observable charges have to be integral multiple of e. Thus if a body contains n_1 electrons and n_2 protons, the total amount of charge on the body is $n_2e + n_1(-e) = (n_2 - n_1)\,e$. Since, n_1 and n_2 are integers, their difference is also an integer. Thus the charge on any body is always an integral multiple of e and can be increased or decreased in terms of e.

Q 153. Assertion (A): The coulomb force is the dominating force in the universe.

Reason (R): The coulomb force is weaker than the gravitational force.

Ans. (d) Gravitational force is the dominating force in nature and not Coulomb's force. Gravitational force is the weakest force. Also, Coulomb force >> gravitational force.

Q 154. Assertion (A): Coulomb force and gravitational force follow the same inverse-square law.

Reason (R): Both laws are same in all aspects.

Ans. (c) Coulomb force and gravitational force follow the same inverse-square law. But gravitational force has only one sign which is always attractive, while coulomb force can be of both signs which are attractive and repulsive.

Q 155. Assertion (A): If there exists coulomb attraction between two bodies, both of them may not be charged.

Reason (R): In coulomb attraction two bodies are oppositely charged.

Ans. (b) Coulomb attraction exists even when one body is charged, and the other is uncharged.

Q 156. Assertion (A): Electric force acting on a proton and an electron, moving in a uniform electric field is same, where as acceleration of electron is 1836 times that of a proton.

Reason (R): Electron is lighter than proton.

Ans. (a) As $F = qE$, and charge (q) on an electron and on a proton has the same magnitude, therefore force (F) on each is same. Now, acceleration $a = F/m$. Mass of electron $= \frac{1}{1836}$ mass of a proton. Therefore, acceleration of electron is 1836 times that of a proton.

Q 157. Assertion (A): For charge to be in equilibrium, sum of the forces on charge due to rest of the two charges must be zero.

Reason (R): A charge is lying at the centre of line joining two similar charges each which are fixed. The system will be in equilibrium, if that charge is one fourth of the similar charges.

Ans. (c) According to Coulomb's law, $F = k\frac{Q_1Q_2}{r^2}$.

The force on q due to A,

$$F_A = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Qq}{(r/2)^2} \text{ (to the right)}$$

Due to B,

$$F_B = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Qq}{(r/2)^2} \text{ (to the left.)}$$

∴ Their sum is zero whether q is $+\frac{Q}{4}$ or $-\frac{Q}{4}$ or any other value.

Therefore, it is not true that the third charge has to be $Q/4$ only. It can be any value.

Q 158. Assertion (A): The force with which two charges attract or repel each other are not affected by the presence of a third charge.

Reason (R): Force on any charge due to a number of other charges is the vector sum of all the forces on that charge due to other charges, taken one at a time.

Ans. (b) Force on any charge due to a number of other charges is the vector sum of all the forces on that charge due to the other charges, taken one at a time. The individual forces are unaffected due to the presence of other charges. This is the principle of superposition of charges.

Q 159. Assertion (A): Electric field at a point superimpose to give one resultant electric field.

Reason (R): Electric lines of force cross each other.

Ans. (d) If electric lines of forces cross each other, then the electric field at the point of intersection will have two direction simultaneously which is not possible physically.

Q 160. Assertion (A): Electric field is always normal to equipotential surfaces and along the direction of decreasing order of potential.

Reason (R): Negative gradient of electric potential is electric field.

Ans. (a) There is no potential gradient along any direction parallel to the surface and hence no such electric field parallel to the surface.

Q 161. Assertion (A): If a proton and an electron are placed in the same uniform electric field. They experience different acceleration.

Reason (R): Electric force on a test charge is independent of its mass.

Ans. (b) Electron and proton have same amount of charge so they have same Coulomb force. They have different accelerations because they have different masses $\left(a = \frac{F}{m}\right)$.

Q 162. Assertion (A): As force is a vector quantity, hence electric field intensity is also a vector quantity.

Reason (R): The unit of electric field intensity is newton per coulomb.

Ans. (b) The electric field intensity is equal to force experienced by unit positive test charge q_0 placed at that point *i.e.*

$$\vec{E} = \frac{\vec{F}}{q_0} \text{ thus } \vec{E} \text{ is also a vector quantity}$$

As, $$E = \frac{F}{q} = \frac{\text{newton}}{\text{coulomb}}$$

Q 163. Assertion (A): In a uniform electric field electron move in the opposite direction of electric field.

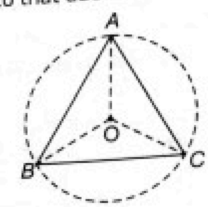
Reason (R): This is because of the negative charge of an electron.

Ans. (a)

Q 164. Assertion (A): Three equal charges are situated on a circle of radius r such that they form an equilateral triangle, then the electric field intensity at the centre is zero.

Reason (R): The force on unit positive charge at the centre, due to the three equal charges are represented by the three sides of a triangle taken in the same order. Therefore, electric field intensity at centre is zero.

Ans. (a) Resultant of electric intensity at O due to B and C is equal and opposite to that due to A.



Q 165. Assertion (A): No two electric lines of force can intersect each other.

Reason (R): Tangent at any point of electric line of force gives the direction of electric field.

Ans. (a) If the two electric lines of force can intersect each other than at the point of intersection, we can draw two tangents to the two lines of force. This would mean two directions of electric field intensity at the point of intersection, which is not possible.

Q 166. Assertion (A): Electrostatic field lines start at positive charges and end at negative charges.

Reason (R): Field lines are continuous curves without any breaks and they form closed loop.

Ans. (c) Electrostatic field lines are continuous curves without any breaks. They start at positive charges and end at negative charges. They cannot from closed loops.

Q 167. Assertion (A): The electric lines of forces diverges from a positive charge and converge at a negative charge.

Reason (R): A charged particle free to move in an electric field always move along an electric line of force.

Ans. (c) If the charged particle is initially at rest in an electric field, it will move along the electric line of force. But when the initial velocity of charged particle makes some angle with the line of force, then the resultant path is not along the line of force. Because electric line of force may not coincide with the line of velocity of the charge.

Q 168. Assertion (A): In electrostatics, electric lines of force can never be closed loops, as a line can never start and end on the same charge.

Reason (R): The number of electric lines of force originating or terminating on a charge is proportional to the magnitude of charge.

Ans. (b) Electrostatic field lines of force can never form any closed loop. Because electric field originate from positive charge and terminates on negative charge.

Q 169. Assertion (A): The surface charge densities of two spherical conductors of different radii are equal. Then the electric field intensities near their surface are also equal.

Reason (R): Surface charge density is equal to charge per unit area.

Ans. (b) As $\sigma_1 = \sigma_2$ (Given)

$$\frac{q_1}{4\pi r_1^2} = \frac{q_2}{4\pi r_2^2} \text{ or } \frac{q_1}{q_2} = \frac{r_1^2}{r_2^2}$$

Then ratio of electric field intensities,

$$\frac{E_1}{E_2} = \frac{q_1}{4\pi\varepsilon_0 r_1^2} \times \frac{4\pi\varepsilon_0 r_2^2}{q_2}$$

$$= \frac{q_1}{q_2} \times \frac{r_2^2}{r_1^2} = \frac{q_1}{q_2} \times \frac{q_2}{q_1} = 1$$

i.e., $E_1 = E_2$

Q 170. Assertion (A): Surface charge density of an irregularly shaped conductor is non-uniform.

Reason (R): Surface density is defined as charge per unit area.

Ans. (b)

Q 171. Assertion (A): Total flux through a closed surface is zero, if net charge enclosed by the surface is zero.

Reason (R): Gauss law is true for any closed surface, no matter what its shape or size is.

Ans. (b) Gauss law implies that the total electric flux through a closed surface is zero if no net charge is enclosed by the surface and it is true for any closed surface, independent of its shape and size.

Q 172. Assertion (A): The electric flux emanating out and entering a closed surface are 8×10^3 and 2×10^3 Vm respectively. The charge enclosed by the surface is 0.053 μC.

Reason (R): Gauss's theorem in electrostatics may be applied to verify.

Ans. (a) According to Gauss's theorem in electrostatics,

$$\phi = \frac{q}{\varepsilon_0}$$

$$q = \varepsilon_0\phi = 8.85 \times 10^{-12} (8 \times 10^3 - 2 \times 10^3)$$

$$= 53.10 \times 10^{-9} \text{ C} = 0.053 \,\mu\text{C}$$

Q 173. Assertion (A): A point charge is lying at the centre of a cube of each side. The electric flux emanating from each surface of the cube is $\frac{1}{6}$th of total flux.

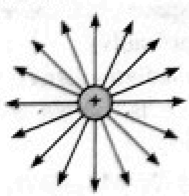
Reason (R): According to Gauss theorem, total electric flux through a closed surface enclosing a charge is equal to $1/\varepsilon_0$ times the magnitude of the charge enclosed.

Ans. (b) The electric flux through the cube, $\phi = q/\varepsilon_0$. A cube has six faces of equal area. Therefore, electric flux through each face $= \frac{1}{6}\phi = \frac{1}{6}(q/\varepsilon_0)$.

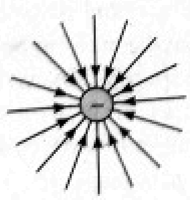
Case Study Based QUESTIONS

Case Study 1

A charge is a property associated with the matter due to which it experiences and produces an electric and magnetic field. Charges are scalar in nature and they add up like real numbers. Also, the total charge of an isolated system is always conserved. When the objects rub against each other charges acquired by them must be equal and opposite.



Electric field lines of a positive point charge



Electric field lines of a negative point charge

Read the above passage carefully and give the answer of the following questions.

Q 1. The cause of charging is:

a. the actual transfer of protons
b. the actual transfer of electrons
c. the actual transfer of neutrons
d. None of the above

Ans. (b) the actual transfer of electrons

The cause is the actual transfer of electrons from one body to the other.

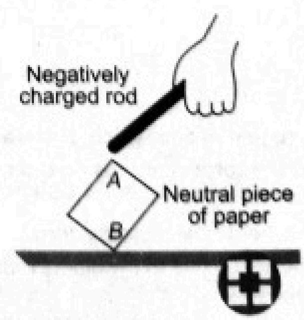
Q 2. When a glass rod is rubbed with silk:

a. negative charge is produced on silk but no charge on glass rod
b. equal but opposite charges are produced on both
c. equal and similar charges are produced on both
d. positive charge is produced on glass rod but no charge on silk

Ans. (b) equal but opposite charges are produced on both

When glass rod is rubbed with silk, glass rod loses electrons and silk grabs them. So after rubbing, glass becomes positively charged and silk becomes negatively charged. Thus, equal but opposite charges are produced on both.

Q 3. A piece of paper appears to be attracted to a charged ebonite rod, even before they touch (see fig.). The charge at *B* is:



a. positive
b. may be positive or negative
c. no charge
d. negative

Ans. (a) positive

It is given that the ebonite rod is negatively charged. Point A will be attracted only, if charge at point A is positive because only unlike charges attract each other.

Hence, charge at A is positive.

Q 4. What happens when a charged balloon is placed near another balloon of the same charge?

a. Attract each other b. Repel each other
c. Neither attract nor repel d. All of the above

Ans. (b) Repel each other

Both the balloons are charged and having same charge, therefore they will repel each other.

Q 5. The cause of quantization of electric charges is:

a. transfer of an integral number of neutrons
b. transfer of an integral number of protons
c. transfer of an integral number of electrons
d. None of the above

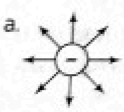
Ans. (c) transfer of an integral number of electrons

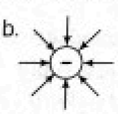
Case Study 2

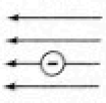
Photocopiers work on the principle that 'opposites attract'. Toner is a powder that is used to create the printed text and images on paper. The powder is negatively charged, and so it is attracted to something positive—the paper. The drum, which is located in the heart of a photocopier, is positively charged using static electricity. An image of the master copy is transferred onto the drum using a laser. The light parts of the image (the white areas on a piece of paper) lose their charge so becomes more negative, and the black areas of the image (where the text is) remain positively charged.

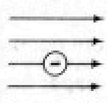
Read the above passage carefully and give the answer of the following questions.

Q 1. Which of the following figures represent the electric field lines due to a single negative charge.

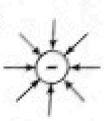
a.


b.


c.


d.


Ans. (b)



Q 2. Consider a region inside which, there are various types of charges but the total charge is zero. At points outside the region:

a. the electric field is necessarily zero
b. the electric field is due to the dipole moment of the charge distribution only
c. the dominant electric field is inversely proportional to r^3, for larger r (distance from origin)
d. the work done to move a charged particle along a closed path, away from the region will not be zero

Ans. (c) the dominant electric field is inversely proportional to r^3, for large r (distance from origin)

Q 3. If a body is negatively charged, then it has:

a. excess of electrons b. excess of protons
c. deficiency of electron d. deficiency of neutron

Ans. (a) excess of electrons

Q 4. A charged particle is free to move in an electric field. It will travel:

a. always along a line of force
b. along a line of force, if its initial velocity is zero
c. along a line of force, if it has some initial velocity in the direction of an acute angle with the line of force
d. None of the above

Ans. (b) along a line of force, if its initial velocity is zero

Q 5. Which of the following statements is incorrect?

(i) The charge q on a body is always given by $q = ne$, where n is any integer, positive or negative.

(ii) By convention, the charge on an electron is taken to be negative.

(iii) The fact that electric charge is always an integral multiple of e is termed as quantisation of charge.

(iv) The quantisation of charge was experimentally demonstrated by Newton in 1912.

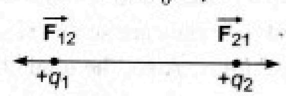
a. Only (i) b. Only (ii) c. Only (iv) d. Only (iii)

Ans. (c) Only (iv)

Case Study 3

Coulomb's law states that the electrostatic force of attraction or repulsion acting between two stationary points charges is given by

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$



where F denotes the force between two charges q_1 and q_2 separated by a distance r in free space, ε_0 is a constant known as permittivity of free space. Free space is vacuum and may be taken to be air practically.

If free space is replaced by a medium, then ε_0 is replaced by $(\varepsilon_0 k)$ or $(\varepsilon_0 \varepsilon_r)$, where k is known as dielectric constant or relative permittivity.

Read the above passage carefully and give the answer of the following questions.

Q 1. In Coulomb's law, $F = k\frac{q_1 q_2}{r^2}$, then on which of the following factors does the proportionality constant k depends?

a. Electrostatic force acting between the two charges
b. Nature of the medium between the two charges
c. Magnitude of the two charges
d. Distance between the two charges

Ans. (b) Nature of the medium between the two charges

The proportionality constant k depends on the nature of the medium between the two charges.

Q 2. Dimensional formula for the permittivity constant ε_0 of free space is:

a. $[ML^{-3}T^4A^2]$ b. $[M^{-1}L^3T^2A^2]$

c. $[M^{-1}L^{-3}T^4A^2]$ d. $[ML^{-3}T^4A^{-2}]$

Ans. (c) $[M^{-1}L^{-3}T^4A^2]$

As, $[\varepsilon_0] = \frac{1}{4\pi F}\cdot\frac{q_1q_2}{r^2} = \frac{[AT]^2}{[MLT^{-2}][L^2]}$

$= [M^{-1}L^{-3}T^4A^2]$

Q 3. The force of repulsion between two charges of 1 C each, kept 1 m apart in vacuum is:

a. $\frac{1}{9\times10^9}$ N b. 9×10^9 N c. 9×10^7 N d. $\frac{1}{9\times10^{12}}$ N

Ans. (b) 9×10^9 N

Q 4. Two identical charges repel each other with a force equal to 10 mgwt when they are 0.6 m apart in air. ($g = 10\ ms^{-2}$). The value of each charge is:

a. 2 mC b. 2×10^{-7} mC

c. 2 nC d. 2 μC

Ans. (d) 2 μC

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{d^2}$$

$$\therefore (10\times10^{-3})\times10 = \frac{(9\times10^9)\times q^2}{(0.6)^2}$$

or $$q^2 = \frac{10^{-1}\times0.36}{9\times10^9} = 4\times10^{-12}$$

or $$q = 2\times10^{-6}\ C = 2\ \mu C$$

Q 5. Coulomb's law for the force between electric charges most closely resembles with:

a. law of conservation of energy

b. Newton's law of gravitation

c. Newton's 2nd law of motion

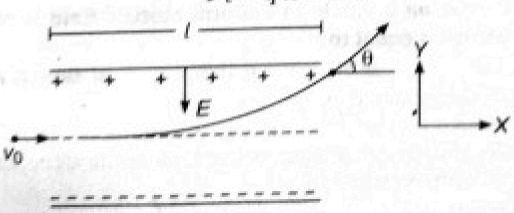
d. law of conservation of charge

Ans. (b) Newton's law of gravitation

Case Study 4

When a charged particle is placed in an electric field, it experiences an electrical force. If this is the only force on the particle, it must be the net force. The net force will cause the particle to accelerate according to Newton's second law. So

$$\vec{F}_e = q\vec{E} = m\vec{a}$$



If $\vec{E}$ is uniform, then $\vec{a}$ is constant and $\vec{a} = q\vec{E}/m$. If the particle has a positive charge, its acceleration is in the direction of the field. If the particle has a negative charge, its acceleration is in the direction opposite to the electric field. Since, the acceleration is constant, the kinematic equations can be used.

Read the above passage carefully and give the answer of the following questions.

Q 1. An electron of mass m, charge e falls through a distance h metre in a uniform electric field E. Then time of fall:

a. $t = \sqrt{\frac{2hm}{eE}}$ b. $t = \frac{2hm}{eE}$ c. $t = \sqrt{\frac{2eE}{hm}}$ d. $t = \frac{2eE}{hm}$

Ans. (a) $t = \sqrt{\frac{2hm}{eE}}$

From Newton's law

$$F = m\vec{a} \text{ or } qE = m\vec{a} \Rightarrow \frac{qE}{m} = \frac{eE}{m}$$

Using $s = ut + \frac{1}{2}at^2$

$$\therefore \quad h = 0 + \frac{1}{2}\times\frac{eE}{m}t^2 \Rightarrow t = \sqrt{\frac{2hm}{eE}}$$

Q 2. An electron moving with a constant velocity v along X-axis enters a uniform electric field applied along Y-axis. Then the electron moves:

a. with uniform acceleration along Y-axis

b. without any acceleration along Y-axis

c. in a trajectory represented as $y = ax^2$

d. in a trajectory represented as $y = ax$

Ans. (c) in a trajectory represented as $y = ax^2$

Q 3. Two equal and opposite charges of masses m_1 and m_2 are accelerated in an uniform electric field through the same distance. What is the ratio of their accelerations, if their ratio of masses is $\frac{m_1}{m_2} = 0.5$?

a. $\frac{a_1}{a_2} = 2$ b. $\frac{a_1}{a_2} = 0.5$ c. $\frac{a_1}{a_2} = 3$ d. $\frac{a_1}{a_2} = 1$

Ans. (a) $\frac{a_1}{a_2} = 2$

Force is same in magnitude for both.

$$\therefore \quad m_1a_1 = m_2a_2$$

$$\frac{a_1}{a_2} = \frac{m_2}{m_1} = \frac{1}{0.5} = 2$$

Q 4. A particle of mass m carrying charge q is kept at rest in a uniform electric field E and then released. The kinetic energy gained by the particle, when it moves through a distance y is:

a. $\frac{1}{2}qEy^2$ b. qEy c. qEy^2 d. qE^2y

Ans. (b) qEy

Here, $u = 0$; $a = \frac{qE}{m}$; $s = y$

Using, $v^2 - u^2 = 2as \Rightarrow v^2 = 2\frac{qE}{m}y$

$$\therefore \quad K.E. = \frac{1}{2}mv^2 = qEy$$

Q 5. A charged particle is free to move in an electric field. It will travel:

a. always along a line of force

b. along a line of force, if its initial velocity is zero

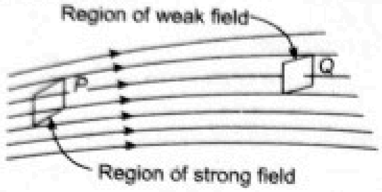
c. along a line of force, if it has some initial velocity in the direction of an acute angle with the line of force

d. None of the above

Ans. (d) None of the above

Case Study 5

Electric field strength is proportional to the density of lines of force *i.e.*, electric field strength at a point is proportional to the number of lines of force cutting a unit area element placed normal to the field at that point. As illustrated in the given figure, the electric field at P is stronger than at Q.



Read the given passage carefully and give the answer of the following questions.

Q 1. Electric lines of force about a positive point charge are:

a. radially outwards b. circular clockwise
c. radially inwards d. parallel straight lines

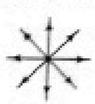
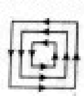
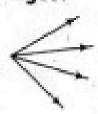
Ans. (a) radially outwards

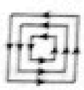
Q 2. Which of the following is false for electric lines of force?

a. They always start from positive charges and terminate on negative charges
b. They are always perpendicular to the surface of a charged conductor
c. They always form closed loops
d. They are parallel and equally spaced in a region of uniform electric field

Ans. (c) They always form closed loops

Q 3. Which one of the following pattern of electric line of force is not possible in filed due to stationary charges?

a.  b.  c.  d. 

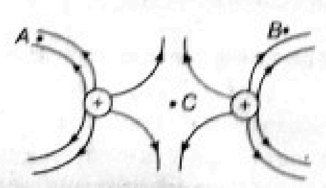
Ans. (c) 

Q 4. Electric lines of force are curved:

a. in the field of a single positive or negative charge
b. in the field of two equal and opposite charges
c. in the field of two like charges
d. Both b. and c.

Ans. (d) Both b. and c.

Q 5. The figure below shows the electric field lines due to two positive charges. The magnitudes E_A, E_B and E_C of the electric fields at points A, B and C respectively are related as:

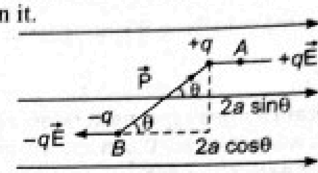


a. $E_A > E_B > E_C$ b. $E_B > E_A > E_C$
c. $E_A = E_B > E_C$ d. $E_A > E_B = E_C$

Ans. (a) $E_A > E_B > E_C$

Case Study 6

When electric dipole is placed in uniform electric field, its two charges experience equal and opposites forces, which cancel each other and hence net force on electric dipole in uniform electric field is zero. However these forces are not collinear, so they give rise to some torque on the dipole. Since, net force on electric dipole in uniform electric field is zero, so no work is done in moving the electric dipole in uniform electric field. However some work is done in rotating the dipole against the torque acting on it.



Read the given passage carefully and give the answer of the following questions.

Q 1. The dipole moment of a dipole in a uniform external field $\vec{E}$ is $\vec{P}$. Then the torque $\vec{\tau}$ acting on the dipole is:

a. $\vec{\tau} = \vec{P} \times \vec{E}$ b. $\vec{\tau} = \vec{P} \cdot \vec{E}$
c. $\vec{\tau} = 2(\vec{P} \times \vec{E})$ d. $\vec{\tau} = (\vec{P} + \vec{E})$

Ans. (a) $\vec{\tau} = \vec{P} \times \vec{E}$

As τ = either force × perpendicular distance between the two forces

$= qaE \sin\theta$ or $\tau = PE \sin\theta$

or $\tau = \vec{P} \times \vec{E}$ $(\because qa = P)$

Q 2. An electric dipole consists of two opposite charges, each of magnitude 1.0 μC separated by a distance of 2.0 cm. The dipole is placed in an external field of 10^5 NC^{-1}. The maximum torque on the dipole is:

a. 0.2×10^{-3} Nm b. 1×10^{-3} Nm
c. 2×10^{-3} Nm d. 4×10^{-3} Nm

Ans. (c) 2×10^{-3} Nm

The maximum torque on the dipole in an external electric field is given by

$$\tau = pE = q(2a) \times E$$

Here, $q = 1\mu C = 10^{-6}$ C, $2a = 2$ cm $= 2 \times 10^{-2}$ m,

$E = 10^5$ NC^{-1}, $\tau = ?$

$\therefore$ $\tau = 10^{-6} \times 2 \times 10^{-2} \times 10^5$

$= 2 \times 10^{-3}$ Nm

Q 3. Torque on a dipole in uniform electric field is minimum when θ is equal to:

a. 0° b. 90° c. 180° d. Both a. and c.

Ans. (d) Both a. and c.

When θ is 0 or 180°, the τ is minimum, which means the dipole moment should be parallel to the direction of the uniform electric field.

Q 4. When an electric dipole is held at an angle in a uniform electric field, the net force F and torque τ on the dipole are:

a. $F = 0, \tau = 0$ b. $F \neq 0, \tau \neq 0$
c. $F = 0, \tau \neq 0$ d. $F \neq 0, \tau = 0$

Ans. (c) $F = 0, \tau \neq 0$

Net force is zero and torque acts on the dipole, trying to align p with E.

Q 5. An electric dipole of moment p is placed in an electric field of intensity E. The dipole acquires a position such that the axis of the dipole makes an angle θ with the direction of the field. Assuming that the potential energy of the dipole to be zero when $\theta = 90°$, the torque and the potential energy of the dipole will respectively be:

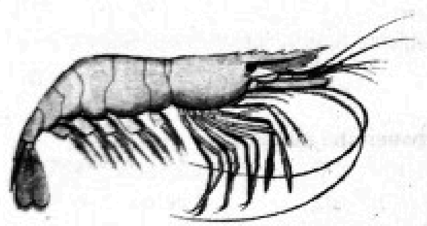
a. $pE \sin\theta, -pE \cos\theta$ b. $pE \sin\theta, -2pE \cos\theta$
c. $pE \sin\theta, 2pE \cos\theta$ d. $pE \cos\theta, -pE \sin\theta$

Ans. (a) $pE \sin\theta, -pE \cos\theta$

Torque, $\tau = pE \sin\theta$ and potential energy $U = -pE \cos\theta$

Case Study 7

Animals emit low frequency electric fields due to a process known as osmoregulation. This process allows the concentration of ions (charged atoms or molecules) to flow between the inside of our bodies and the outside. In order for our cells to stay intact, the flow of ions needs to be balanced. But balanced doesn't necessarily mean equal. The concentration of ions within a shrimp's body is much lower than that of the sea water it swims in. Their voltage, or potential difference generated between the two concentrations across 'leaky' surfaces, can then be measured.



Read the above passage carefully and give the answer of the following questions.

Q 1. The Gaussian surface for ions in the body of animals:

a. can pass through a continuous charge distribution
b. cannot pass through a continuous charge distribution
c. can pass through any system of discrete charges
d. can pass through a continuous charge distribution as well as any system of discrete charges

Ans. (d) can pass through a continuous charge distribution as well as any system of discrete charges

Q 2. Gauss's law is valid for:

a. any closed surface
b. only regular close surfaces
c. any open surface
d. only irregular open surfaces

Ans. (a) any closed surface

Q 3. The electric field inside a shrimp's body of uniform charge density is:

a. zero
b. constant different from zero
c. proportional to the distance from the curve
d. None of the above

Ans. (a) zero

Q 4. If a small piece of linear isotropic dielectric is swallowed by a shrimp and inside the body it is influenced by an electric field E, then the polarization P is:

a. independent of E
b. inversely proportional to E
c. directly proportional to $\sqrt{E}$
d. directly proportional to E

Ans. (d) directly proportional to E

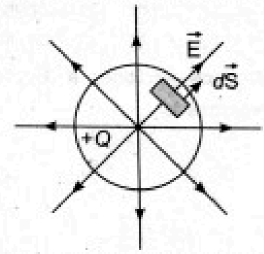
Q 5. Field due to multiple charges/ions inside shrimp's body at a point is found by using:
(i) superposition principle (ii) Coulomb's law
(iii) law of conservation of charges

a. (i) and (ii) b. (ii) and (iii) c. (i) and (iii) d. (i), (ii) and (iii)

Ans. (a) (i) and (ii)

Case Study 8

Gauss's law and Coulomb's law, although expressed in different forms, are equivalent ways of describing the relation between charge and electric field in static conditions. Gauss's law is $\varepsilon_0 \phi = q_{encl}$, when q_{encl} is the net charge inside an imaginary closed surface called Gaussian surface. $\phi = \oint \vec{E} \cdot d\vec{A}$ gives the electric flux through the Gaussian surface. The two equations hold only when the net charge is in vacuum or air.



Gaussian spherical surfaces

Read the given passage carefully and give the answer of the following questions.

Q 1. If there is only one type of charge in the universe, then ($\vec{E} \to$ Electric field, $d\vec{S} \to$ Area vector)

a. $\oint \vec{E} \cdot d\vec{S} \neq 0$ on any surface
b. $\oint \vec{E} \cdot d\vec{S}$ could not be defined
c. $\oint \vec{E} \cdot d\vec{S} = \infty$, if charge is inside
d. $\oint \vec{E} \cdot d\vec{S} = 0$, if charge is outside, $\oint \vec{E} \cdot d\vec{S} = \frac{q}{\varepsilon_0}$, if charge is inside

Ans. (d) $\oint \vec{E} \cdot d\vec{S} = 0$ if charge is outside, $\oint \vec{E} \cdot d\vec{S} = \frac{q}{\varepsilon_0}$, if charge is inside.

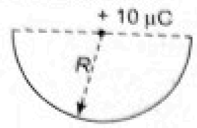
If there is only one type of charge in the universe, then it will produce electric field somehow. Hence, Gauss's law is valid.

Q 2. What is the nature of Gaussian surface involved in Gauss law of electrostatic?

a. Magnetic b. Scalar c. Vector d. Electrical

Ans. (c) Vector

Q 3. A charge 10 μC is placed at the centre of a hemisphere of radius $R = 10$ cm as shown. The electric flux through the hemisphere (in MKS units) is:



a. 20×10^5 b. 10×10^5 c. 6×10^5 d. 2×10^5

Ans. (c) 6×10^5

According to Gauss's theorem,

Electric flux through the sphere $= \frac{q}{\varepsilon_0}$

$\therefore$ Electric flux through the hemisphere $= \frac{1}{2}\frac{q}{\varepsilon_0}$

$$= \frac{10 \times 10^{-6}}{2 \times 8.854 \times 10^{-12}}$$

$$= 0.56 \times 10^6 \text{ Nm}^2\text{C}^{-1}$$

$$\approx 0.6 \times 10^6 \text{ Nm}^2\text{C}^{-1} = 6 \times 10^5 \text{ Nm}^2\text{C}^{-1}$$

Q 4. The electric flux through a closed surface area S enclosing charge Q is ϕ. If the surface area is doubled, then the flux is:

a. 2ϕ b. $\phi / 2$ c. $\phi / 4$ d. ϕ

Ans. (d) ϕ

As flux is the total number of lines passing through the surface, for a given charge, it is always the charge enclosed Q / ε_0. If area is doubled, the flux remains the same.

Q 5. A Gaussian surface encloses a dipole. The electric flux through this surface is:

a. $\frac{q}{\varepsilon_0}$ b. $\frac{2q}{\varepsilon_0}$ c. $\frac{q}{2\varepsilon_0}$ d. zero

Ans. (d) zero

As net charge on a dipole is

$$(-q + q) = 0$$

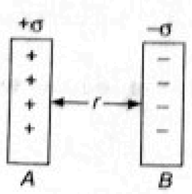
Thus, when a Gaussian surface encloses a dipole, as per Gauss's theorem, electric flux through the surface,

$$\oint \vec{E} \cdot d\vec{S} = \frac{q}{\varepsilon_0} = 0$$

Case Study 9

Surface charge density is defined as charge per unit surface area of surface charge distribution *i.e.*, $\sigma = \frac{dq}{dS}$.

Two large, thin metal plates are parallel and close to each other. On their inner faces, the plates have surface charge densities of opposite signs having magnitude of 17.0×10^{-22} Cm^{-2} as shown. The intensity of electric field at a point is $E = \frac{\sigma}{\varepsilon_0}$, where ε_0 = permittivity of free space.



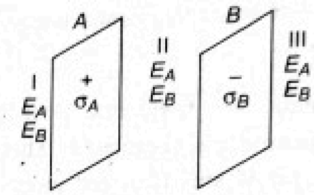
Read the above passage carefully and give the answer of the following questions.

Q 1. E in the outer region of the first plate is:

a. 17×10^{-22} N/C b. 1.5×10^{-25} N/C
c. 1.9×10^{-10} N/C d. zero

Ans. (d) zero

There are two plates A and B having surface charge densities, $\sigma_A = 17.0 \times 10^{-22}$ C/m^2 on A and $\sigma_B = -17.0 \times 10^{-22}$ C/m^2 on B, respectively.



According to Gauss's theorem, if the plates have same surface charge density but having opposite signs, then the electric field in region I is zero.

$$E_I = E_A + E_B = \frac{\sigma}{2\varepsilon_0} + \left(-\frac{\sigma}{2\varepsilon_0}\right) = 0$$

Q 2. E is the outer region of the second plate is:

a. 17×10^{-22} N/C b. 1.5×10^{-15} N/C
c. 1.9×10^{-10} N/C d. zero

Ans. (d) zero

The electric field in region III is also zero.

$$E_{III} = E_A + E_B = \frac{\sigma}{2\varepsilon_0} + \left(-\frac{\sigma}{2\varepsilon_0}\right) = 0$$

Q 3. E between the plates is:

a. 17×10^{-22} N/C b. 1.5×10^{-15} N/C
c. 1.9×10^{-10} N/C d. zero

Ans. (c) 1.9×10^{-10} N/C

In region II or between the plates, the electric field

$$E_{II} = E_A - E_B = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0}$$

$$= \frac{\sigma(\sigma_A \text{ or } \sigma_B)}{\varepsilon_0} = \frac{17.0 \times 10^{-22}}{8.85 \times 10^{-12}}$$

$$E = 1.9 \times 10^{-10} \text{NC}^{-1}$$

Q 4. The ratio of E from right side of B at distances 2 cm and 4 cm, respectively is:

a. 1 : 2 b. 2 : 1
c. 1 : 1 d. 1: $\sqrt{2}$

Ans. (c) 1 : 1

Electric field due to an infinite plane sheet of charge does not depend on the distance of observation point from the plane sheet of charge.

So, ratio of E will be 1 : 1.

Q 5. In order to estimate the electric field due to a thin finite plane metal plate, the Gaussian surface considered is:

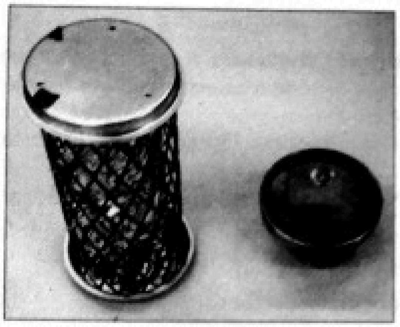
a. spherical b. cylindrical
c. straight line d. None of these

Ans. (b) cylindrical

We take a cylindrical cross-sectional area A and length $2r$ as Gaussian surface.

Case Study 10

Faraday Cage: A Faraday cage or Faraday shield is an enclosure made of a conducting material. The fields within a conductor cancel out with any external fields, so the electric field within the enclosure is zero. These Faraday cages act as big hollow conductors you can put things into shield them from electrical fields. Any electrical shocks the cage receives, pass harmlessly around the outside of the cage.



Read the above passage carefully and give the answer of the following questions.

Q 1. Which of the following materials can be used to make a Faraday cage?

a. Plastic
b. Glass
c. Copper
d. Wood

Ans. (c) Copper

Q 2. Example of a real-world Faraday cage is:

a. car
b. plastic box
c. lightning rod
d. metal rod

Ans. (a) car

Q 3. What is the electrical force inside a Faraday cage when it is struck by lightning?

a. The same as the lightning
b. Half that of the lightning
c. Zero
d. A quarter of the lightning

Ans. (c) Zero

Q 4. An isolated point charge $+q$ is placed inside the Faraday cage. Its surface must have charge equal to:

a. zero
b. $+q$
c. $-q$
d. $+2q$

Ans. (c) $-q$

Q 5. A point charge of 2 C is placed at centre of Faraday cage in the shape of cube with surface of 9 cm edge. The number of electric field lines passing through the cube normally will be:

a. 1.9×10^5 Nm^2 / C entering the surface
b. 1.9×10^5 Nm^2 / C leaving the surface
c. 2.0×10^5 Nm^2 / C leaving the surface
d. 2.0×10^5 Nm^2 / C entering the surface

Ans. (b) 1.9×10^5 Nm^2 / C leaving the surface

CHAPTER

2 Electrostatic Potential and Capacitance

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Fastrack REVISION

- **Electric Potential:** The electric potential at a point in an electric field is the amount of work done in moving a unit positive charge from infinity to that point against the electrostatic forces.
- **Electric Potential Difference:** The electric potential difference between two points is defined as the work done by external agent in moving a unit charge from one point to another without acceleration.
  - It is a scalar quantity.
  - Potential difference $= \frac{W}{q}$
  - Its units is $\frac{J}{C}$ = volt (V).
- **Potential Difference at a Point to a Point Charge**

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

- **Principle of Superposition:** Potential at a point due to number of charges is equal to the algebraic sum of all the potentials produced at that point due to all charges separately.

$$V = V_1 + V_2 + V_3 + \ldots$$

- **Potential on the Axis of a Dipole**

$$V = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^2 - l^2}$$

If $r^2 >> l^2$ then, $V = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^2}$

- **Potential at Equatorial Point**

$$V = 0$$

- **Potential due to Dipole at any General Point**

$$V = \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{r_1} - \frac{q}{r_2}\right) = \frac{1}{4\pi\varepsilon_0} q\left[\frac{r_2 - r_1}{r_1 r_2}\right]$$

$$V = \frac{1}{4\pi\varepsilon_0}\left[\frac{p\cos\theta}{r^2}\right]$$

- **Equipotential Surfaces:** A surface at which potential of each points is same is called equipotential surface. *e.g.*, surface of a charged conductor.
- **Characteristics of Equipotential Surface**
  - Work done in carrying a charge from one point to another on equipotential surface is zero.
  - The direction of electric field near the equipotential surface is always perpendicular to it.
  - Two equipotential surface do not cross each other. If they do, it means two potentials at the same point which is absurd.
  - Electric field is stronger where equipotential surface are close to each other and where they are farther apart, electric field is weaker.
- **Electric Potential Energy:** Potential energy of a system of charge is defined as the work done in bringing the charge from infinity to its present position without acceleration.
- **Potential Energy of System of Two Charges**

$$U = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1 q_2}{r}\right]$$

- **Potential Energy of a Dipole in Uniform Electric Field**

$$U = -pE\cos\theta = -\vec{p}\cdot\vec{E}$$

- **Electrostatics of Conductors:** A conductor is a substance that can be used to carry or conduct electric charges from one place to the another as it contains a large number of free electrons.
  Some of the important results regarding electrostatics of conductors:
  (i) Electric field inside the charged conductor is zero.
  (ii) Just outside the surface of charged conductor, electric field is perpendicular to the surface.
  (iii) The interior of conductor can have no excess charge in static situation.
  (iv) It behaves as the total charge is concentrated at the centre of the sphere.
  (v) Potential at every point inside the charged conductor is same and is equal to the potential at surface of conductor.

$$E = -\frac{dV}{dr} = 0 \quad \text{or} \quad dV = 0$$

- **Electric Field at the Surface of Charged Conductor**

$$E = \frac{\sigma}{\varepsilon_0}$$

- **Electrostatic Shielding:** Electrostatic shielding/screening is the phenomenon of protecting a certain region of space from external electric field.
- **Application of Electrostatic Shielding**
  - To protect sensitive electronic devices from external electric field by placing them in metallic boxes.
  - During thunderstorm or lightning it is safe to sit in the car.
  - Coaxial cable are shielded by metallic wire gauge.
- **Dielectric Materials:** Dielectrics are non-conducting materials in which electrons are tightly bound to their atoms or molecules.
- **Dielectric Polarisation:** When a non-polar dielectric is held in an external electric field, the centre of positive charge is pulled in the direction of electric field and the centre of negative charge is pulled in the direction opposite to electric field. Thus molecule develops an induced dipole moment and the dielectric is said to be polarised.
- **Polarisation:** The dipole moment per unit volume is called polarisation and is denoted by P.

$$P = \varepsilon_0 \chi_e E$$

- **Capacitors and Capacitance:** A capacitor is a system of two conductors separated by an insulator. The conductors have charges Q_1 and Q_2 and potentials V_1 and V_2.
  - The total charge of capacitor is zero.
  - The electric field in the region between the conductor is proportional to the charge Q.

$$V \propto Q \text{ so, } C = Q/V$$

  where, C is called the capacitance of the capacitor.
  - C depends only on geometrical configuration (shape, size, separation).
  - Its S.I. unit is farad (CV^{-1}).

- **Dielectric Strength:** The maximum electric field that a dielectric medium can withstand without break-down is called its dielectric strength.
- **Parallel Plate Capacitor**

$$C = \frac{\varepsilon_0 A}{d}$$

- **Capacitance of a Parallel Plate Capacitor with a Conducting Slab Inserted between its Plate**

$$C = \frac{Q}{V} = \frac{\varepsilon_0 A}{\left(d - t + \frac{t}{K}\right)}$$

- **Combination of Capacitors**

Capacitors in series:

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

Capacitors in parallel:

$$C = C_1 + C_2$$

- **Energy Stored in a Capacitor**

$$W = \frac{Q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$$

Objective TYPE QUESTIONS

Multiple Choice Questions

Q 1. Which of the following statement is not true?

a. Electrostatic force is a conservative force

b. Potential energy of charge q at a point is the work done per unit charge in bringing a charge from any point to infinity

c. Spring force and gravitational force are conservative force

d. Both a. and c.

Ans. (b) Potential energy of charge q at a point is the work done per unit charge in bringing a charge from any point to infinity

Q 2. This question contains Statement-1 and Statement-2. Of the four choices given after the statements, choose the one that best describes the two statements.

Statement-1: For a charged particle moving from point P to point Q, the net work done by an electrostatic field on the particle is independent of the path connecting point P to point Q.

Statement-2: The net work done by a conservative force on an object moving along a closed loop is zero.

a. Statement-1 is true, Statement-2 is false

b. Statement-1 is true, Statement-2 is true; Statement-2 is the correct explanation of Statement-1

c. Statement-1 is true, Statement-2 is true; Statement-2 is not the correct explanation of Statement-1

d. Statement-1 is false, Statement-2 is true

Ans. (c) Statement-1 is true, Statement-2 is true; Statement-2 is not the correct explanation of Statement-1

Q 3. Work done in bringing a unit positive charge from infinity to a point is:

a. potential energy

b. electrostatic potential

c. electric field

d. work

Ans. (b) electrostatic potential

Q 4. Which of the following is true about electrostatic potential?

a. It is conservative in nature

b. It is the ratio of work and charge

c. Both a. and b.

d. It is not conservative in nature

Ans. (c) Both a. and b.

Q 5. 1 volt is equivalent to:

a. $\frac{\text{newton}}{\text{second}}$ b. $\frac{\text{newton}}{\text{coulomb}}$

c. $\frac{\text{joule}}{\text{coulomb}}$ d. $\frac{\text{joule}}{\text{second}}$

Ans. (c) $\frac{\text{joule}}{\text{coulomb}}$

Q 6. A charge Q is placed at the origin. The electric potential due to this charge at a given point in space is V. The work done by an external force in bringing another charge q from infinity upto the point is:

a. V / q b. Vq c. $V + q$ d. V

Ans. (b) Vq

Potential at a point in a field is defined as the amount of work done in bringing a unit positive test charge (q) from that point along any arbitrary path

$$V = \frac{W}{q_0}$$

$\therefore$ Work done, $W = qV$

Q 7. Which of the following is true about electrostatic potential for a point charge?

a. It is inversely proportional to distance

b. It is the product of charge and work done

c. Electric field and potential can never be equal in magnitude

d. Both a. and c.

Ans. (a) It is inversely proportional to distance

KNOWLEDGE BOOSTER

Electrostatic potential due to a point charge $= \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$.

Q 8. Which of the following is true for bringing a positive test charge close to a negative charge Q?

a. $W > 0, V > 0$ b. $W < 0, V > 0$

c. $W < 0, V < 0$ d. None of these

Ans. (b) $W < 0, V > 0$

Q 9. Electric potential due to a point charge $-q$ at distance x from it is given by:

a. Kq / x^2 b. Kq / x c. $-Kq / x^2$ d. $-Kq / x$

Ans. (d) $-Kq / x$

Electric potential at distance x due to charge $-q$ is given by,

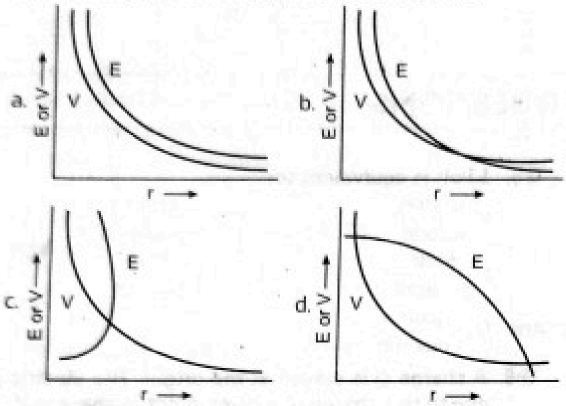
$$V = \frac{(-q)}{4\pi\varepsilon_0 x} = \frac{-Kq}{x} \qquad \left[\because K = \frac{1}{4\pi\varepsilon_0}\right]$$

Q 10. Electrostatic potential V at a point, distant r from a charge q varies as:

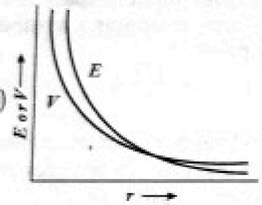
a. $\frac{q}{r^2}$ b. $\frac{q^2}{r}$ c. $\frac{q}{r}$ d. $\frac{q^2}{r^2}$

Ans. (c) $\frac{q}{r}$

Q 11. The variation potential V with r and electric field with r for a point charge is correctly shown in the graphs:



Ans. (b)



Q 12. The potential at a point, due to a positive charge of 100 μC at a distance of 9 m, is:

a. 10^4 V b. 10^6 V c. 10^5 V d. 10^7 V

Ans. (c) 10^5 V

Here, $q = 100\,\mu C = 100 \times 10^{-6}$ C, $r = 9$ m

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

$$= \frac{9 \times 10^9 \times 100 \times 10^{-6}}{9} = 10^5 \text{ V}$$

Q 13. What is the electric potential at a distance of 9 cm from 3 nC?

a. 270 V b. 3 V c. 300 V d. 30 V

Ans. (c) 300 V

Here, $q = 3\text{ nC} = 3 \times 10^{-9}$ C

and $r = 9\text{ cm} = 9 \times 10^{-2}$ m

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

$$= \frac{9 \times 10^9 \times 3 \times 10^{-9}}{9 \times 10^{-2}}$$

$$= 3 \times 10^2 = 300 \text{ V}$$

Common ! Error

Most students forget to convert cm into m.

Q 14. The electric potential at the surface of an atomic nucleus ($Z = 50$) of radius 9.0×10^{-13} cm is:

a. 9×10^5 V b. 8×10^6 V c. 80 V d. 9 V

Ans. (b) 8×10^6 V

We know that,

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r} = \frac{1}{4\pi\varepsilon_0}\frac{Ze}{r}$$

$$= \frac{9 \times 10^9 \times 50 \times 1.6 \times 10^{-19}}{9 \times 10^{-13} \times 10^{-2}} = 8 \times 10^6 \text{ V}$$

Q 15. The potential at a point due to a charge of 5×10^{-7} C located 10 cm away is:

a. 3.5×10^5 V b. 3.5×10^4 V
c. 4.5×10^4 V d. 4.5×10^5 V

Ans. (c) 4.5×10^4 V

Here, $q = 5 \times 10^{-7}$ C, $r = 10\text{ cm} = 0.1$ m

Potential, $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r} = \frac{9 \times 10^9 \times 5 \times 10^{-7}}{0.1} = 4.5 \times 10^4$ V

Q 16. In the question number 15, work done in bringing a charge of 4×10^{-9} C from infinity to that point is:

a. 2.4×10^{-4} J b. 1.8×10^{-4} J c. 3.2×10^{-5} J d. 4.1×10^{-5} J

Ans. (b) 1.8×10^{-4} J

Work done, $W = q(V_f - V_i)$

$$= 4 \times 10^{-9} \times 4.5 \times 10^4 = 1.8 \times 10^{-4} \text{ J}$$

Q 17. The electric field intensity at a point P due to point charge q kept at point Q is 24 NC^{-1} and the electric potential at point P due to same charge is 12 JC^{-1}. The order of magnitude of charge q is:

a. 10^{-6} C b. 10^{-7} C c. 10^{-10} C d. 10^{-9} C

Ans. (d) 10^{-9} C

Electric field of a point charge,

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2} = 24 \text{ NC}^{-1}$$

Electric potential of a point charge,

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r} = 12 \text{ JC}^{-1}$$

The distance PQ is $r = \frac{V}{E} = \frac{12}{24} = 0.5$ m

$\therefore$ Magnitude of charge $= 4\pi\varepsilon_0 Vr$

$$= \frac{1}{9 \times 10^9} \times 12 \times 0.5 = 0.667 \times 10^{-9} \text{ C} \approx 10^{-9} \text{ C}$$

Q 18. How much work is required to carry a 6 μC charge from the negative to the positive terminal of a 9 V battery?

a. 54×10^{-3} J b. 54×10^{-9} J
c. 54×10^{-6} J d. 54×10^{-12} J

Ans. 54×10^{-6} J

Here, $q = 6\,\mu C = 6 \times 10^{-6}$ C, $V = 9$ V

We know that, $W = qV = 6 \times 10^{-6} \times 9$

$$= 54 \times 10^{-6} \text{ J}$$

Q 19. A hollow metal sphere of radius 10 cm is charged such that the potential on its surface becomes 80 V. The potential at the centre of the sphere is:

a. 80 V b. 800 V c. 8 V d. zero

Ans. (a) 80 V

The potential at the centre of the sphere is 80 V, because it remains same at each point under the metallic hollow sphere.

Q 20. If a charged spherical conductor of radius 10 cm has potential V at a point distant 5 cm from its centre, then the potential at a point distant 15 cm from the centre will be:

a. 2/3 V b. 3/2 V c. 3 V d. 1/3 V

Ans. (a) 2/3 V

Radius of sphere = 10 cm

Potential inside sphere is same as on its surface

$$\therefore \quad V = \frac{Kq}{10} \quad ...(1)$$

Now, $$V' = \frac{Kq}{15} \quad ...(2)$$

$$\frac{V}{V'} = \frac{Kq}{10} \times \frac{15}{Kq} = \frac{3}{2}$$

$$\Rightarrow \quad V' = \frac{2}{3} V$$

Q 21. Which of the following is not true?

a. For a point charge, the electrostatic potential varies as $1/r$

b. For a dipole, the potential depends on the position vector and dipole moment vector

c. The electric dipole potential varies as $1/r$ at large distance

d. For a point charge, the electrostatic field varies as $1/r^2$

Ans. (c) The electric dipole potential varies as $1/r$ at large distance

Q 22. The potential of an electric dipole vary with distance r as:

a. $\frac{1}{r}$ b. $\frac{1}{r^3}$ c. $\frac{1}{r^4}$ d. $\frac{1}{r^2}$

Ans. (d) $\frac{1}{r^2}$

The potential of electric dipole at a distance r from the centre of the dipole is

$$V = \frac{1}{4\pi\varepsilon_0} \frac{p\cos\theta}{r^2}$$

$$V \propto \frac{1}{r^2}$$

Q 23. Which of the following is true about electrostatic potential for an electric dipole?

a. It is inversely proportional to square of distance

b. It depends upon angle between dipole moment and distance

c. For distance much greater than dipole length and 1, potential of a point charge is greater than potential of a dipole

d. All of the above

Ans. (d) All of the above

Q 24. The electric potential due to an electric dipole at an equatorial point is:

a. $\frac{1}{4\pi\varepsilon_0}\frac{q}{r}$ b. $\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$ c. zero d. $\frac{1}{4\pi\varepsilon_0}\frac{p}{r^2}$

Ans. (c) zero

Electric potential at any point in the equatorial plane of a dipole is zero.

Q 25. The ratio of potential on the equatorial line and on the axial line of a dipole is:

a. zero b. $\frac{1}{(4\pi\varepsilon_0)}\cdot\frac{p}{r^2}$

c. $\frac{W}{q_0}$ d. None of these

Ans. (a) zero

Q 26. A dipole is placed in a uniform electric field. Its potential energy will be minimum when the angle between its axis and field is:

a. zero b. π c. $\frac{\pi}{2}$ d. 2π

Ans. (a) zero

Potential energy of electric dipole = $-pE\cos\theta$

Potential energy is minimum, when $\theta = 0$

Q 27. The distance between H^+ and Cl^- ions in HCl molecules is 1.38 Å. The potential due to this dipole at a distance of 10 Å on the axis of dipole is:

a. 2.1 V b. 1.8 V c. 0.2 V d. 1.2 V

Ans. (c) 0.2 V

Here, $2a = 1.38 \times 10^{-10}$ m, $r = 10 \times 10^{-10}$ m

Charge, $q = 1.6 \times 10^{-19}$ C

As potential, $$V = \frac{p}{4\pi\varepsilon_0 r^2} = \frac{q(2a)}{4\pi\varepsilon_0 r^2}$$

$$= \frac{9 \times 10^9 \times 1.6 \times 10^{-19} \times 1.38 \times 10^{-10}}{(10 \times 10^{-10})^2} = 0.2 \text{ V}$$

Q 28. A dipole is placed parallel to the electric field. If W is the work done in rotating the dipole by 60°, then the work done in rotating it by 180° is:

a. $2W$ b. $3W$ c. $4W$ d. $\frac{W}{2}$

Ans. (c) $4W$

Work done in rotating dipole by θ,

$$W = pE(1 - \cos\theta)$$

$$= pE(1 - \cos 60^\circ) = pE\left(1 - \frac{1}{2}\right) = \frac{1}{2}pE$$

$$\Rightarrow \quad pE = 2W$$

$$W' = pE(1 - \cos 180^\circ)$$

$$W' = 2W[1 - (-1)]$$

$$W' = 4W$$

Q 29. For system of charges, the total potential at a point depends upon:

a. charges

b. position of point with respect to charges

c. nature of medium

d. All of the above

Ans. (d) All of the above

Q 30. Two point charges q and $-2q$ are kept at distance d apart. At what point, potential due to the charges is zero:

a. At a distance $d/2$ from charge q

b. At a distance $d/2$ from charge $-2q$

c. At a distance $d/3$ from charge q

d. At a distance $d/3$ from charge $-2q$

Ans. (c) At a distance $d/3$ from charge q

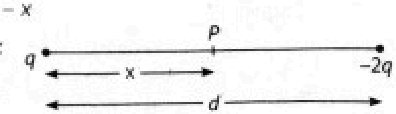
Let P be the required point at distance x from charge q.

$$\therefore \quad \frac{1}{4\pi\varepsilon_0}\frac{q}{x} + \frac{1}{4\pi\varepsilon_0}\frac{(-2q)}{d-x} = 0$$

$$\frac{1}{x} = \frac{2}{d-x}$$

$$d - x = 2x$$

$$\Rightarrow \quad x = \frac{d}{3}$$



$\therefore$ Required point is at a distance $d/3$ from charge q.

Q 31. When the separation between two charges is increased, the electric potential of the charges:

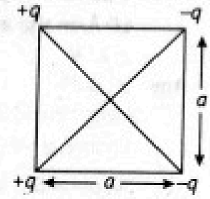
a. increases b. decreases
c. remains the same d. may increase or decrease

Ans. (d) may increase or decrease

KNOWLEDGE BOOSTER

Potential energy depends whether the charges are of same or opposite sign, if both are of same sign, then potential energy will decrease and if opposite charges, then it will decrease.

Q 32. The potential at the centre of the square is:

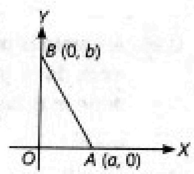


a. zero b. $\frac{kq}{a\sqrt{2}}$
c. $\frac{kq}{a^2}$ d. $\frac{kq}{a^3}$

Ans. (a) zero

The potential at the centre due to pair of dipole cancel each other and hence net potential is zero.

Q 33. A charge $+q$ is placed at the origin O of X-Y axes as shown in the figure. The work done in taking a charge Q from A to B along the straight line AB is:



a. $\frac{qQ}{4\pi\varepsilon_0}\left(\frac{a-b}{ab}\right)$ b. $\frac{qQ}{4\pi\varepsilon_0}\left(\frac{b-a}{ab}\right)$
c. $\frac{qQ}{4\pi\varepsilon_0}\left(\frac{b}{a^2}-\frac{1}{b}\right)$ d. $\frac{qQ}{4\pi\varepsilon_0}\left(\frac{a}{b^2}-\frac{1}{b}\right)$

Ans. (a) $\frac{qQ}{4\pi\varepsilon_0}\left(\frac{a-b}{ab}\right)$

Potential at point A is $V_A = \frac{1}{4\pi\varepsilon_0}\frac{q}{a}$

Potential at point B is $V_B = \frac{1}{4\pi\varepsilon_0}\frac{q}{b}$

Work done in taking a charge Q from A to B is

$$W = Q(V_B - V_A) = \frac{Qq}{4\pi\varepsilon_0}\left[\frac{1}{b}-\frac{1}{a}\right]$$

$$= \frac{Qq}{4\pi\varepsilon_0}\left[\frac{a-b}{ab}\right]$$

Q 34. The radii of two metallic spheres are 5 cm and 10 cm and both carry equal charge of 75 μC. If the two spheres are shorted, then charges will be transferred:

a. 25 μC from smaller to bigger
b. 25 μC from bigger to smaller
c. 50 μC from smaller to bigger
d. 50 μC from bigger to smaller

Ans. (a) 25 μC from smaller to bigger

Here, $r_1 = 5$ cm, $r_2 = 10$ cm

$C_1 = 75\ \mu C$, $C_2 = 75\ \mu C$

At equilibrium,

$$V_1 = V_2$$

$$\Rightarrow \frac{Kq_1}{r_1} = \frac{Kq_2}{r_2} \Rightarrow \frac{q_1}{5} = \frac{q_2}{10}$$

$$\Rightarrow q_2 = 2q_1 \quad ...(1)$$

We know that, $q_1 + q_2 = 75 + 75$

$\Rightarrow q_1 + 2q_1 = 150$

$\Rightarrow 3q_1 = 150$

$\Rightarrow q_1 = 50\ \mu C$

$\Rightarrow q_2 = 2 \times 50 = 100\ \mu C$

Hence, 25 μC (75 − 50) charge is transferred from smaller to bigger.

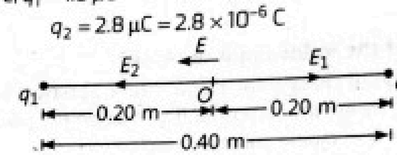
Q 35. Two tiny spheres carrying charges 1.8 μC and 2.8 μC are located at 40 cm apart. The potential at the mid-point of the line joining the two charges is:

a. 3.8×10^4 V b. 2.1×10^5 V c. 4.3×10^4 V d. 3.6×10^5 V

Ans. (b) 2.1×10^5 V

Here, $q_1 = 1.8\ \mu C = 1.8 \times 10^{-6}$ C,

$q_2 = 2.8\ \mu C = 2.8 \times 10^{-6}$ C



Distance between the two spheres = 40 cm = 0.4 m

For the mid-point $r_1 = r_2 = \frac{0.40}{2} = 0.2$ m

Potential at O,

$$V = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1}{r_1}+\frac{q_2}{r_2}\right]$$

$$= \frac{9\times10^9(1.8+2.8)\times10^{-6}}{0.2} = 2.1\times10^5\ \text{V}$$

Q 36. Three charges 1 μC, 2 μC, 3 μC are kept at vertices of an equilateral triangle of side 1 m. If they are brought nearer, so they now form an equilateral triangle of side 0.5 m, then the work done is:

a. 11 J b. 1.1 J
c. 0.01 J d. 0.1 J

Ans. (c) 0.01 J

Initial PE of the three charges,

$$U_i = k\frac{q_1q_2 + q_2q_3 + q_1q_3}{r}$$

$$= 9\times10^9\left[\frac{1\times2\times10^{-12} + 2\times3\times10^{-12} + 1\times3\times10^{-12}}{1}\right]$$

$$= 99\times10^{-3}\ \text{J}$$

Final PE of the system

$$U_f = 9\times10^9\left[\frac{1\times2\times10^{-12} + 2\times3\times10^{-12} + 1\times3\times10^{-12}}{0.5}\right]$$

$$= \frac{99\times10^{-3}}{0.5} = 198\times10^{-3}\ \text{J}$$

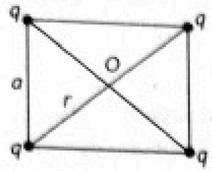
$$W = U_f - U_i = (198-99)\times10^{-3}\ \text{J}$$

$$= 99\times10^{-3}\ \text{J} = 0.099 = 0.01\ \text{J}$$

Q 37. Four equal charges q are placed at four corners of a square of each side a each. Work done in carrying a charge $-q$ from its centre to infinity is:

a. zero b. $\frac{(2q^2)}{(\pi\varepsilon_0 a)}$ c. $\frac{(\sqrt{2}\,q^2)}{(\pi\varepsilon_0 a)}$ d. $\frac{q^2}{(2\pi\varepsilon_0 a)}$

Ans. (c) $\frac{(\sqrt{2}\,q^2)}{(\pi\varepsilon_0 a)}$



Potential at centre $O = V_0 = 4 \times (k \cdot q / r)$

Here, $r = [(\text{diagonal})/2] = (a/\sqrt{2})$

$\therefore \quad V_0 = 4 \times [q/(4\pi\varepsilon_0]/(a/\sqrt{2})$

$= [(q/\sqrt{2})/(\pi\varepsilon_0 a)]$ ...(1)

Work done in shifting $(-q)$ from centre to infinity.

$W = -q(V_\infty - V_0) = qV_0$

$= q \times [(q\sqrt{2})/(\pi\varepsilon_0 a)]$ [From eq. (1)]

$W = [(q^2\sqrt{2})/(\pi\varepsilon_0 a)]$

Q 38. A cube of side x has charge q at each of its vertices. The potential due to this charge array at the centre of the cube is:

a. $\frac{4q}{3\pi\varepsilon_0 x}$ b. $\frac{4q}{\sqrt{3}\,\pi\varepsilon_0 x}$ c. $\frac{3q}{4\pi\varepsilon_0 x}$ d. $\frac{2q}{\sqrt{3}\,\pi\varepsilon_0 x}$

Ans. (b) $\frac{4q}{\sqrt{3}\,\pi\varepsilon_0 x}$

The length of diagonal of the cube of each side x is $\sqrt{3x^2} = x\sqrt{3}$

$\therefore$ Distance between centre of cube and each vertex, $r = \frac{x\sqrt{3}}{2}$

Now, potential, $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

Since, cube has 8 vertices and 8 charges each of value q are present there

$\therefore \quad V = \frac{1}{4\pi\varepsilon_0}\frac{8q}{\frac{x\sqrt{3}}{2}} = \frac{4q}{\sqrt{3}\,\pi\varepsilon_0 x}$

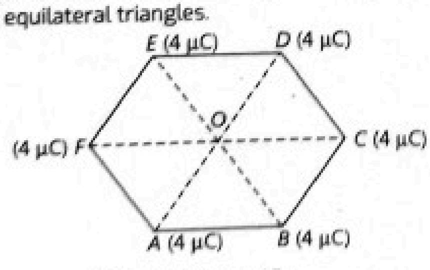
Q 39. A hexagon of side 8 cm has a charge 4μC at each of its vertices. The potential at the centre of the hexagon is:

a. 2.7×10^6 V b. 7.2×10^{11} V

c. 2.5×10^{12} V d. 3.4×10^4 V

Ans. (a) 2.7×10^6 V

As shown in the figure, O is the centre of hexagon $ABCDEF$ of each side 8 cm. As it is a regular hexagon OAB, OBC, etc. are equilateral triangles.



$\therefore \quad OA = OB = OC = OD$

$= OE = OF = 8\text{ cm} = 8 \times 10^{-2}$ m

So, the potential at O is

$V = 6 \times \frac{q}{4\pi\varepsilon_0 r}$

$= \frac{6 \times 9 \times 10^9 \times 4 \times 10^{-6}}{8 \times 10^{-2}} = 2.7 \times 10^6$ V

Q 40. Which of the following is not a equipotential surface?

a. Sphere with a point charge at its centre

b. Infinitely long sheet with charge at the centre

c. Non-interesting spheres in case of a dipole

d. All of the above

Ans. (b) Infinitely long sheet with charge at the centre

Q 41. Equipotential surfaces:

a. are closer in regions of large electric fields compared to regions of lower electric fields

b. will be more crowded near sharp edges of a conductor

c. will always be equally spaced

d. Both a. and b. are correct

Ans. (b) Both a. and b. are correct

Q 42. What is not true for equipotential surface for uniform electric field?

a. Equipotential surface is flat

b. Two equipotential surfaces can cross each other

c. Electric lines are perpendicular to equipotential surface

d. Work done is zero

Ans. (b) Two equipotential surfaces can cross each other

Q 43. *A*, *B* and *C* are three points in a uniform electric field. The electric potential is:

a. maximum at A

b. maximum at B

c. maximum at C

d. same at all the three points A, B and C

Ans. (b) maximum at B

The electric field maximum at B, because electric field is directed along decreasing potential

$$V_B > V_C > V_A$$

Q 44. For constant potential on the surface, the value of electric field is:

a. zero b. negative c. positive d. infinity

Ans. (a) zero

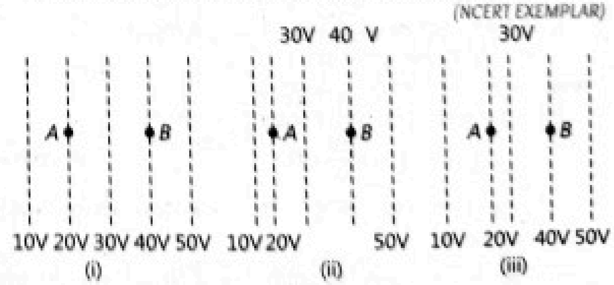
Q 45. What is the angle between electric field and equipotential surface?

a. 90° always b. 0° always c. 0° to 90° d. 0° to 180°

Ans. (a) 90° always

Q 46. Figure shows some equipotential lines distributed in space. A charged object is moved from point *A* to point *B*.

(NCERT EXEMPLAR)



a. The work done in figure (i) is the greatest

b. The work done in figure (ii) is the least

c. The work done is the same in figure (i), (ii) and (iii)

d. The work done in figure (iii) is greater than figure (ii) but equal to that in figure (i)

Ans. (c) The work done is the same in figure (i), (ii) and (iii)

In all the three figures, $V_A = 20$ V and $V_B = 40$ V

Work done in carrying a charge q from A to B is

$$W = q(V_B - V_A)$$

Hence, work done is same in all figures.

Q 47. The electrostatic potential on the surface of a charged conducting sphere is 100 V. Two statements are made in this regard: *(NCERT EXEMPLAR)*

S_1: At any point inside the sphere, electric intensity is zero.

S_2: At any point inside the sphere, the electrostatic potential is 100 V.

Which of the following is a correct statement?

a. S_1 is true but S_2 is false

b. Both S_1 and S_2 are false

c. S_1 is true, S_2 is true and S_1 is the cause of S_2

d. S_1 is true, S_2 is also true but the statements are independent

Ans. (c) S_1 is true, S_2 is true and S_1 is the cause of S_2

Potential at any point inside a charged conducting sphere = potential on the surface,

$$V = \frac{kq}{R} = 100 \text{ V}$$

Now, $E = -\frac{dV}{dr} = 0$ ($\because V$ is constant)

Q 48. Equipotentials at a great distance from a collection of charges whose total sum is not zero are approximately: *(NCERT EXEMPLAR)*

a. spheres b. planes c. paraboloids d. ellipsoids

Ans. (a) spheres

For a collection of charges, whose total sum is not zero, equipotentials at large distances must be spheres only.

Q 49. In a certain range, a uniform electric field exists along *X*-direction. The equipotential surfaces associated with this field will be:

a. equidistant planes parallel to *YZ*-plane

b. equidistant planes parallel to *XY*-plane

c. equidistant planes parallel to *XZ*-plane

d. coaxial cylinders of increasing radii around the *X*-axis.

Ans. (a) equidistant planes parallel to *YZ*-plane

Q 50. In a region of constant potential:

a. the electric field is uniform

b. the electric field is zero

c. there can be no charge inside the region

d. Both b. and c. are correct

Ans. (d) Both b. and c. are correct

In a region of constant potential

$$E = -\frac{dV}{dr} = 0 \qquad (\because V = \text{constant})$$

i.e., electric field is zero, so there can be no charge inside the region.

Q 51. The work done to move a unit charge along an equipotential surface from *P* to *Q*:

a. must be defined as $-\int_P^Q \vec{E}\cdot d\vec{l}$

b. is zero

c. can have a non-zero value

d. Both a. and b. are correct

Ans. (d) Both a. and b. are correct

Work done to move a unit charge along an equipotential surface from P to Q,

$$W = -\int_P^Q \vec{E}\cdot d\vec{l}$$

On equipotential surface $\vec{E} \perp d\vec{l}$

$$W = -\int_P^Q E(dl)\cos 90^\circ = 0$$

Q 52. Work done in carrying an electric charge Q_1 once round a circle of radius *R* with a charge Q_2 at the centre of the circle is:

a. $\frac{Q_1Q_2}{4\pi\varepsilon_0 R}$ b. ∞ c. $\frac{Q_1Q_2}{4\pi\varepsilon_0 R^2}$ d. 0

Ans. (d) 0

Electrostatic force is a conservative force.

So, work done in carrying an electric charge Q_1 once round a circle of radius R with a charge Q_2 at the centre of the circle is zero.

Q 53. Work done for bringing a charge *q* form infinity to a point in space is:

a. positive

b. negative

c. zero

d. depends on the presence of electric field

Ans. (d) depends on the presence of electric field

Q 54. Which of the following condition leads to negative potential energy between two charges?

a. One charge is negative and other charge is positive

b. Repulsive electrostatic force

c. Both a. and b.

d. None of the above

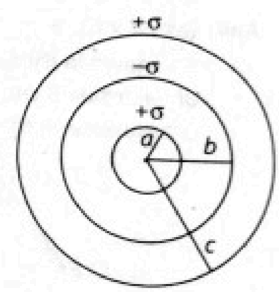
Ans. (a) One charge is negative and other charge is positive

Q 55. Three concentric spherical shells have radii *a*, *b* and *c* ($a < b < c$) and have surface charge densities $+\sigma, -\sigma$ and $+\sigma$ respectively. If V_A, V_B and V_C denote the potentials of the three shells, then, for $c = a + b$, we have:

a. $V_C = V_B = V_A$ b. $V_A = V_C \neq V_B$

c. $V_C = V_B \neq V_A$ d. $V_C = V_A \neq V_B$

Ans. (b) $V_A = V_C \neq V_B$



$$V_A = \frac{1}{4\pi\varepsilon_0}\left\{\frac{q_A}{a} - \frac{q_B}{b} + \frac{q_C}{c}\right\}$$

$$= \frac{4\pi}{4\pi\varepsilon_0}\left\{\frac{a^2\sigma}{a} - \frac{b^2\sigma}{b} + \frac{c^2\sigma}{c}\right\}$$

$$V_A = \frac{1}{\varepsilon_0}\left\{\frac{a^2\sigma}{a} - \frac{b^2\sigma}{b} + \frac{c^2\sigma}{c}\right\}$$

$$V_B = \frac{1}{\varepsilon_0}\left\{\frac{a^2\sigma}{b} - \frac{b^2\sigma}{b} + \frac{c^2\sigma}{c}\right\}$$

$$V_C = \frac{1}{\varepsilon_0}\left\{\frac{a^2\sigma}{c} - \frac{b^2\sigma}{c} + \frac{c^2\sigma}{c}\right\}$$

Given, $c = a + b$

If $a = a$, $b = 2a$ and $c = 3a$ for example, as $c > b > a$,

$$V_A = \frac{1}{\varepsilon_0}\left\{\frac{a^2\sigma}{a} - \frac{4a^2\sigma}{2a} + \frac{c^2\sigma}{c}\right\}$$

$$V_B = \frac{1}{\varepsilon_0}\left\{\frac{a^2\sigma}{2a} - \frac{4a^2\sigma}{2a} + \frac{c^2\sigma}{c}\right\}$$

$$V_C = \frac{1}{\varepsilon_0}\left[\frac{a^2\sigma}{3a} - \frac{4a^2\sigma}{3a} + \frac{c^2\sigma}{c}\right]$$

It can seen by taking out common factors that

$$V_A = V_C > V_B \text{ i.e., } V_A = V_C \neq V_B$$

Q 56. A system consists of two charges 4 μC and –3 μC with no external field placed at (–5 cm, 0, 0) and (5 cm, 0, 0) respectively. The amount of work required to separate the two charges infinitely away from each other is:

a. –1.1 J
b. 2 J
c. 2.5 J
d. 3 J

Ans. (a) –1.1 J

Here, $q_1 = 4\,\mu C$, $q_2 = -3\,\mu C$, $r = 10\text{ cm} = 0.1\text{ m}$

Electrostatic potential energy,

$$U = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r}$$

$$= 9\times10^9 \times \frac{4\times10^{-6}\times(-3)\times10^{-6}}{0.1} = -1.1\text{ J}$$

Q 57. Two charges of magnitude 5 nC and –2 nC, one placed at points (2 cm, 0, 0) and (xcm, 0, 0) in a region of space, where there is no other external field. If the electrostatic potential energy of the system is –0.5 μJ. The value of *x* is:

a. 20 cm
b. 80 cm
c. 4 cm
d. 16 cm

Ans. (a) 20 cm

Potential energy of system $U = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r}$

$$\Rightarrow -0.5\times10^{-6} = \frac{9\times10^9\times5\times10^{-9}\times(-2)\times10^{-9}}{(x-2)\times10^{-2}}$$

$$\Rightarrow \quad x = 20\text{ cm}$$

Q 58. An electric dipole consisting of charges +q and –q separated by a distance L is in stable equilibrium in a uniform electric field $\vec{E}$. The electrostatic potential energy of the dipole is: (CBSE 2020)

a. qLE
b. zero
c. $-qLE$
d. $-2qEL$

Ans. (c) $-qLE$

At stable equilibrium,

Potential energy is maximum

i.e., Potential energy $= -pE(+1)$ $\quad[\because \cos\theta = +1]$

$$= -pE$$

$$= -qLE \qquad [\because p = qL]$$

Q 59. Two point charges +10 μC and –10 μC are separated by a distance of 2 cm in water of dielectric constant 80. The potential energy of the system is:

a. –45 J
b. –0.56 J
c. +45 J
d. +0.56 J

Ans. (b) –0.56 J

Potential energy, $U = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r}$

$$= 9\times10^9\times\frac{10\times10^{-6}\times-10\times10^{-6}}{2\times10^{-2}}$$

$$= -\frac{9}{2}\times10^9\times10^{-12}\times10^4$$

$$= -45\text{ J}$$

Due to dielectric, potential energy $= \frac{U}{k} = -\frac{45}{80} = -0.56$ J

Q 60. Which of the following angle has minimum potential energy when dipole is placed in uniform potential field?

a. 0°
b. 180°
c. 90°
d. 45°

Ans. (a) 0°

Q 61. An electric dipole of length 20 cm having $\pm3\times10^{-3}$ C charge placed at 60° with respect to a uniform electric field experiences a torque of magnitude of 6 Nm. The potential energy of the dipole is:

a. $-2\sqrt{3}$ J
b. $5\sqrt{3}$ J
c. $-3\sqrt{2}$ J
d. $3\sqrt{5}$ J

Ans. (a) $-2\sqrt{3}$ J

Here, length of dipole, $2a = 20\text{ cm} = 20\times10^{-2}$ m

Charge $\quad q = \pm3\times10^{-3}$ C, $\theta = 60°$

and torque $\tau = 6$ Nm

As $\tau = pE\sin\theta$

or $\quad E = \frac{\tau}{p\sin\theta} = \frac{\tau}{q(2a)\sin\theta} \qquad [\because p = q(2a)]$

$$\therefore \quad E = \frac{6}{3\times10^{-3}\times20\times10^{-2}\times\sin60°}$$

$$= \frac{10^5}{5\sqrt{3}}\text{ NC}^{-1}$$

Potential energy of dipole,

$$U = -pE\cos\theta = -q(2a)E\cos\theta$$

$$= -3\times10^{-3}(20\times10^{-2})\frac{10^5}{5\sqrt{3}}\cos60°$$

$$= \frac{-3\times10^{-5}\times20\times10^5}{5\sqrt{3}\times2} = -2\sqrt{3}\text{ J}$$

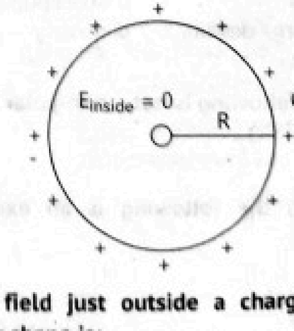
Q 62. A conducting sphere of radius *R* is given a charge *Q*. The electric potential and the electric field at the centre of the sphere respectively are:

a. zero and $\frac{Q}{4\pi\varepsilon_0R^2}$
b. $\frac{Q}{4\pi\varepsilon_0R}$ and zero
c. $\frac{Q}{4\pi\varepsilon_0R}$ and $\frac{Q}{4\pi\varepsilon_0R^2}$
d. Both are zero

Ans. (b) $\frac{Q}{4\pi\varepsilon_0R}$ and zero

$$E_{\text{inside}} = 0$$

and $\quad V_{\text{inside}} = V_{\text{surface}} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$



Q 63. Electric field just outside a charged conductor of an arbitrary shape is:

a. always parallel to the surface of conductor
b. always perpendicular to the surface of conductor
c. always zero
d. directed randomly

Ans. (b) always perpendicular to the surface of conductor

Q 64. When a conductor is subjected to electric field, which of the following property it follows?

a. Electric field is normal to the surface
b. Electric field is zero in the interior of the conductor
c. Potential is constant inside the conductor
d. All of the above

Ans. (d) All of the above

Q 65. Which of the following statements is false for a perfect conductor?

a. The surface of the conductor is an equipotential surface
b. The electric field just outside the surface of a conductor is perpendicular to the surface
c. The charge carried by a metallic sphere is always uniformly distributed over its surface
d. None of the above

Ans. (d) None of the above

Q 66. You are travelling in a car during a thunder storm. In order to protect yourself from lightening, would you prefer to:

a. remain in the car
b. take shelter under a tree
c. get out and be flat on the ground
d. touch the nearest electric pole

Ans. (a) remain in the car

Q 67. When a ringing mobile is placed in a stainless steel box, it stops ringing because of:

a. increase in electrical capacitance inside box
b. electrostatic potential induced by the battery of mobile
c. electrostatic shielding provided by box
d. absorption of E.M. waves by stainless steel box

Ans. (c) electrostatic shielding provided by box

Q 68. A charge q is supplied to a metallic conductor. Which is true?

a. Electric field inside it is same as on the surface
b. Electric potential inside it is zero
c. Electric potential on the surface is zero
d. Electric potential inside it is constant

Ans. (d) Electric potential inside it is constant
Since, the electric field at any point inside the conductor is zero, the potential is constant throughout the volume.

Q 69. The dipole moment per unit volume is:

a. polarisation
b. susceptibility
c. surface charge density
d. density

Ans. (a) polarisation

Q 70. Which of the following is not a non-polar molecule?

a. H_2
b. O_2
c. H_2O
d. CO_2

Ans. (c) H_2O

Q 71. Which among the following is an example of polar molecule?

a. O_2
b. H_2
c. N_2
d. HCl

Ans. (d) HCl

Q 72. Choose the correct statement.

a. Polar molecules have permanent electric dipole moment
b. CO_2 molecule is a polar molecule
c. H_2O is a non-polar molecule
d. The dipole field at large distances falls of as $\frac{1}{r^2}$

Ans. (a) Polar molecules have permanent electric dipole moment

Q 73. Identify the relation between dielectric constant K and electric susceptibility χ of a material:

a. $K = \chi - 1$
b. $K = \chi + 1$
c. $\chi = K + 1$
d. $K = \chi^2$

Ans. (d) $K = \chi^2$

Q 74. The SI unit of polarisation are:

a. Cm^2
b. Cm^{-2}
c. C^2m
d. None of these

Ans. (b) Cm^{-2}

Q 75. Due to polarisation of an dielectric slab, the value of electric field is:

a. reduced
b. increased
c. remains same
d. cannot be determined

Ans. (a) reduced

Q 76. In case of polarisation, polarisation density is numerically equal to:

a. electric field
b. charge induced per unit area
c. dielectric constant
d. electrical susceptibility

Ans. (b) charge induced per unit area

Q 77. Under what condition, non-polar dielectric behaves as polar dielectric?

a. In the absence of electric field
b. In the presence of large external electric field
c. In the presence of small external electric field
d. None of the above

Ans. (b) In the presence of large external electric field

Q 78. Capacitance depends upon which of the following factors?

a. Size and shape of conductor
b. Permittivity
c. Presence of other conductors nearby
d. All of the above

Ans. (d) All of the above

Q 79. Dimension of capacitance is:

a. $[M^{-2}L^{-3}T^2A^1]$
b. $[M^{-1}L^{-3}T^4A^2]$
c. $[M^{-1}L^{-2}T^4A^2]$
d. $[M^{-2}L^{-2}T^2A^1]$

Ans. (c) $[M^{-1}L^{-2}T^4A^2]$

Q 80. The ratio of charge to potential of a body is known as:

a. capacitance
b. conductance
c. inductance
d. resistance

Ans. (a) capacitance

Q 81. The SI unit of capacitance is:

a. J/C
b. C^2/J
c. J^2/C
d. C/J

Ans. (b) C^2/J

Q 82. A farad is the same as a:

a. N/C
b. V/J
c. C/V
d. V/C

Ans. (c) C/V

Q 83. If two conducting spheres are separately charged and then brought in contact:

a. the total energy of the two spheres is conserved
b. the total charge on the two spheres is conserved
c. Both the total energy and charge are conserved
d. the final potential is always the mean of the original potentials of the two spheres

Ans. (b) the total charge on the two spheres is conserved

Q 84. The capacity of an isolated conducting sphere of radius R is proportional to:

a. R^2 b. $\frac{1}{R^2}$ c. $\frac{1}{R}$ d. R

Ans. (d) R

On giving a charge q to a conductor, the electric potential of the conductor becomes V.

Then, the capacitance of the conductor is

$$C = \frac{q}{V}$$

Potential on sphere of radius R is $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{R}$ V

$$\Rightarrow \quad C = \frac{q \times 4\pi\varepsilon_0 R}{q} = 4\pi\varepsilon_0 R$$

$$\Rightarrow \quad C \propto R$$

Q 85. The dielectric strength for air is:

a. 3×10^6 V/m b. 13×10^6 V/m
c. 30×10^6 V/m d. 0.3×10^6 V/M

Ans. (d) 0.3×10^6 V/M

Q 86. When charge is supplied to a conductor, its potential depends upon:

a. the amount of charge
b. geometry and size of conductor
c. Both a. and b.
d. Only on a.

Ans. (c) Both a. and b.

Potential depends on amount of charge as well as on size of conductor.

Q 87. The capacitance of a metallic sphere will be 1μF, if its radius is nearly:

a. 9 km b. 10 m c. 1.11 m d. 1.11 cm

Ans. (a) 9 km

We know that, $C = 4\pi\varepsilon_0 r$

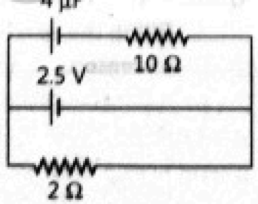
$$\therefore \quad r = \frac{C}{4\pi\varepsilon_0} = 10^{-6} \times 9 \times 10^9 = 9 \times 10^3 \text{ m} = 9 \text{ km}$$

Q 88. The magnitude of electric field E in the annular region of a charged cylindrical capacitor:

a. is the same throughout
b. is higher near the outer cylinder than near the inner cylinder
c. varies as $\frac{1}{r^2}$, where r is the distance from the axis
d. varies as $\frac{1}{r^3}$, where r is the distance from the axis

Ans. (c) varies as $\frac{1}{r^2}$, where r is the distance from the axis

Q 89. A capacitor of 4μF is connected as shown in the circuit. The internal resistance of the battery is 0.5 Ω. The amount of charge on the capacitor plates will be: *(NCERT EXEMPLAR)*



a. 0 b. 4μC
c. 16μC d. 8μC

Ans. (d) 8μC

Current in the lower arm of the circuit,

$$I = \frac{2.5 \text{ V}}{2\ \Omega + 0.5\ \Omega} = 1 \text{ A}$$

Potential difference across the internal resistance of cell

$$= (0.5\ \Omega)(1 \text{ A}) = 0.5 \text{ V}$$

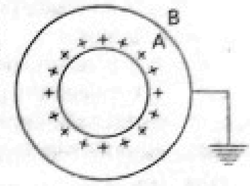
and potential difference across the 4 μF capacitor

$$= 2.5 \text{ V} - 0.5 \text{ V} = 2 \text{ V}$$

Charge on the capacitor plates, $Q = CV$

$$= (4\ \mu\text{F})(2\text{V}) = 8\ \mu\text{C}$$

Q 90. A and B are two concentric spheres. If A is given a charge Q while B is earthed as shown in figure:



a. the charge density of A and B are same
b. the field inside and outside A is zero
c. the field between A and B is not zero
d. the field inside and outside B is zero

Ans. (c) the field between A and B is not zero

This arrangement is equivalent to a spherical capacitor. The electric field within the sphere A is zero. Electric field outside the sphere B is also zero.

The electric field between the spheres A and B is non-zero and is given by $\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$.

Q 91. The capacity of parallel plate capacitor depends on:

a. the type of metal used
b. the thickness of plates
c. the potential applied across the plates
d. the separation between the plates

Ans. (d) the separation between the plates

Q 92. The capacitance of a parallel plate condenser does not depend on:

a. area of the plates
b. medium between the plates
c. distance between the plates
d. metal of the plates

Ans. (d) metal of the plates

Q 93. Capacitance of parallel plate capacitor is derived by using:

a. Gauss's Law b. Coulomb's law
c. Polarisation d. Electrostatic induction

Ans. (a) Gauss's Law

Q 94. Identify how we can increase the capacitance of a parallel plate capacitor.

a. Increasing the charge
b. Decreasing the plate area
c. Increasing the plate separation
d. Decreasing the plate separation

Ans. (d) Decreasing the plate separation

Q 95. The capacitance of a parallel capacitor whose area of cross section is A and distance between plates is d is:

a. $A d / \varepsilon_0$ b. $\varepsilon_0 d / A$
c. $\varepsilon_0 A / d$ d. $2\varepsilon_0 A / d$

Ans. (d) $2\varepsilon_0 A / d$

Q 96. A parallel plate capacitor is charged. If the plates are pulled apart:

a. the capacitance increases
b. the potential difference increases
c. the total charges increases
d. the charge and potential difference remain the same

Ans. (b) the potential difference increases

Q 97. The intensity of electric field at a point between the plates of a charged capacitor:

a. is directly proportional to the distance between the plates
b. is inversely proportional to the distance between the plates
c. is inversely proportional to the square of the distance between the plates
d. does not depend upon the distance between the plates

Ans. (d) does not depend upon the distance between the plates

Q 98. When we say a parallel plate capacitor with charge Q, the charges on its plates are:

a. Q, 0 b. $\frac{Q}{2}, \frac{Q}{2}$ c. Q, −Q d. $\frac{Q}{2}, -\frac{Q}{2}$

Ans. (c) Q, −Q

Q 99. In a parallel plate capacitor of capacitance C, a metal sheet is inserted between the plates, parallel to them. If the thickness of the sheet is half of the separation between the plates. The capacitance will be:

a. $\frac{C}{2}$ b. 2C c. $\frac{3C}{8}$ d. $\frac{4C}{5}$

Ans. (b) 2C

Before the metal sheet is inserted, $C = \frac{\varepsilon_0 A}{d}$

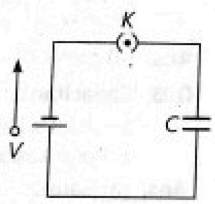
After the sheet is inserted, the system is equivalent to two capacitors in series, each of capacitance

$$C' = \frac{\varepsilon_0 A}{(d/4)} = \frac{4\varepsilon_0 A}{d} = 4C$$

Equivalent capacitance $\frac{1}{C_{eq}} = \frac{1}{4C} + \frac{1}{4C} = \frac{2}{4C}$

$$C_{eq} = \frac{4C}{2} = 2C$$

Q 100. A parallel plate capacitor is connected to a battery as shown in figure. Consider two situations:



(i) key K is kept closed and plates of capacitors are moved apart using insulating handle.

(ii) key K is opened and plates of capacitors are moved apart using insulating handle.

Which of the following statements is correct?

a. In (i), Q remains same but C changes
b. In (ii), V remains same but C changes
c. In (i), V remains same and hence Q changes
d. In (ii), both Q and V changes

Ans. (c) In (i), V remains same and hence Q changes

Q 101. Two plates have net charge 70 pC and −70pC connected to a potential of 20 V, the capacitance of the system is:

a. 3.5 pF b. 7 pF c. 7 pC d. 10.5 pF

Ans. (a) 3.5 pF

Capacitance is given by,

$$C = \frac{q}{V} = \frac{70}{20} = 3.5 \text{ pF}$$

Q 102. Charge on a parallel plate capacitor is 1 mC when charged by a 100 V battery. Calculate the capacitance of the capacitor.

a. 1μF b. 10 μF c. 100 μF d. 1000 μF

Ans. (b) 10 μF

$$\text{Capacitance} = \frac{q}{V} = \frac{1\text{mC}}{100}$$

$$= 0.01\text{mF} = 10\,\mu\text{F} \quad [\because 1\text{mF} = 1000\,\mu\text{F}]$$

Q 103. The distance between the plates of a charged plate capacitor disconnected from the battery is 5 cm and the intensity of the field in it is E = 300 V/cm. An uncharged metal bar 1 cm thick is introduced into the capacitor parallel to its plates. The potential difference between the plates now is:

a. 1500 V b. 1200 V c. 900 V d. zero

Ans. (b) 1200 V

Potential, $V = E \times d = 300 \times (5-1)$

$= 300 \times 4 = 1200$ V

Q 104. If dielectric constant and dielectric strength be denoted by K and X respectively, then a material suitable for use as a dielectric in a capacitor must have:

a. high K and high X b. high K and low X
c. low K and high X d. low K and low X

Ans. (a) high K and high X

The material suitable for using as a dielectric must have high dielectric strength X and large dielectric constant K.

Q 105. When a slab of dielectric material is introduced between the parallel plates of a capacitor which remains connected to a battery, then charge on plates relative to earlier charge:

a. is same
b. is more
c. may be less or more depending on the nature of the material introduced
d. is less

Ans. (b) is more

Q 106. When a dielectric material is introduced between the plates of a charged condenser then electric field between the plates:

a. decreases
c. increases
c. remain constant
d. first increases then decreases

Ans. (a) decreases

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Electric field gets reduced, i.e., $E = \frac{E_0}{k}$.

Q 107. An air capacitor is connected to a battery. The effect of filling the space between the plates with a dielectric is to increase:

a. the charge and the potential difference
b. the potential difference and the electric field
c. the electric field and the capacitance
d. the charge and the capacitance

Ans. (d) the charge and the capacitance

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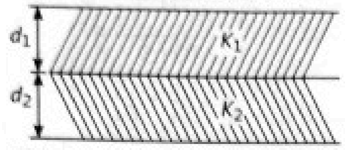
When battery is connected,

Charge increases, i.e., $q = kq_0$

Capacitance increases, i.e., $C = kC_0$

Q 108. A parallel plate capacitor is made of two dielectric blocks in series. One of the blocks has thickness d_1 and dielectric constant K_1 and the other has thickness d_2 and dielectric constant K_2 as shown in figure. This arrangement can be thought as a dielectric slab of thickness d $(= d_1 + d_2)$ and effective dielectric constant K. The K is: (NCERT EXEMPLAR)



a. $\frac{K_1d_1 + K_2d_2}{d_1 + d_2}$ b. $\frac{K_1d_1 + K_2d_2}{K_1 + K_2}$

c. $\frac{K_1K_2(d_1 + d_2)}{K_2d_1 + K_1d_2}$ d. $\frac{2K_1K_2}{K_1 + K_2}$

Ans. (c) $\frac{K_1K_2(d_1 + d_2)}{K_2d_1 + K_1d_2}$

Q 109. A parallel plate capacitor with air between the plates has a capacitance of 10 pF. The capacitance, if the distance between the plates is reduced by half and the space between them is filled with a substance of dielectric constant 4 is:

a. 80 pF b. 96 pF c. 100 pF d. 120 pF

Ans. (a) 80 pF

Here, $C_1 = \frac{\varepsilon_0 A}{d} = 10 \text{ pF}$ ...(1)

and $C_2 = K\frac{\varepsilon_0 A}{d/2} = \frac{4 \times 2\varepsilon_0 A}{d}$ $(\because K = 4)$

$= 8 \times 10$ (using eq. (1))

$= 80 \text{ pF}$

Q 110. The capacitance of a parallel plate capacitor with air as medium is 3 μF. With the introduction of a dielectric medium between the plates, the capacitance becomes 15μF. The permittivity of the medium is:

a. $5 \text{ C}^2\text{N}^{-1}\text{m}^{-2}$ b. $15 \text{ C}^2\text{N}^{-1}\text{m}^{-2}$

c. $0.44 \times 10^{-10} \text{ C}^2\text{N}^{-1}\text{m}^{-2}$ d. $8.854 \times 10^{-11} \text{ C}^2\text{N}^{-1}\text{m}^{-2}$

Ans. (c) $0.44 \times 10^{-10} \text{ C}^2\text{N}^{-1}\text{m}^{-2}$

Capacitance of a parallel plate capacitor with air is $C = \frac{\varepsilon_0 A}{d}$

Capacitance of a same parallel plate capacitor with the introduction of a dielectric medium is $C' = \frac{K\varepsilon_0 A}{d}$,

where, K is the dielectric constant of a medium.

or $\frac{C'}{C} = K$ or $K = \frac{15}{3} = 5$ or $K = \frac{\varepsilon}{\varepsilon_0}$

or $\varepsilon = K\varepsilon_0 = 5 \times 8.854 \times 10^{-12}$

$= 0.44 \times 10^{-10} \text{ C}^2\text{N}^{-1}\text{m}^{-2}$

Q 111. Air-filled parallel plate capacitor has a capacitance of 1 nF. The plate separation is then tripled and a dielectric is inserted, completely filling the space between the plates. As a result, the capacitance increases to 3 nF. The dielectric constant of the dielectric is:

a. 2 b. 3 c. 6 d. 9

Ans. (d) 9

Capacitance of parallel plate capacitor with air

$$C = \frac{\varepsilon_0 A}{d} \quad ...(1)$$

Capacitance of parallel plate capacitor with dielectric

$$C' = \frac{K\varepsilon_0 A}{3d} \quad ...(2)$$

$\Rightarrow$ $\frac{C'}{C} = \frac{K\varepsilon_0 A}{3d} \times \frac{d}{\varepsilon_0 A}$

$\Rightarrow$ $\frac{3}{1} = \frac{K}{3} \Rightarrow K = 9$

Q 112. A slab of material dielectric constant K has the same area A as the plates of a parallel plate capacitor, and has thickness $\left(\frac{3}{4}d\right)$, where d is the separation of the plates. The change in capacitance when the slab is inserted between the plates is:

a. $C = \frac{\varepsilon_0 A}{d}\left(\frac{K+3}{4K}\right)$ b. $C = \frac{\varepsilon_0 A}{d}\left(\frac{2K}{K+3}\right)$

c. $C = \frac{\varepsilon_0 A}{d}\left(\frac{K}{K+3}\right)$ d. $C = \frac{\varepsilon_0 A}{d}\left(\frac{4K}{K+3}\right)$

Ans. (d) $C = \frac{\varepsilon_0 A}{d}\left(\frac{K}{K+3}\right)$

Here, thickness of the slab, $t = \frac{3}{4}d$

Capacitance, $C = \frac{\varepsilon_0 A}{d - t\left(1 - \frac{1}{K}\right)}$

$$= \frac{\varepsilon_0 A}{d - \frac{3}{4}d\left(1 - \frac{1}{K}\right)} = \frac{\varepsilon_0 A}{\frac{d}{4} + \frac{3}{4}\frac{d}{K}} = \frac{\varepsilon_0 A}{\frac{d}{4}\left(1 + \frac{3}{K}\right)}$$

$$= \frac{\varepsilon_0 A}{d}\frac{4K}{(K+3)}$$

Q 113. When number of capacitors are connected in parallel, which quantity remains constant:

a. common potential difference

b. charge

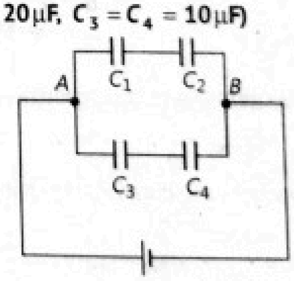
c. capacitance

d. energy

Ans. (a) common potential difference

Q 114. Effective capacitance between A and B in the figure shows below is:

($C_1 = C_2 = 20\mu F$, $C_3 = C_4 = 10\mu F$)



a. 10 μF b. 15 μF

c. 20 μF d. 25 μF

Ans. (b) 15 μF

Here, C_1 and C_2 are in series, hence their capacitance is given by

$$\frac{1}{C'} = \frac{1}{C_1} + \frac{1}{C_2}$$

$\Rightarrow$ $\frac{1}{C'} = \frac{1}{20} + \frac{1}{20}$

$\Rightarrow$ $C' = 10 \mu F$

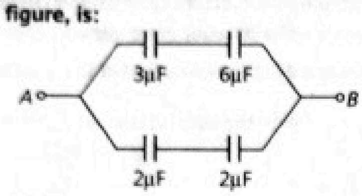
Similarly, $\frac{1}{C''} = \frac{1}{C_3} + \frac{1}{C_4}$

$\Rightarrow \quad \frac{1}{C''} = \frac{1}{10} + \frac{1}{10} \Rightarrow C'' = 5\ \mu F$

Now, C' and C'' are in parallel. Hence, resultant capacitance C will be

$$C = C' + C'' = 10 + 5 = 15\ \mu F$$

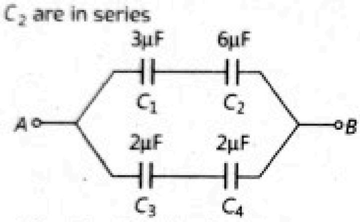
Q 115. The equivalent capacitance between points *A* and *B* in the given figure, is:



a. $\frac{36}{13\ \mu F}$ b. 2 μF c. 1μF d. 3 μF

Ans. (d) 3 μF

C_1 and C_2 are in series



$\therefore \quad \frac{1}{C'} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{3} + \frac{1}{6}$

$\Rightarrow \quad C' = 2\ \mu F$

Similarly, C_3 and C_4 are in series

$\frac{1}{C''} = \frac{1}{C_3} + \frac{1}{C_4} = \frac{1}{2} + \frac{1}{2}$

$\Rightarrow \quad C'' = 1 \mu F$

Now, C and C'' are in parallel

$\therefore \quad C_{eq} = C' + C'' = 2 + 1 = 3 \mu F$

Q 116. If *n* number of capacitors are connected in series and then in parallel, then their ratio of capacitance is:

a. 1 : 1 b. 1 : n^2

c. n^2 : 1 d. None of these

Ans. (b) 1 : n^2

When n capacitors are connected in series,

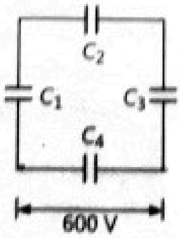
$$C_{series} = \frac{C}{n}$$

When n capacitors are connected in parallel,

$$C_{parallel} = nC$$

$$\frac{C_{series}}{C_{parallel}} = \frac{C/n}{nC} = \frac{1}{n^2}$$

Q 117. A network of four 20 μF capacitors is connected to a 600 V supply as shown in the figure. The equivalent capacitance of the network is:

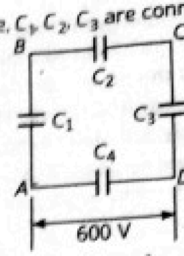


a. 30.26 μF b. 20 μF

c. 26.67 μF d. 10 μF

Ans. (c) 26.67 μF

From the figure, C_1, C_2, C_3 are connected in series.



$\therefore \quad \frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ ...(i)

$= \frac{1}{20} + \frac{1}{20} + \frac{1}{20} = \frac{3}{20} \mu F$

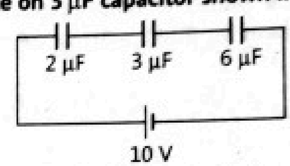
or $\quad C_s = \frac{20}{3} \mu F$

Now C_s is in parallel with C_4

$\therefore$ Equivalent capacitance,

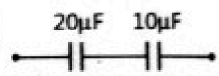
$C_{eq} = C_s + C_4 = \frac{20}{3} + 20 = \frac{80}{3} = 26.67\ \mu F$

Q 118. The charge on 3 μF capacitor shown in the figure is:



a. 2 μC b. 10 μC c. 6 μC d. 8 μC

Ans. (b) 10 μC



Since, all the capacitors are connected in series, therefore, equivalent capacitance is

$$\frac{1}{C_{eq}} = \frac{1}{2} + \frac{1}{3} + \frac{1}{6} = 1$$

$\therefore \quad C_{eq} = 1 \mu F$

Charge on each capacitor is same ($\because V = 10$ V)

$q = C_{eq}V = 1 \times 10 = 10\ \mu C$

Q 119. Three capacitors of capacitances 1 μF, 2 μF and 3 μF are connected in series and a potential difference of 11 V is applied across the combination, then the potential difference across the plates of 1 μF capacitor is:

a. 2 V b. 4 V

c. 1 V d. 6 V

Ans. (d) 6 V

In series combination

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$\Rightarrow \quad \frac{1}{C} = \frac{1}{1} + \frac{1}{2} + \frac{1}{3} \Rightarrow \frac{1}{C} = \frac{6+3+2}{6}$

$C = \frac{6}{11} \mu F$

Now, $\quad C = \frac{Q}{V}$

So, $\quad Q = CV = \frac{6}{11} \times 11 = 6\ C$

So, potential difference across 1μF capacitor is

$$V = \frac{Q}{C} = \frac{6}{1} = 6\ V$$

Q 136. The ratio of energy stored in a capacitor and energy dissipated during charging a capacitor with a source:

a. 1 : 1 b. 1 : 2 c. 2 : 1 d. 1 : 3

Ans. (a) 1 : 1

Half of the energy provided by the source is dissipated during charging a capacitor and other half stored in capacitor.

$$\therefore \frac{\text{Energy stored in a capacitor}}{\text{Energy dissipated during charging a capacitor}} = \frac{1}{1}$$

Q 137. A capacitor of capacitance C has charge Q and stored energy is W. If the charge is increased to $2Q$, the stored energy will be:

a. $W/4$ b. $W/2$ c. $2W$ d. $4W$

Ans. (d) $4W$

Energy stored in a capacitor, $W = \frac{Q^2}{2C}$.

Now, if charge Q increases to $2Q$, then energy stored

$$W' = \frac{(2Q)^2}{2C} = \frac{4Q^2}{2C} = 4W$$

Q 138. A 10 microfarad capacitor is charged to 500 V and then its plates are joined together a resistance of 10 Ω. The heat produced in the resistance is:

a. 500 J b. 250 J c. 125 J d. 1.25 J

Ans. (d) 1.25 J

Here, $C = 10\,\mu F$, $V = 500$ V, $R = 10\,\Omega$

$$\text{Energy stored in capacitor} = \frac{1}{2}CV^2$$
$$= \frac{1}{2} \times 10 \times 10^{-6} \times (500)^2$$
$$= 5 \times 10^{-6} \times 25 \times 10^4$$
$$= 125 \times 10^{-2} = 1.25 \text{ J}$$

Energy stored in capacitor is converted into heat.

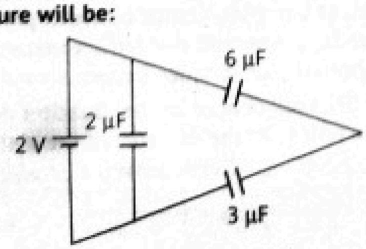
Hence, heat produced = 1.25 J.

Q 139. A battery is used to charge a parallel-plate capacitor, after which it is disconnected. Then the plates are pulled apart to twice their original separation. This process will double the:

a. capacitance
b. surface charge density on each plate
c. stored energy
d. electric field between the two plates

Ans. (c) stored energy

Q 140. The total energy stored in the condenser system shown in the figure will be:



a. 8 μJ b. 16 μJ c. 2 μJ d. 4 μJ

Ans. (a) 8 μJ

3 μF and 6 μF are in series.

$$\therefore \frac{3 \times 6}{(3+6)} = 2\,\mu F$$

This is in parallel with 2 μF.

∴ Total capacitance in the circuit is 4 μF, $Q = CV$.

$$\text{Energy} = \frac{1}{2}QV = (1/2)V^2C$$
$$= (1/2) \times 2^2 \times 4 \times 10^{-6} \text{ J} = 8\,\mu J$$

Q 141. A parallel plate air capacitor of capacitance C is connected to a cell of emf V and then disconnected from it. A dielectric slab of dielectric constant K, which can just fill the air gap of the capacitor, is now inserted in it. Which of the following is incorrect?

a. The energy stored in the capacitor decreases K times
b. The change in energy stored is $1/2CV^2(1/K - 1)$
c. The charge on the capacitor is not conserved
d. The potential difference between the plates decreases K times

Ans. (c) The charge on the capacitor is not conserved

Assertion and Reason Type Questions

Directions (Q.Nos. 142 to 169): In the following questions, astatement of Assertion (A) is followed by a statement of Reason (R). Mark the correct choice as:

a. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A)
b. Both Assertion (A) and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A)
c. Assertion (A) is true but Reason (R) is false
d. Assertion (A) is false and Reason (R) is also false

Q 142. Assertion (A): Work done in moving a charge between any two points in an electric field is independent of the path followed by the charge, between these points.

Reason (R): Electrostatic force is a non-conservative force.

Ans. (c) Electrostatic force is conservative force.

Q 143. Assertion (A): Electric potential of the earth is zero.

Reason (R): The electric field due to the earth is zero.

Ans. (c) Earth is a good conductor of very large size. When some small charge is given to earth, its potential does not change. Hence, potential of earth is assumed to be zero. It is just like sea level which does not alter materially when water is added to it or removed from it. Thus, the potential of all other bodies are measured with reference to the earth. For this, if the connection of a charged body to the ground by a metallic conductor would cause electrons to flow to that body from ground, the body is at positive potential. Conversely, is also true. In either case the conductor is neutralized and brought to zero potential. In fact the atmosphere does possess significant electric field.

Q 144. Assertion (A): No work is done in taking a positive charge from one point to other inside a positively charged metallic sphere while outside the sphere work is done in taking the charge toward the sphere.

Reason (R): Inside the sphere electric potential is same at each potential, but outside it is different for different points.

Ans. (a) Inside the charged metallic sphere every point is at the same electric potential, hence $W = q\,\Delta V = 0$. But outside the sphere, there exists a potential gradient at every point, hence $W \neq 0$.

Q 145. Assertion (A): For a point charge concentric spheres centered at a location of the charge are equipotential surfaces.

Reason (R): An equipotential surface is a surface over which potential has zero value.

Ans. (c) An equipotential surface is a surface over which potential is constant.

Q 146. Assertion (A): The surface of a conductor is an equipotential surface.

Reason (R): Conductor allows the flow of charge.

Ans. (a) If two points on a conductor were at different potentials, charge would flow from higher potential to lower potentials, till their potentials become equal. A surface on which the potential has the same value everywhere is called an equipotential surface.

Q 147. Assertion (A): The electric field inside a cavity is always zero.

Reason (R): Charges reside only on the outer surface of a conductor with cavity.

Ans. (a)

Q 148. Assertion (A): Two adjacent conductors, carrying the same positive charge have no potential difference between them.

Reason (R): The potential of a conductor does not depend upon the charge given to it.

Ans. (d) The potential of a conductor depends upon the charge given to it and there exist a potential different between two adjacent conductors.

Q 149. Assertion (A): An applied electric field will polarize the polar dielectric material.

Reason (R): In polar dielectrics, each molecule has a permanent dipole moment but these are randomly oriented in the absence of an externally applied electric field.

Ans. (b) If a material contain polar molecules, they will generally be in random orientations when no electric field is applied. An applied electric field will polarize the material by orienting the dipole moment of polar molecules.

Q 150. Assertion (A): Dielectric polarisation means formation of positive and negative charges inside the dielectric.

Reason (R): Free electrons are formed in this process.

Ans. (c) When an electric field is applied to the dielectric, each molecule of dielectric gets polarised, centres of gravity of positive and negative charges get displaced from each other. Electric dipoles are produced inside.

Q 151. Assertion (A): Polar molecules have permanent dipole moment.

Reason (R): In polar molecule, the centres of positive and negative charges coincide even when there is no external field.

Ans. (c) The molecules of a substance may be polar or non-polar. In a non-polar molecule, the centres of positive and negative charges coincide. This molecule has no permanent dipole moment. On the other hand, a polar molecule is one in which the centres of positive and negative charges are separated even when there is no external field. Such molecules have a permanent dipole moment.

Q 152. Assertion (A): In the absence of an external electric field the dipole moment per unit volume of a polar dielectric is zero.

Reason (R): The dipoles of a polar dielectric are randomly oriented.

Ans. (a) There are polar and non polar dielectric materials. The molecules of a polar dielectric have a permanent dipole moment. However due to random orientations, net dipole moment is zero. If there is no external electric field, there is no polarisation.

Q 153. Assertion (A): Increasing the charge on the plates of a capacitor means increasing the capacitance.

Reason (R): Capacitance is directly proportional to charge.

Ans. (d) On increasing the charge, potential increases. But capacity of a capacitor is fixed by geometry of condenser $\left(C = \frac{\varepsilon_0 A}{d}\right)$. Capacitance is independent of charge.

Q 154. Assertion (A): The potential difference between the two conductors of a capacitor is small.

Reason (R): A capacitor is so configured that it confines the electric field lines within a small region of space.

Ans. (a) Even though field may have considerable strength, the potential difference between the two conductors of a capacitor is small because the field lines are confined within a small region of space.

Q 155. Assertion (A): Capacity of a parallel plate capacitor increases when distance between the plates is decreased.

Reason (R): Capacitance of capacitor is inversely proportional to distance between them.

Ans. (a) Capacitance of parallel plate capacitor is $C = \frac{\varepsilon_0 A}{d}$. Thus distance decreases and capacitance of capacitor increases.

Q 156. Assertion (A): When a dielectric medium is filled between the plates of a condenser, its capacitance increases.

Reason (R): The dielectric medium reduces the potential difference between the plates of the condenser.

Ans. (a) The dielectric molecules are polarised, producing an opposite electric field. Thus the effective electric field and hence the potential difference between the plates is reduced and consequently the capacitance is increased ($\because C = Q/V$).

Q 157. Assertion (A): If the distance between parallel plates of a capacitor is halved and dielectric constant is made three times, then the capacitance becomes six times.

Reason (R): Capacitance of the capacitor does not depend upon the nature of the material of the plates.

Ans. (c) The capacitance C, with dielectric between the plates is given as

$$C = \frac{\varepsilon_0 KA}{d}$$

As, $d' = \frac{d}{2}$, $K' = 3K$, then new capacitance becomes

$$C' = \frac{\varepsilon_0 3KA}{\frac{d}{2}} \Rightarrow C' = \frac{6\varepsilon_0 KA}{d} = 6C$$

The capacitance C depends only on the geometrical configuration (shape, size, separation) of the system of two conductors.

Q 158. Assertion (A): The dielectric constant for metals is infinity.

Reason (R): When a charged capacitor is filled completely with a metallic slab, its capacity becomes very large.

Ans. (c) The capacitance of a capacitor filled partially with a dielectric of thickness t given by

$$C = \frac{\varepsilon_0 A}{d - t(1 - 1/K)}$$

For metals, $K = \infty$

$$\therefore \quad C = \frac{\varepsilon_0 A}{d - t}$$

Now, if the capacitor is filled completely with a metallic slab, then $t = d$.

$\therefore C = \infty$ *i.e.*, when a charged capacitor filled fully with a metallic slab, then capacitor is short circuited *i.e.*, it will no more work as a capacitor.

Q 159. Assertion (A): If distance between the parallel plates of a capacitor is halved, then its capacitance is doubled.

Reason (R): The capacitance depends on the introduced dielectric.

Ans. (b) The capacitance of a parallel plates capacitor is given by $C = \frac{\varepsilon_0 A}{d}$, where A is area of each plate, d is the distance between plates.

$$\therefore \quad \frac{C_1}{C_2} = \frac{\frac{\varepsilon_0 A}{d}}{\frac{\varepsilon_0 A}{d/2}} = \frac{1}{2}$$

$$\therefore \quad C_2 = 2C_1$$

When dielectric of dielectric constant K is introduced in between the plates, then the capacitance $C = \frac{K\varepsilon_0 A}{d}$ *i.e.*, $C \propto K$

Capacitance C depends on introduced dielectric.

Q 160. Assertion (A): When air between the plates of a parallel plate condenser is replaced by an insulating medium of dielectric constant its capacity increases.

Reason (R): Electric field intensity between the plates with dielectric in between it is reduced.

Ans. (a) The capacity of a parallel plate condenser is given by,

$$C = \frac{q}{V} \quad ...(1)$$

Electric field intensity becomes $\frac{1}{K}$ times [as $K = E_0 / E$], therefore potential V also becomes $1/K$ times.

Hence, from eq. (1) capacity becomes K times.

Thus electric field decreases and capacitance increases when condenser is filled with insulated medium of some dielectric constant.

Q 161. Assertion (A): Capacity of parallel plate condenser remains unaffected on introducing a insulating slab between the plates.

Reason (R): Electric field intensity between the plates increases on introducing the insulating slab.

Ans. (d) If the medium between the plates of a capacitor is filled with an insulating substance, the electric field due to the charged plate induces a net dipole moment in the dielectric. This give rise to field in the opposite direction. The net electric field inside the capacitor decreases and hence the potential difference between the plates is reduced. Consequently, the capacitance C increases from its value, when there is no medium.

Q 162. Assertion (A): Charge on all the condensers connected in series is the same.

Reason (R): Capacitance of capacitor is directly proportional to charge on it.

Ans. (c) Let two capacitors be connected in series. If $+q$ charge is installed on left plate of the first capacitor, then $-q$ charge is induced on right plate of this capacitor. This charge comes from electron drawn from the left plate of second capacitor. Thus there will be equal charge $+q$ on the left plate of second capacitor and $-q$ charge induced on the right plate of second capacitor. Thus each capacitor has same charge (q) when connected in series. Capacitance is quantity dependent on construction of capacitor and independent of charge.

Q 163. Assertion (A): In a parallel combination of capacitors, the total capacitance of the combination is the sum of capacitance of the individual capacitors.

Reason (R): In such a combination, voltage across each capacitor is same.

Ans. (a)

Q 164. Assertion (A): A capacitor is connected to a battery. If we move its plate further apart, work will be done against the electrostatic attraction between the plates and the energy of the capacitor gets decreased.

Reason (R): The energy stored in capacitor is dissipated in the form of heat energy.

Ans. (b) When the plates of a capacitor are moved further apart, the capacitance gets decreased. As battery remains connected, hence charge q ($= CV$) on the plates is decreased and energy $U = (1/2\, CV^2)$ also decreases. Some charge from the plates flows to the battery *i.e.*, some energy of capacitor is transferred to the battery. Work done against electrostatic attraction between plates is used in the transference of energy and is dissipated in the form of heat energy in connection wires.

Q 165. Assertion (A): Surface of a symmetrical conductor can be treated as equipotential surface.

Reason (R): Charges can easily flow in a conductor.

Ans. (a) Potential is constant on the surface of a sphere so it behaves as an equipotential surface.

Q 166. Assertion (A): If three capacitors of capacitance $C_1 < C_2 < C_3$ are connected in parallel then their equivalent capacitance (C_p) > equivalent capacitance in series.

Reason (R): $\frac{1}{C_p} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$.

Ans. (c) Equivalent capacitance of parallel combination is $C_p = C_1 + C_2 + C_3$ and in series it will be $\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

Q 167. Assertion (A): The capacitance of a given conductor remains same even if charge is varied on it.
Reason (R): Capacitance depends upon nearly medium as well as size and shape of conductor.

Ans. (a) Capacitance is basically a geometrical quantity.

Q 168. Assertion (A): A charged capacitor is disconnected from a battery. Now if its plate are separated farther, the potential energy will fall.
Reason (R): Energy stored in a capacitor is not equal to the work done in charging it.

Ans. (d) Battery is disconnected from the capacitor.
So, Q = constant.

$$\text{Energy} = \frac{Q^2}{2C} = \frac{Q^2 d}{2\varepsilon_0 A} \Rightarrow \text{Energy} \propto d$$

Also, energy stored in a capacitor is not equal to the work done in charging it.

Q 169. Assertion (A): A parallel plate capacitor is connected across battery through a key. A dielectric slab of constant K is introduced between the plates. The energy which is stored becomes K times.
Reason (R): The surface density of charge on the plate remains constant or unchanged.

Ans. (c) In the given case $V = V_0$ (constant)

Energy stored in the capacitor $= \frac{1}{2}CV^2$

When a dielectric slab of constant K is introduced, between the plates then energy stored will become K times

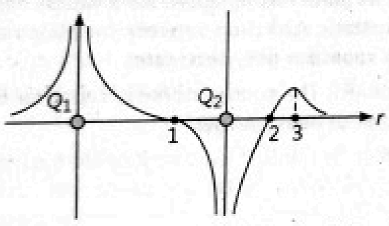
In this case, charge also becomes QK.

$\therefore$ Surface charge density $\sigma = \frac{KQ}{A} = K\sigma_0$

Case Study Based QUESTIONS

Case Study 1

The potential at any observation point P of a static electric field is defined as the work done by the external agent (or negative of work done by electrostatic field) in slowly bringing a unit positive point charge from infinity to the observation point. Figure shows the potential variation along the line of charges. Two point charges Q_1 and Q_2 lie along a line at a distance from each other.



Read the given passage carefully and give the answer of the following questions.

Q 1. At which of the points 1, 2 and 3 is the electric field is zero?
a. 1 b. 2 c. 3 d. Both a. and b.

Ans. (c) 3
As $\frac{-dV}{dr} = E_r$, the negative of the slope of V versus r curve represents the components of electric field along r. Slope of curve is zero only at point 3.
Therefore, the electric field vector is zero at point 3.

Q 2. The signs of charges Q_1 and Q_2 respectively are:
a. positive and negative b. negative and positive
c. positive and positive d. negative and negative

Ans. (a) positive and negative
Near positive charge, net potential is positive and near a negative charge, net potential is negative. Thus charge Q_1 is positive and Q_2 is negative.

Q 3. Which of the two charges Q_1 and Q_2 is greater in magnitude?
a. Q_2 b. Q_1 c. Same d. Can't determined

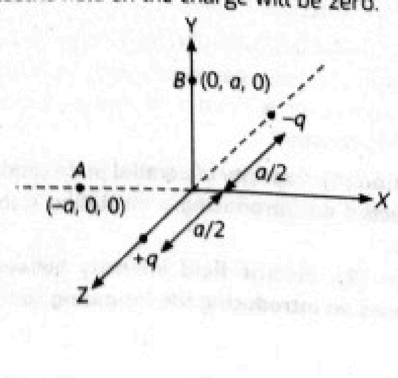
Ans. (b) Q_1
From the figure, it can be seen that net potential due to two charges is positive everywhere in the region left to charge Q_1. Therefore the magnitude of potential due to charge Q_1 is greater than due to Q_2.

Q 4. Which of the following statement is not true?
a. Electrostatic force is a conservative force
b. Potential energy of charge q at a point is the work done per unit charge in bringing a charge from any point to infinity
c. When two like charges lie infinite distance apart, their potential energy is zero
d. Both a. and c.

Ans. (b) Potential energy of charge q at a point is the work done per unit charge in bringing a charge from any point to infinity

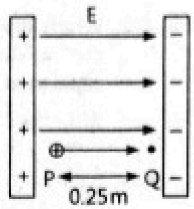
Q 5. Positive and negative charges of equal magnitude are kept at $\left(0, 0, \frac{a}{2}\right)$ and $\left(0, 0, \frac{-a}{2}\right)$ respectively. The work done by the electric field when another positive point charge is moved from $(-a, 0, 0)$ to $(0, a, 0)$ is:
a. positive b. negative
c. zero
d. depends on the path connecting the initial and final position

Ans. (c) zero
It can be seen that potential at the points both A and B are zero. When the charge is moved from A to B, work done by the electric field on the charge will be zero.



Case Study 2

Potential difference (ΔV) between two points A and B separated by a distance x, in a uniform electric field E is given by $\Delta V = -Ex$, where x is measured parallel to the field lines. If a charge q_0 moves from P to Q, the change in potential energy (ΔU) is given as $\Delta U = q_0 \Delta V$. A proton is released from rest in uniform electric field of magnitude 4.0×10^8 Vm^{-1} directed along the positive X-axis. The proton undergoes a displacement of 0.25 m in the direction of E.



Mass of a proton $= 1.66 \times 10^{-27}$ kg and charge of proton $= 1.6 \times 10^{-19}$ C

Read the given passage carefully and give the answer of the following questions.

Q 1. The change in electric potential of the proton between the points *A* and *B* is:

a. -1×10^8 V b. 1×10^8 V
c. 6.4×10^{-19} V d. -6.4×10^{-19} V

Ans. (a) -1×10^8 V

$$\Delta V = -E\,\Delta x$$
$$= -(4 \times 10^8) \times 0.25 = -10^8 \text{ V}$$

Q 2. The change in electric potential energy of the proton for displacement from *A* to *B* is:

a. 1.6×10^{11} J b. 0.5×10^{23} J
c. -1.6×10^{-11} J d. 3.2×10^{22} J

Ans. (c) -1.6×10^{-11} J

As $\Delta U = q\,\Delta V$
$$= 1.6 \times 10^{-19} \times (-1.0 \times 10^8)$$
$$= -1.6 \times 10^{-11} \text{ J}$$

Q 3. The mutual electrostatic potential energy between two protons which are at a distance of 9×10^{-15} m, in $_{92}U^{235}$ nucleus is:

a. 1.56×10^{-14} J b. 5.5×10^{-14} J
c. 2.56×10^{-14} J d. 4.56×10^{-14} J

Ans. (c) 2.56×10^{-14} J

$$U = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r}$$
$$= \frac{9 \times 10^9 \times 1.6 \times 10^{-19} \times 1.6 \times 10^{-19}}{9 \times 10^{-15}} = 2.56 \times 10^{-14} \text{ J}$$

Q 4. If a system consists of two charges 4 mC and −3 mC with no external field placed at (−5 cm, 0, 0) and (5 cm, 0, 0) respectively. The amount of work required to separate the two charges infinitely away from each other is:

a. −1.1 J b. 2 J
c. 2.5 J d. 3 J

Ans. (a) −1.1 J

$$U = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r}$$
$$= \frac{9 \times 10^9 \times 4 \times 10^{-6} \times (-3) \times 10^{-6}}{0.1} = -1.1 \text{ J}$$

Q 5. As the proton moves from *P* to *Q*, then:

a. the potential energy of proton decreases
b. the potential energy of proton increases
c. the proton loses kinetic energy
d. total energy of the proton increases

Ans. (a) the potential energy of proton decreases

As proton moves in the direction of the electric field, then its potential energy decreases.

Case Study 3

This energy possessed by a system of charges by virtue of their positions. When two like charges lie infinite distance apart, their potential energy is zero because no work has to be done in moving one charge at infinite distance from the other. In carrying a charge q from point A to point B, work done $W = q(V_A - V_B)$. This work may appear as change in KE/PE of the charge. The potential energy of two charges q_1 and q_2 at a distance r in air is $\frac{q_1 q_2}{4\pi\varepsilon_0 r}$. It is measured in joule. It may be positive, negative or zero depending on the signs of q_1 and q_2.

Read the given passage carefully and give the answer of the following questions.

Q 1. Calculate work done in separating two electrons form a distance of 1 m to 2 m in air, where *e* is electric charge and *k* is electrostatic force constant.

a. ke^2 b. $e^2/2$ c. $-ke^2/2$ d. zero

Ans. (c) $-ke^2/2$

$$W = (\text{P.E.})_{\text{final}} - (\text{P.E.})_{\text{initial}}$$
$$= \frac{ke^2}{2} - \frac{ke^2}{1} = \frac{-ke^2}{2}$$

Q 2. Four equal charges *q* each are placed at four corners of a square of side *a* each. Work done in carrying a charge −*q* from its centre to infinity is:

a. zero b. $\frac{\sqrt{2}q^2}{\pi\varepsilon_0 a}$ c. $\frac{\sqrt{2}q}{\pi\varepsilon_0 a}$ d. $\frac{q^2}{\pi\varepsilon_0 a}$

Ans. (b) $\frac{\sqrt{2}q^2}{\pi\varepsilon_0 a}$

Potential at the centre of the square due to four equal charges q at four corners

$$V = \frac{4q}{4\pi\varepsilon_0 (a\sqrt{2})/2} = \frac{\sqrt{2}q}{\pi\varepsilon_0 a}$$
$$W_{0 \to \infty} = -W_{\infty \to 0} = -(-q)V = \frac{\sqrt{2}q^2}{\pi\varepsilon_0 a}$$

Q 3. Two points *A* and *B* are located in diametrically opposite directions of a point charge +2 μC at distances 2 m and 1 m respectively from it. The potential difference between *A* and *B* is:

a. 3×10^3 V b. 6×10^4 V c. -9×10^3 V d. -3×10^3 V

Ans. (c) -9×10^3 V

Here, $q = 2\ \mu C = 2 \times 10^{-6}$ C, $r_A = 2$ m, $r_B = 1$m

$$\therefore\ V_A - V_B = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r_A} - \frac{1}{r_B}\right]$$
$$= 2 \times 10^{-6} \times 9 \times 10^9 \left[\frac{1}{2} - \frac{1}{1}\right] \text{V}$$
$$= -9 \times 10^3 \text{ V}$$

Q 4. Two points charges $A = +3$ nC and $B = +1$ nC are placed 5 cm apart in air. The work done to move charge B towards A by 1 cm is:

a. 2.0×10^{-7} J b. 1.35×10^{-7} J
c. 2.7×10^{-7} J d. 12.1×10^{-7} J

Ans. (b) 1.35×10^{-7} J

Required work done = Change in potential energy of the system

$$W = U_f - U_i = k\frac{q_1q_2}{r_f} - k\frac{q_1q_2}{r_i}$$

$$= kq_1q_2\left[\frac{1}{r_f} - \frac{1}{r_i}\right]$$

$$\therefore \quad W = (9 \times 10^9)(3 \times 10^{-9} \times 1 \times 10^{-9}) \times \left[\frac{1}{4 \times 10^{-2}} - \frac{1}{5 \times 10^{-2}}\right]$$

$$= 27 \times 10^{-7} \times (0.05) = 1.35 \times 10^{-7} \text{ J}$$

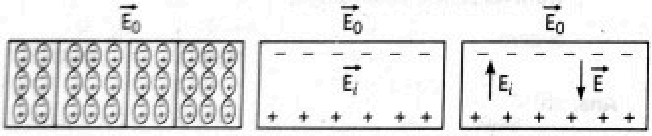
Q 5. A charge Q is placed at the origin. The electric potential due to this charge at a given point in space is V. The work done by an external force in bringing another charge q from infinity up to the point is:

a. $\frac{V}{q}$ b. Vq c. $V + q$ d. V

Ans. (b) Vq

Case Study 4

When an insulator is placed in an external field, the dipoles become aligned. Induced surface charges on the insulator establish a polarization field $\vec{E}_i$ in its interior. The net field $\vec{E}$ in the insulator is the vector sum of $\vec{E}_0$ and $\vec{E}_i$ as shown in the figure.



(a) (b) (c)

On the application of external electric field, the effect of aligning the electric dipoles in the insulator is called polarisation and the field $\vec{E}_i$ is known as the polarisation field.

The dipole moment per unit volume of the dielectric is known as polarisation ($\vec{P}$).

For linear isotropic dielectrics, $\vec{P} = \chi\,\vec{E}$, where χ = electrical susceptibility of the dielectric medium.

Read the given passage carefully and give the answer of the following questions.

Q 1. Which among the following is an example of polar molecule?

a. O_2 b. H_2
c. N_2 d. HCl

Ans. (d) HCl

In polar molecule the centres of positive and negative charges are separated even when there is no external field. Such molecule have a permanent dipole moment. Ionic molecule like HCl is an example of polar molecule.

Q 2. When air is replaced by a dielectric medium of constant K, the maximum force of attraction between two charges separated by a distance:

a. increases K times b. remains unchanged
c. decreases K times d. increases $2K$ times

Ans. (c) decreases K times

As $F_m = \frac{F_0}{K}$

$\therefore$ The maximum force decreases by K times.

Q 3. Which of the following is a dielectric?

a. Copper b. Glass
c. Antimony (Sb) d. None of these

Ans. (b) Glass

Q 4. For a polar molecule, which of the following statements is true?

a. The centre of gravity of electrons and protons coincide
b. The centre of gravity of electrons and protons do not coincide
c. The charge distribution is always symmetrical
d. The dipole moment is always zero

Ans. (b) The centre of gravity of electrons and protons do not coincide

A polar molecule is one in which the centre of gravity for positive and negative charges are separated.

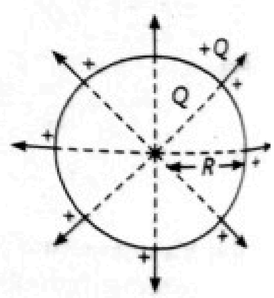
Q 5. When a comb rubbed with dry hair attracts pieces of paper. This is because the:

a. comb polarizes the piece of paper
b. comb induces a net dipole moment opposite to the direction of field
c. electric field due to the comb is uniform
d. comb induces a net dipole moment perpendicular to the direction of field

Ans. (a) comb polarizes the piece of paper

Case Study 5

The electrical capacitance of a conductor is the measure of its ability to hold electric charge. An isolated spherical conductor of radius R. The charge Q is uniformly distributed over its entire surface. It can be assumed to be concentrated at the centre of the sphere. The potential at any point on the surface of the spherical conductor will be



$$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}.$$

Capacitance of the spherical conductor situated in vacuum is

$$C = \frac{Q}{V} = \frac{Q}{\frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{R}} \quad \text{or} \quad C = 4\pi\varepsilon_0 R$$

Clearly, the capacitance of a spherical conductor is proportional to its radius.

The radius of the spherical conductor is 1 F capacitance is $R = \frac{1}{4\pi\varepsilon_0} \cdot C$ and this radius is about 1500 times the radius of earth ($\sim 6 \times 10^3$ km).

Read the given passage carefully and give the answer of the following questions.

Q 1. If an isolated sphere has a capacitance 50 pF then radius is:

a. 90 cm b. 45 cm
c. 45 m d. 90 m

Ans. (b) 45 cm

Here, $C = 50\text{ pF} = 50 \times 10^{-12}$ F, $V = 10^4$ V

$$R = \frac{1}{4\pi\varepsilon_0} \cdot C = 9 \times 10^9 \text{ mF}^{-1} \times 50 \times 10^{-12} \text{ F}$$

$$= 45 \times 10^{-2} \text{ m} = 45 \text{ cm}$$

Q 2. How much charge should be placed on a capacitance of 25 pF to raise its potential to 10^5 V?

a. 1 μC b. 1.5 μC c. 2 μC d. 2.5 μC

Ans. (d) 2.5 μC

As $q = CV = 25 \times 10^{-12} \times 10^5 = 2.5\ \mu\text{C}$

Q 3. Dimensions of capacitance is:

a. $[ML^{-2}T^4A^2]$ b. $[M^{-1}L^{-1}T^3A^1]$
c. $[M^{-1}L^{-2}T^4A^2]$ d. $[M^0L^{-2}T^4A^1]$

Ans. (c) $[M^{-1}L^{-2}T^4A^2]$

Q 4. Metallic sphere of radius R is charged to potential V. Then charge q is proportional to:

a. V b. R
c. Both a. and b. d. None of these

Ans. (c) Both a. and b.

As charge, $q = CV = (4\pi\varepsilon_0 R)V$

$\therefore$ q depends on both V and R.

Q 5. If 64 identical spheres of charge q and capacitance C each are combined to form a large sphere. The charge and capacitance of the large sphere is:

a. $64q, C$ b. $16q, 4C$
c. $64q, 4C$ d. $16q, 64C$

Ans. (c) $64q, 4C$

64 drops have formed a single drop of radius R.

Volume of large sphere = 64 × Volume of small sphere

$$\therefore \quad \frac{4}{3}\pi R^3 = 64 \times \frac{4}{3}\pi r^3$$

$$\Rightarrow \quad R = 4r \quad \text{and} \quad Q_{total} = 64q$$

$$C' = 4\pi\varepsilon_0 R \Rightarrow C' = (4\pi\varepsilon_0) \cdot 4r$$

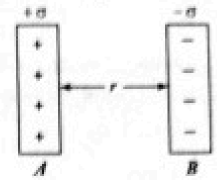
$$\Rightarrow \quad C' = 4C$$

Case Study 6

Surface charge density is defined as charge per unit surface area of surface charge distribution. *i.e.*, $\sigma = \frac{dq}{dS}$.

Two large, thin metal plates are parallel and close to each other. On their inner faces, the plates have surface charge densities of opposite signs having magnitude of 17.0×10^{-22} **Cm^{-2} as shown. The intensity of electric** field at a point is $E = \frac{\sigma}{\varepsilon_0}$,

where, ε_0 = permittivity of free space.



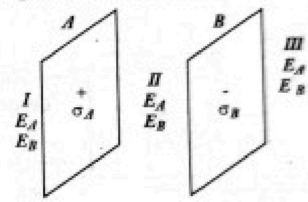
Read the given passage carefully and give the answer of the following questions.

Q 1. E in the outer region of the first plate is:

a. 17×10^{-22} N/C b. 1.5×10^{-25} N/C
c. 1.9×10^{-10} N/C d. zero

Ans. (d) zero

There are two plates A and B having surface charge densities, $\sigma_A = 17.0 \times 10^{-22}$ C/m^2 on A and $\sigma_B = -17.0 \times 10^{-22}$ C/m^2 on B, respectively. According to Gauss' theorem, if the plates have same surface charge density but having opposite signs, then the electric field in region I is zero.



$$E_I = E_A + E_B = \frac{\sigma}{2\varepsilon_0} + \left(-\frac{\sigma}{2\varepsilon_0}\right) = 0$$

Q 2. E in the outer region of the second plate is:

a. 17×10^{-22} N/C b. 1.5×10^{-15} N/C
c. 1.9×10^{-10} N/C d. zero

Ans. (d) zero

The electric field in region III is also zero.

$$E_{III} = E_A + E_B = \frac{\sigma}{2\varepsilon_0} + \left(-\frac{\sigma}{2\varepsilon_0}\right) = 0$$

Q 3. E between the plates is:

a. 17×10^{-22} N/C b. 1.5×10^{-15} N/C
c. 1.9×10^{-10} N/C d. zero

Ans. (c) 1.9×10^{-10} N/C

In region II or between the plates, the electric field

$$E_{II} = E_A - E_B = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0}$$

$$= \frac{\sigma(\sigma_A \text{ or } \sigma_B)}{\varepsilon_0} = \frac{17.0 \times 10^{-22}}{8.85 \times 10^{-12}}$$

$$E = 1.9 \times 10^{-10} \text{ N/C}$$

Q 4. The ratio of E from right side of B at distances 2 cm and 4 cm respectively, is:

a. 1 : 2 b. 2 : 1 c. 1 : 1 d. 1 : $\sqrt{2}$

Ans. (c) 1 : 1

Since, electric field due to an infinite-plane sheet of charge does not depend on the distance of observation point from the plane sheet of charge. So, for the given distances, the ratio of E will be 1 : 1.

Q 5. In order to estimate the electric field due to a thin finite plane metal plate, the Gaussian surface considered is:

a. spherical b. cylindrical
c. straight line d. None of these

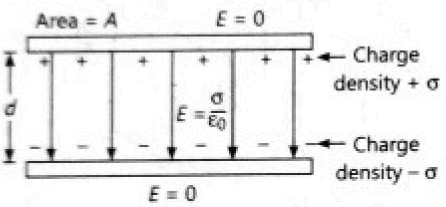
Ans. (b) cylindrical

In order to estimate the electric field due to a thin finite plane metal plate, we take a cylindrical cross-sectional area A and length $2r$ as the Gaussian surface.

Case Study 7

The simplest and the most widely used capacitor is the parallel plate capacitor. It consists of two large plane parallel conducting plates, separated by a small distance. In the outer regions above the upper plate and below the lower plate, the electric fields due to the two charged plates cancel out. The net field is zero.

In the inner region between the two capacitor plates, the electric fields due to the two charged plates add up. The net field is $\frac{\sigma}{\varepsilon_0}$.



For a uniform electric field, potential difference between the plates = Electric field × distance between the plates. Capacitance of the parallel plate capacitor is, the charge required to supplied to either of the conductors of the capacitor so as to increase the potential difference between, then by unit amount.

Read the given passage carefully and give the answer of the following questions.

Q 1. A parallel plate capacitor is charged and then isolated. The effect of increasing the plate separation on charge, potential and capacitance respectively are:

a. increases, decreases, decreases
b. constant, increases, decreases
c. constant, decreases, decreases
d. constant, decreases, increases

Ans. (b) constant, increases, decreases

As the capacitor is isolated after charging, charge Q on it remains constant. Plate separation d increases, capacitance decreases as $C = \frac{\varepsilon_0 A}{d}$ and hence, potential increases as $V = \frac{Q}{C}$.

Q 2. In a parallel plate capacitor, the capacity increases if:

a. area of the plate is decreases
b. distance between the plates increases
c. area of the plate is increases
d. dielectric constant decreases

Ans. (c) area of the plate is increases

In a parallel plate capacitor, the capacity of capacitor

$$C = \frac{K\varepsilon_0 A}{d} \text{ i.e., } C \propto A$$

The capacity of capacitor increases, if area of the plate increases.

Q 3. A parallel plate capacitor has two square plates with equal and opposite charges. The surface charge densities on the plates are $+\sigma$ and $-\sigma$ respectively. In the region between the plates the magnitude of the electric field is:

a. $\frac{\sigma}{2\varepsilon_0}$ b. $\frac{\sigma}{\varepsilon_0}$ c. 0 d. None of these

Ans. (b) $\frac{\sigma}{\varepsilon_0}$

The magnitude of the electric field between the plate is

$$E = \frac{\sigma}{2\varepsilon_0} - \left(-\frac{\sigma}{2\varepsilon_0}\right) = \frac{\sigma}{\varepsilon_0}$$

Q 4. If a parallel plate air capacitor consists of two circular plates of diameter 8 cm. At what distance should the plate be held so as to have the same capacitance as that of sphere of diameter 20 cm?

a. 9 mm b. 4 mm c. 8 mm d. 2 mm

Ans. (b) 4 mm

As, $\frac{\varepsilon_0 A}{d} = 4\pi\varepsilon_0 R$

or $\frac{\varepsilon_0 \pi D^2}{4d} = 4\pi\varepsilon_0 R$

or $d = \frac{D^2}{16R} = \frac{(0.08)^2}{16 \times 0.10} = 4 \times 10^{-3}\text{ m} = 4\text{ mm}$

Q 5. If a charge of $+2.0 \times 10^{-8}$ C is placed on the positive plate and a charge of -1.0×10^{-8} C on the negative plate of a parallel plate capacitor of capacitance 1.2×10^{-3} μF, then the potential difference developed between the plates is:

a. 6.25 V b. 3.0 V c. 12.5 V d. 25 V

Ans. (c) 12.5 V

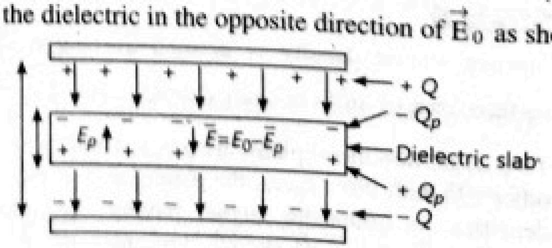
Here, $V = \frac{q_1 - q_2}{2C}$

$$= \frac{2.0 \times 10^{-8} + 1.0 \times 10^{-8}}{2 \times 1.2 \times 10^{-9}} = 12.5\text{ V}$$

Case Study 8

A dielectric slab is a substance which does not allow the flow of charges through it but permits them to exert electrostatic forces on one another.

When a dielectric slab is placed between the plates, the field E_0 polarises the dielectric. This induce charge $-Q_p$ on the upper surface are $+Q_p$ on the lower surface of the dielectric. These induced charges set up a field E_p inside the dielectric in the opposite direction of $\vec{E}_0$ as shown.



Read the given passage carefully and give the answer of the following questions.

Q 1. In a parallel plate capacitor, the capacitance increases from 4μF to 80μF, on introducing a dielectric medium between the plates. What is the dielectric constant of the medium?

a. 10 b. 20 c. 50 d. 100

Ans. (b) 20

$$K = \frac{\text{Capacitance with dielectric}}{\text{Capacitance without dielectric}} = \frac{80\,\mu F}{4\,\mu F} = 20$$

Q 2. A parallel plate capacitor with air between the plates has a capacitance of 8 pF. The separation between the plates is now reduced half and the space between them is filled with a medium of dielectric constant 5. Calculate the value of capacitance of the capacitor in second case.

a. 8 pF b. 10 pF c. 80 pF d. 100 pF

Ans. (c) 80 pF

Capacitance of the capacitor with air between plates

$$C' = \frac{\varepsilon_0 A}{d} = 8\text{ pF}$$

With the capacitor is filled with dielectric ($k = 5$) between its plates and the distance between the plates is reduced by half, capacitance become

$$C = \frac{\varepsilon_0 kA}{d/2} = \frac{\varepsilon_0 \times 5 \times A}{d/2} = 10C' = 10 \times 8 = 80\text{ pF}$$

Q 3. A dielectric introduced between the plates of a parallel plate condenser:

a. decreases the electric field between the plates
b. increases the capacity of the condenser
c. increases the charge stored in the condenser
d. increases the capacity of the condenser

Ans. (d) increases the capacity of the condenser

If a dielectric medium of dielectric constant K is filled completely between the plates, then capacitance increases by K times.

Q 4. A parallel plate capacitor of capacitance 1pF has separation between the plates is d. When the distance of separation becomes $2d$ and wax of dielectric constant x is inserted in it the capacitance becomes 2 pF. What is the value of x?

a. 2 b. 4 c. 6 d. 8

Ans. (b) 4

$$C = \frac{\varepsilon_0 A}{d} = 1\text{pF} \quad \text{...(1)}$$

$$C' = \frac{x\varepsilon_0 A}{(2d)} = 2\text{ pF} \quad \text{...(2)}$$

Dividing eq. (2) by eq. (1), $\frac{x}{2} = \frac{2}{1} \Rightarrow x = 4$

Q 5. A parallel plate capacitor having area A and separated by distance d is filled by copper plate of thickness b. The new capacity is:

a. $\frac{\varepsilon_0 A}{d + \frac{b}{2}}$ b. $\frac{\varepsilon_0 A}{2d}$ c. $\frac{\varepsilon_0 A}{d - b}$ d. $\frac{2\varepsilon_0 A}{d + \frac{b}{2}}$

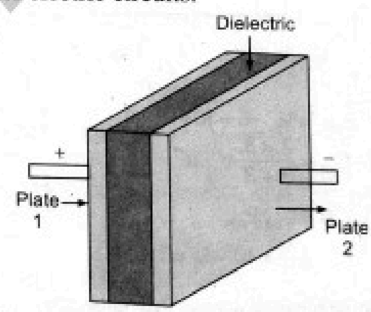
Ans. (c) $\frac{\varepsilon_0 A}{d - b}$

As capacitance, $C_0 = \frac{\varepsilon_0 A}{d}$

$\therefore$ After inserting copper plate, $C = \frac{\varepsilon_0 A}{d - b}$

Case Study 9

An arrangement of two conductors separated by an insulating medium can be used to store electric charge and electric energy. Such a system is called a capacitor. The more charge a capacitor can store, the greater is its capacitance. Usually, a capacitor consists of two conductors having equal and opposite charge $+Q$ and $-Q$. Hence, there is a potential difference V between them. By the capacitance of a capacitor, we mean the ratio of the charge Q to the potential difference V. By the charge on a capacitor we mean only the charge Q on the positive plate. Total charge of the capacitor is zero. The capacitance of a capacitor is a constant and depends on geometric factors, such as the shape, size and relative position of the two conductors, and the nature of the medium between them. The unit of capacitance is farad (F), but the more convenient units are μF and pF. A commonly used capacitor consists of two long strips or metal foils, separated by two long strips of dielectrics, rolled up into a small cylinder. Common dielectric materials are plastics (such as polyestors and polycarbonates) and aluminium oxide. Capacitors are widely used in television, computer, and other electric circuits.



Read the given passage carefully and give the answer of the following questions.

Q 1. A parallel plate capacitor C has a charge $Q/2$. The actual charges on its plates are:

a. Q, Q b. $Q/2, Q/2$ c. $Q, -Q$ d. $Q/2, -Q/2$

Ans. (d) $Q/2, -Q/2$

The Q charge on a capacitor indicates that the charges on its plates are $+Q/2$ and $-Q/2$.

Q 2. A parallel plate capacitor is charged. If the plates are pulled apart:

a. the capacitance increases
b. the potential difference increases
c. the total charge increases
d. the charge and potential difference remain the same.

Ans. (b) the potential difference increases

$$V = Ed$$

i.e., E remains the same, as V increases with increase of distance.

Q 3. If n capacitors, each of capacitance C, are connected in series, then the equivalent capacitance of the combination will be:

a. nC b. n^2C c. C/n d. C/n^2

Ans. (c) C/n

$$\frac{1}{C_S} = \frac{1}{C} + \frac{1}{C} + \frac{1}{C} + \ldots n \text{ factors} = \frac{n}{C}$$

$$\therefore \quad C_S = \frac{C}{n}$$

Q 4. Three capacitons of 2.0, 3.0 and 6.0 μF are connected in series to a 10 V source. The charge on the 3.0μF capacitor is:

a. 5μC b. 10μC c. 12 μC d. 15μC

Ans. (b) 10μC

$$\frac{1}{C_{eq}} = \frac{1}{2} + \frac{1}{3} + \frac{1}{6} = \frac{6}{6} = \frac{1}{1}$$

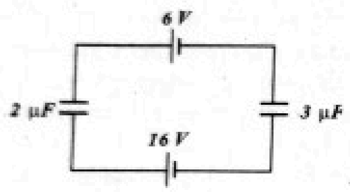
$$C_{eq} = 1\mu F$$

Charge on each capacitor is

$$\therefore \quad Q = CV = 1\mu F \times 10 \text{ V}$$

$$= 10\,\mu C$$

Q 5. What is the potential difference across 2μF capacitor in the circuit shown?



a. 12 V b. 4 V c. 6 V d. 18 V

Ans. (c) 6 V

$$E_{net} = 16 - 6 = 10\text{V}$$

$$C_{eq} = \frac{2 \times 3}{2+3} = \frac{6}{5}\mu F$$

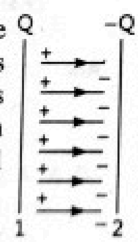
$$Q = C_{eq} E_{net}$$

$$= \frac{6}{5} \times 10 = 12\,\mu C$$

Potential difference across 2 μC capacitor,

$$V_1 = \frac{Q}{C_1} = \frac{12\,\mu C}{2\,\mu F} = 6\text{V}$$

Case Study 10



A capacitor is a device to store energy. The process of charging up a capacitor involves the transferring of electric charges from its one place to another. This work done in charging the capacitor is stored as its electrical potential energy.

If q is the charge and V is the potential difference across a capacitor at any instant during its charging, then small work done in storing an additional small charge dq against the repulsion of charge q already stored on it is $dW = V \cdot dq = (q/C)\,dq$.

Read the given passage carefully and give the answer of the following questions.

Q 1. A system of 2 capacitors of capacitance 2μF and 4μF is connected in series across a potential difference of 6 V. The energy stored in the system is:

a. 3μJ b. 24μJ

c. 30μJ d. 108μJ

Ans. (b) 24 μJ

As, $C_1 = 2\,\mu F$, $C_2 = 4\,\mu F$

In series combination, the equivalent capacitance will be,

$$C = \frac{C_1 C_2}{C_1 + C_2} = \left(\frac{2 \times 4}{2+4}\right)\mu F = \frac{4}{3}\mu F$$

Potential difference applied, $V = 6$ V

Energy stored in the system, $U = \frac{1}{2}CV^2$

$$= \frac{1}{2} \times \frac{4}{3} \times 10^{-6} \times (6)^2 \text{ J} = 24\,\mu J$$

Q 2. A capacitor of capacitance of 10μF is charged to 10 V. The energy stored in it is:

a. 100 μJ b. 500 μJ c. 1000 μJ d. 1 μJ

Ans. (b) 500 μJ

The energy stored in a capacitor is

$$U = \frac{1}{2}CV^2 = \frac{1}{2} \times (10 \times 10^{-6})(10)^2 = 500\,\mu J$$

Q 3. A parallel plate air capacitor has capacity C farad, potential V volt and energy E joule. When the gap between the plates is completely filled with dielectric:

a. Both V and E increase b. Both V and E decrease

c. V decreases, E increases d. V increases, E decreases

Ans. (b) Both V and E decrease

When the gap between the plates is completely filled with dielectric of dielectric constant K, then potential is

$$V = \frac{Qd}{A\varepsilon_0 K} \quad \text{...(1)}$$

and electric field is

$$E = \frac{Q}{A\varepsilon_0 K} \quad \text{...(2)}$$

From eqs. (1) and (2), both electric field and potential decrease.

Q 4. A capacitor with capacitance 5μF is charged to 5μC. If the plates are pulled apart to reduce the capacitance to 2μF, how much work is done?

a. 6.25×10^{-6} J b. 3.75×10^{-6} J

c. 2.16×10^{-6} J d. 2.55×10^{-6} J

Ans. (b) 3.75×10^{-6} J

Work done $= U_f - U_i$

$$= \frac{1}{2}\frac{q^2}{C_f} - \frac{1}{2}\frac{q^2}{C_i}$$

$$= \frac{q^2}{2}\left[\frac{1}{C_f} - \frac{1}{C_i}\right]$$

$$= \frac{(5 \times 10^{-6})^2}{2}\left[\frac{1}{2 \times 10^{-6}} - \frac{1}{5 \times 10^{-6}}\right]$$

$$= 3.75 \times 10^{-6} \text{ J}$$

Q 5. A metallic sphere of radius 18 cm has been given a charge of 5×10^{-6} C. The energy of the charged conductor is:

a. 0.2 J b. 0.6 J c. 1.2 J d. 2.4 J

Ans. (b) 0.6 J

Here, $r = 18$ cm $= 18 \times 10^{-2}$ m, $q = 5 \times 10^{-6}$ C

As $C = 4\pi\varepsilon_0 r$

$$= \frac{18 \times 10^{-2}}{9 \times 10^9} = 2 \times 10^{-11} \text{ F}$$

Energy of charged conductor is

$$U = \frac{q^2}{2C} = \frac{(5 \times 10^{-6})^2 \text{ C}}{2 \times 2 \times 10^{-11} \text{ F}} = 0.625 \text{ J}$$

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CHAPTER 3

Current Electricity

Fastrack REVISION

▶ **Electric Current:** The flow of charge in a definite direction contributes the electric current.

It is measured as:

$$\text{Electric current, } I = \frac{\text{Total charge flown}}{\text{Time taken}} = \frac{q}{t}$$

Unit of electric current is ampere (A), $1\ A = 1\ Cs^{-1}$

The direction of flow of positive charge gives the direction of conventional current.

The direction of flow of electrons gives the direction of electric current.

Current is a scalar quantity.

▶ **Electric Current in Conductors:** Conductors are those materials which have large number of free electrons and develop strong electric currents in them; when an electric field is applied.

Due to this electric field applied, there will be a current for a very short time called transient current.

▶ **Drift Velocity:** Drift velocity is defined as the average velocity with which the free electrons get drifted towards the positive end of the conductor under the influence of an external electric field applied.

$$\vec{v}_d = \frac{-e\vec{E}}{m}\tau$$

where, $\tau = \frac{\lambda}{v}$, λ = mean free path.

▶ **Average Relaxation Time:** The average time between two successive collision of an electron.

$$\tau = \frac{\tau_1 + \tau_2 + \ldots\ldots + \tau_n}{n}$$

▶ **Mobility:** Mobility is defined as the magnitude of drift velocity per unit electric field applied.

Mobility of electron, $\mu_e = \frac{q\tau_e}{m_e}$

Its S.I. unit is $m^2s^{-1}V^{-1}$

▶ **Relation between Current and Mobility:**

(i) For a conductor

$$I = n\,e\,A\mu_e E$$

(ii) For a semiconductor

$$I = e\,AE(n\mu_e + p\mu_h)$$

▶ **Relation between Current and Drift Velocity:**

$$I = neAv_d$$

▶ **Ohm's Law:** If the physical conditions of a conductor like temperature, length, area of cross-section, stress, etc. do not change then current flowing through the conductor is directly proportional to the potential difference applied across the conductor.

$$V \propto I$$

or

$$V = RI$$

$$\frac{V}{I} = R \text{ (constant)}$$

▶ **Limitations of Ohm's Law:**

The conditions under which Ohm's law is not obeyed:

(i) The relation between V and I is non-linear.

(ii) The relation between V and I depends on the sign of V, *e.g.* junction diode.

(iii) The relation between V and I is not unique, *e.g.* a light emitting diode.

(iv) V-I graph does not pass through origin.

▶ **Non-ohmic Devices:** Those devices which do not obey Ohm's law are called non-ohmic devices. *e.g.* transistor, semiconductor diode, etc.

▶ **Resistance:** It is defined as the obstruction possessed by the conductor to the flow of electric current through it.

i.e., $$R = \frac{V}{I}$$

Its S.I. unit is Ohm (Ω).

▶ **Resistivity:** It is defined as the resistance of a unit length with unit area of cross-section of the material of the conductor.

$$\rho = R\frac{A}{l}$$

▶ **Temperature Dependence of Resistivity:** The resistivity of a material is found to be dependent on the temperature.

The resistivity of a metallic conductor, over a range of temperature is given by

$$\rho_T = \rho_0[1 + \alpha(T - T_0)]$$

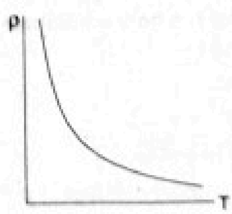
where, ρ_T = resistivity at temperature T,

ρ_0 = resistivity at reference temperature T_0,

α = temperature co-efficient of resistivity.

▶ **For Metal Conductors:** The value of α is positive, their electrical resistivity increases with temperature. For most metals the resistivity *vs* time graph is linear in nature.

▶ **For Semiconductors and Insulators:** However n (number of free electrons per unit volume) increases with temperature, but I decreases and thus ρ decreases with temperature.



▶ **Electrical Energy and Power:**

Electrical energy, $E = Vq = VIt = I^2Rt = \frac{V^2}{R}t$ ...(1)

We know, $P = VI$

Using Ohm's law, $V = IR$

$$P = I^2R = V^2R$$

P is the power loss or ohmic loss in a conductor of resistance R carrying a current.

- **Relation between Cell emf and Internal Resistance:**

$$I = \frac{\varepsilon}{R+r}$$, where r is the internal resistance of a cell

- **Series Combination of Cells:**

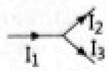
$$I_S = \frac{n\varepsilon}{R+nr}$$

- **Parallel Combination of Cells:**

$$I_P = \frac{n\varepsilon}{nR+r}$$

- **Kirchhoff's Laws:**
  (i) Kirchhoff's First Law or Kirchhoff's Junction Law: It states that the algebraic sum of the currents meeting at a junction in a closed electric current is zero. *i.e.*, $\Sigma I = 0$.

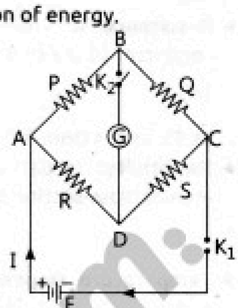
$$I_1 = I_2 + I_3$$



This is called the law of conservation of charge.

  (ii) Kirchhoff's Second Law or Kirchhoff's Loop Law: It states that the algebraic sum of changes in potential around any closed path of electric circuit involving resistors and cell in the loop is zero. *i.e.*, $\Sigma V = 0$.
  This law is called the law of conservation of energy.

- **Wheatstone Bridge:** Wheatstone bridge principle states that if four resistances *P*, *Q*, *R* and *S* are arranged to form a bridge, with a cell of emf '*E*' and one way key 'K_1' between the points A and C and a galvanometer 'G' and tapping key 'K_2', between the points B and D, then on closing K_1, first and K_2 later on, if galvanometer shows no deflection, the bridge is balanced.



i.e.,
$$\frac{P}{Q} = \frac{R}{S}$$

- **Meter Bridge or Slide Wire Bridge:** It measures unknown resistance and works on the principle of Wheatstone Bridge.

$$\frac{P}{Q} = \frac{R}{S}$$

$$\frac{lr}{(100-l)r} = \frac{R}{S}$$

$$S = \frac{(100-l)R}{l}$$

Knowing *l* and *R*, we can calculate *S*.

- **Potentiometer:** Potentiometer is an instrument used for measuring the emf of a cell or potential difference between two points in an electrical circuit accurately.

$$V = IR$$

$$R = \rho\frac{l}{A}$$

$$V = I\rho\frac{l}{A} = Kl$$

where
$$K = \frac{I\rho}{A}$$

$$V \propto l$$

- **Comparison of emf's of Two Cells using Potentiometer:**

$$\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2}$$

- **Determination of Internal Resistance of the Cell:**

$$r = R\left(\frac{l_1}{l_2} - 1\right)$$

Objective TYPE QUESTIONS

Multiple Choice Questions

Q 1. Lighting is an electrical discharge caused by imbalanced between

a. clouds and the ground b. within the clouds
c. Both a. and b. d. None of these

Ans. (c) Both a. and b.

Q 2. Electric current has both magnitude and direction it is a:

a. vector quantity b. scalar quantity
c. tensor quantity d. None of these

Ans. (b) scalar quantity

KNOWLEDGE BOOSTER

Current is a scalar quantity although it possesses magnitude and direction because it follows algebraic addition and do not obey the law of addition of vectors.

Q 3. Conventional current flows from

a. point of higher potential to lower potential
b. point of lower potential to higher potential
c. point of lower potential to lower potential
d. all of the above

Ans. c. point of higher potential to lower potential

Q 4. One coulomb per second is equal to:

a. 1 farad b. 1 ampere
c. 1 volt d. None of these

Ans. (b) 1 ampere

Q 5. A charge of 60 C passes through an electric lamp in 2 minutes. Then the current in the lamp is:

a. 30 A b. 1 A
c. 0.5 A d. 5 A

Ans. (c) 0.5 A

T!P

We measure the charge in coulombs and time in seconds to find electric current.

Electric current, $I = \frac{q}{t}$

$$= \frac{60}{2 \times 60} = 0.5 \text{ A}$$

Q 6. Charge through a conductor is given as a function of time as $q = 4t^2 + 4t + 4$ coulomb. At 2 s what is the current flowing?

a. 12 A b. 8 A
c. 20 A d. 28 A

Ans. (c) 20 A

$$I = \frac{dq}{dt} = \frac{d}{dt}(4t^2 + 4t + 4)$$
$$= 8t + 4$$
$$I(t = 2\,s) = 8 \times 2 + 4$$
$$= 16 + 4 = 20\ A$$

Q 7. Charge through a cross-section of a conductor is given by $Q = 5t^2 - 2t$ coulomb. Find the average current through the conductor in the interval $t_1 = 2$ s to $t_2 = 4$ s.

a. 14 A b. 28 A c. 56 A d. 7 A

Ans. (b) 28 A

Given, $Q = 5t^2 - 2t$

Q (at $t = 2$) $= 5(2)^2 - 2(2) = 20 - 4 = 16$ C

Q (at $t = 4$) $= 5(4)^2 - 2(4) = 80 - 8 = 72$ C

Current, $I = \frac{\Delta Q}{\Delta t} = \frac{72 - 16}{4 - 2} = \frac{56}{2} = 28$ A

Q 8. The current in a wire varies with time according to the equation $I = 4 + 2t$, where, I is an ampere and t is in second. The quantity of charge which has to be passed through a cross-section of the wire during the time $t = 2$ s to $t = 6$ s is:

a. 40 C b. 48 C c. 38 C d. 43 C

Ans. (b) 48 C

Let dq be the charge which passes in a small interval on time dt. Then

$$dq = Idt \text{ or } dq = (4 + 2t)\,dt$$

On integrating, we get

$$q = \int_2^6 (4 + 2t)\,dt = [4t + t^2]_2^6 = 48\ C$$

Q 9. An electric charge will experience a ...., when an electric field is applied.

a. pressure b. momentum

c. force d. None of these

Ans. (c) force

Q 10. In earth's atmosphere where do the free charged particles exist?

a. ionosphere b. mesosphere

c. troposphere d. stratosphere

Ans. (a) ionosphere

Q 11. Mechanisms which maintain a steady electric field are:

a. cells b. batteries

c. Both a. and b. d. None of these

Ans. (c) Both a. and b.

Q 12. In the current against voltage curve in Ohm's law, the slope gives:

a. resistance b. conductance

c. resistivity d. conductivity

Ans. (b) conductance

Common Error

Most students commit error in answering this question as they do not read the question properly.

T!P

*The slope of V-I graph = **Resistance***

*The slope of I-V graph = $\frac{1}{\text{Resistance}}$ **Conductance***

Q 13. The electrical resistance of a conductor depends upon:

a. size of the conductor

b. temperature of the conductor

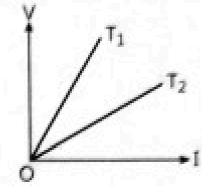
c. geometry of the conductor

d. All of the above

Ans. (d) All of the above

The electrical resistance of a conductor is depend upon all factors *i.e.*, size, temperature and geometry of conductor.

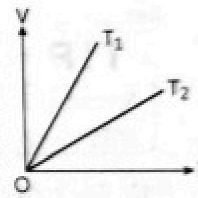
Q 14. The voltage V and current I graphs for a conductor at two different temperatures T_1 and T_2 are shown in the figure. The relation between T_1 and T_2 is:



a. $T_1 > T_2$ b. $T_1 < T_2$

c. $T_1 = T_2$ d. $T_1 = \frac{1}{T_2}$

Ans. (a) $T_1 > T_2$



The slope of V-I graph gives the resistance of a conductor at a given temperature. From the graph, it follows that resistance of a conductor at temperature T_1 is greater than at temperature T_2. As the resistance of a conductor is more at higher temperature and less at lower temperature, hence $T_1 > T_2$.

Q 15. A 220 V main supply is connected to a resistance of 100 k Ω. The effective current is

a. 2.2 mA b. $2.2\sqrt{2}$ mA

c. $\frac{2.2}{\sqrt{2}}$ mA d. None of these

Ans. (a) 2.2 mA

As, $V = IR$

$\Rightarrow$ $I = \frac{V}{R} = \frac{220}{100 \times 10^3}$

$\Rightarrow$ $I = 2.2 \times 10^{-3}$ A $= 2.2$ mA

Q 16. Consider a current carrying wire (current I) in the shape of a circle. Note that as the current progresses along the wire, the direction of $\vec{J}$ (current density) changes in an exact manner, while the current I remains unaffected. The agent that is essentially responsible for it is: *(NCERT EXEMPLAR)*

a. source of emf

b. electric field produced by charges accumulated on the surface of wire

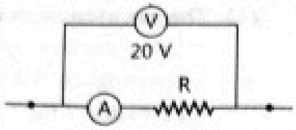
c. the charges just behind a given segment of wire which push them just right way by repulsion

d. the charges ahead

Ans. (b) electric field produced by charges accumulated on the surface of wire

The direction of current density is the direction of flow of positive charge in the circuit which is possible due to electric field produced by charges accumulated on the surface of wire.

Q 17. In the diagram shown, the reading of voltmeter is 20 V and that of ammeter is 4 A. The value of R should be (Consider given ammeter and voltmeter are not ideal):



a. equal to 5 Ω
b. greater than 5 Ω
c. less than 5 Ω
d. greater or less than 5 Ω

Ans. (c) less than 5 Ω

It is given that ammeter is not ideal.

∴ Resistance of ammeter = r

$\Rightarrow \quad V = IR$

$\Rightarrow \quad 20 = 4(R_{eq})$

$\Rightarrow \quad R_{eq} = 5$

$\Rightarrow \quad R + r = 5$

$\Rightarrow \quad R < 5\ \Omega$

Q 18. There are three copper wires of equal length and the ratio of their radii is 1 : 2 : 3. What is the ratio of their resistivity?

a. 1 : 2 : 3
b. 3 : 2 : 1
c. 1 : 1 : 1
d. 1 : 4 : 9

Ans. (c) 1 : 1 : 1

T!P

Resistivity is independent of shape and size of the body and depends upon the nature of the material.

Q 19. The condition for the validity of Ohm's law is that the:

a. temperature should remain constant
b. current should be proportional to voltage
c. resistance must be wire wound type
d. all of the above

Ans. (a) temperature should remain constant

Q 20. The unit of specific conductivity is:

a. $\Omega\text{-cm}^{-1}$
b. $\Omega\text{-cm}^{-2}$
c. $\Omega^{-1}\text{cm}$
d. $\Omega^{-1}\text{cm}^{-1}$

Ans. (d) $\Omega^{-1}\text{cm}^{-1}$

$$\text{Conductivity} = \frac{1}{\text{Resistivity}}$$

Its unit = mho/cm or $\Omega^{-1}\text{cm}^{-1}$

Q 21. A metal rod of length 10 cm and a rectangular cross-section of 1 cm $\times \frac{1}{2}$ cm is connected to a battery across opposite faces. The resistance will be: *(NCERT EXEMPLAR)*

a. maximum when the battery is connected across 1 cm $\times \frac{1}{2}$ cm faces
b. maximum when the battery is connected across 10 cm × 1 cm faces
c. maximum when the battery is connected across 10 cm $\times \frac{1}{2}$ cm faces
d. same irrespective of the three faces

Ans. (a) maximum when the battery is connected across 1 cm $\times \frac{1}{2}$ cm faces

As $R = \rho \frac{l}{A}$, resistance is maximum when l is large and A is least. For the given dimensions of wire, resistance will be maximum for $l = 10$ cm and $A = 1\text{cm} \times \frac{1}{2}$ cm.

Q 22. The resistance of a wire is 10 Ω. What will be the new resistance, if it is stretched uniformly 8 times its original length?

a. 640 Ω
b. 64 Ω
c. 10 Ω
d. 6400 Ω

Ans. (a) 640 Ω

We know that,

$$\text{Resistance}(R) = \rho \frac{l}{A} = 10 \qquad ...(1)$$

When it is stretched, length (l') increases 8 times and cross-sectional area (A') decreases eight times of previous.

Hence, $\quad l' = 8l$ and $A' = \frac{A}{8}$

$$\text{New resistance, } R' = \frac{\rho\,(8l)}{A/8} = 64\rho\left(\frac{l}{A}\right)$$

$$= 64 \times 10 \qquad \text{(from eq.(1))}$$

$$= 640\ \Omega$$

Q 23. A cylindrical rod is reformed to half of its original length keeping volume constant. If its resistance before this change were R, then the resistance after reformation of rod will be:

a. R
b. $R/4$
c. $3R/4$
d. $R/2$

Ans. (b) $R/4$

The resistance of rod before reformation

$$R_1 = R = \frac{\rho l_1}{\pi r_1^2} \qquad \left[\because R = \frac{\rho l}{A} = \frac{\rho l}{\pi r^2}\right]$$

Now, the rod is reformed such that

$$l_2 = \frac{l_1}{2}$$

$$\therefore \quad \pi r_1^2 l_1 = \pi r_2^2 l_2 \qquad (\because \text{Volume remains constant})$$

$$\text{or} \quad \frac{r_1^2}{r_2^2} = \frac{l_2}{l_1} \qquad ...(1)$$

Now, the resistance of the rod after reformation

$$R_2 = \frac{\rho l_2}{\pi r_2^2}$$

$$\therefore \quad \frac{R_1}{R_2} = \frac{\rho l_1}{\pi r_1^2} \Big/ \frac{\rho l_2}{\pi r_2^2} = \frac{l_1}{l_2} \times \frac{r_2^2}{r_1^2}$$

$$\text{or} \quad \frac{R_1}{R_2} = \frac{l_1}{l_2} \times \frac{l_1}{l_2} = \left(\frac{l_1}{l_2}\right)^2 = (2)^2 \qquad \text{(using eq. (1))}$$

$$\therefore \quad R_2 = \frac{R}{4}$$

Q 24. The conductivity of a metal decreases with the increase in temperature on account of: *(CBSE 2020)*

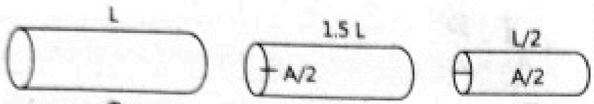
a. decrease in number density of electrons
b. decrease in resistivity
c. decrease in relaxation time
d. increase in mean free path

Ans. (c) decrease in relaxation time

T!P

Conductivity $\propto \frac{1}{\text{Resistance}} \propto$ *Relaxation time*

Q 25. The figure shows three cylindrical copper conductors along with their face areas and lengths. Rank them according to the current through them, greatest first when the same potential difference V is placed across their lengths.



(I) (II) (III)

a. $i_I = i_{II} = i_{III}$ b. $i_I > i_{II} > i_{III}$
c. $i_I < i_{II} < i_{III}$ d. $(i_I = i_{III}) < i_{II}$

Ans. (d) $(i_I = i_{III}) < i_{II}$

We know that, $R = \rho \frac{l}{A}$

$$\therefore \quad R_I = \rho \frac{L}{A} \quad ...(1)$$

$$R_{II} = \rho \frac{1.5L}{A/2} = 3\rho \frac{L}{A} \quad ...(2)$$

$$R_{III} = \rho \frac{L/2}{A/2} = \rho \frac{L}{A} \quad ...(3)$$

Using eqs. (1), (2) and (3), we can say that

$$R_{II} > (R_I = R_{III})$$

$$\therefore \quad (i_I = i_{III}) < i_{II}$$

From Ohm's law, we know that $V = IR$ when same potential difference is applied

$$I \propto \frac{1}{R}$$

Q 26. When there is an electric current through a conducting wire along its length, then an electric field must exist:

a. outside the wire but normal to it
b. outside the wire but parallel to it
c. inside the wire but parallel to it
d. inside the wire but normal to it

Ans. (c) inside the wire but parallel to it

As current is flowing through the wire along its length, it means charges are flowing along its length, therefore their must be some electric field parallel to the length of the wire.

Q 27. Which of the following characteristics of electrons determines the current in a conductor? *(NCERT EXEMPLAR)*

a. Drift velocity alone
b. Thermal velocity alone
c. Both drift velocity and thermal velocity
d. Neither drift nor thermal velocity

Ans. (a) Drift velocity alone

Q 28. Drift velocity v_d varies with the intensity of electric field as per the relation:

a. $v_d \propto E$ b. $v_d \propto \frac{1}{E}$
c. v_d = constant   d. $v_d \propto E^2$

Ans. (a) $v_d \propto E$

T!P

Drift velocity is given by $v_d = \frac{eE}{m}\tau$

Q 29. The unit of mobility is

a. ms^{-1} b. $ms^{-1}V$
c. $m^2V^{-1}s^{-1}$ d. $m^2V^{-1}s$

Ans. (c) $m^2V^{-1}s^{-1}$

T!P

Mobility, $\mu = \frac{v_d}{E} = \frac{m/s}{V/m}$

Q 30. A steady current flows in a metallic conductor of non-uniform cross-section. The quantity/quantities constant along the length of the conductor is/are:

a. current, electric field and drift speed
b. drift speed only
c. current and drift speed
d. current only

Ans. (d) current only

When a steady current flows through a metallic conductor of non-uniform cross-section, then drift velocity $= \frac{1}{enA}$

$$\Rightarrow \quad v_d \propto \frac{1}{A}$$

$$E = \frac{I}{\sigma A}$$

$$\Rightarrow \quad E \propto \frac{1}{A}$$

Both v_d and E change with A, only current constant as it does not depend on the area of the conductor.

Q 31. A charged particle having drift velocity of 7.5×10^{-4} ms^{-1} in electric field of 3×10^{-10} Vm^{-1}, mobility is:

a. $6.5 \times 10^6\ m^2V^{-1}s^{-1}$ b. $2.5 \times 10^6\ m^2V^{-1}s^{-1}$
c. $2.5 \times 10^4\ m^2V^{-1}s^{-1}$ d. $6.5 \times 10^4\ m^2V^{-1}s^{-1}$

Ans. (b) $2.5 \times 10^6\ m^2V^{-1}s^{-1}$

Mobility of charged particle

$$\mu = \frac{|v_d|}{E} = \frac{7.5 \times 10^{-4}}{3 \times 10^{-10}}$$

$$= 2.5 \times 10^6\ m^2V^{-1}s^{-1}$$

Q 32. The resistance of a metal wire increases with increasing temperature on account of: *(CBSE 2020)*

a. decrease in free electron density
b. decrease in relaxation time
c. increase in mean free path
d. increase in the mass of electron

Ans. (b) decrease in relaxation time

T!P

Resistance $\propto \frac{1}{\text{Relaxation time}}$

Q 33. The dimensions of mobility of charge carriers are:

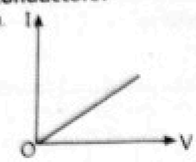
a. $[M^{-2}T^2A]$ b. $[M^{-1}T^2A]$
c. $[M^{-2}T^3A]$ d. $[M^{-1}T^3A]$

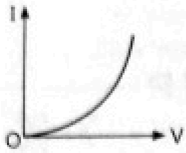
Ans. (b) $[M^{-1}T^2A]$

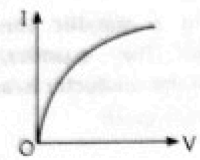
T!P

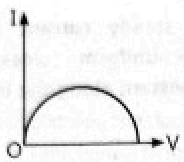
Mobility, $\mu = \frac{e\tau}{m} = [AT]\,[T]\,[M]^{-1} = [M^{-1}T^2A]$

Q 34. Which of the following *I-V* graph represents ohmic conductors?

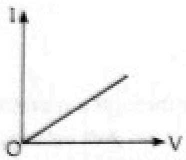
a. 

b. 

c. 

d. 

Ans. (a)



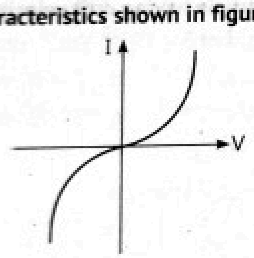
Ohm's law $V = IR$ is an equation of straight line. Hence *I-V* characteristics for ohmic conductors is also a straight line and its slope gives resistance of the conductor.

Q 35. Ohm's law is not applicable to:

a. dc circuits b. high currents
c. small resistors d. semi-conductors

Ans. (d) semi-conductors

Q 36. The *I-V* characteristics shown in figure represents:



a. ohmic conductors b. non-ohmic conductors
c. insulators d. superconductors

Ans. (b) non-ohmic conductors

Q 37. Ohm's law fails in:

a. Diode b. Thyristor
c. PN junction system d. All of these

Ans. (d) All of these

KNOWLEDGE BOOSTER

Ohm's law is not applicable to semiconductors because they do not obey Ohm's law, since I-V characteristics is a curved line instead of a straight line.

Q 38. Range of resistivity for metals is:

a. 10^{-6} Ωm to 10^{-4} Ωm b. 10^{-7} Ωm to 10^{-5} Ωm
c. 10^{-8} Ωm to 10^{-6} Ωm d. 10^{-9} Ωm to 10^{-7} Ωm

Ans. (c) 10^{-8} Ωm to 10^{-6} Ωm

Q 39. Which meterial is expected to have least resistivity?

a. Copper b. Lead c. Mercury d. Zinc

Ans. (a) Copper

Q 40. A copper wire is stretched to make it 0.2%. What is the percentage change in its resistivity?

a. 0.4% b. 2.0%
c. 4.0% d. None of these

Ans. (d) None of these

T!P

Resistivity is independent of shape and size of conductor.

Q 41. Arrange the following materials in increasing order of their resistivity:

Nichrome, Copper, Germanium, Silicon

a. Copper < Nichrome < Germanium < Silicon
b. Germanium < Copper < Nichrome < Silicon
c. Nichrome < Copper < Germanium < Silicon
d. Silicon < Nichrome < Germanium < Copper

Ans. (a) Copper < Nichrome < Germanium < Silicon

Materials	**Resistivity (ρ) (Ωm at 0°C)**
Copper (Cu)	1.7×10^{-8}
Nichrome (alloy of Ni, Fe, Cr)	100×10^{-8}
Germanium	0.46
Silicon	2300

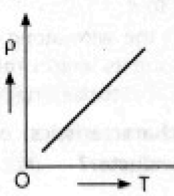
Q 42. The resistance of the fuse wire is:

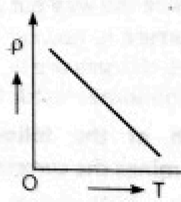
a. low b. moderate
c. zero d. very high

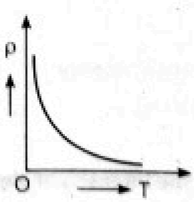
Ans. (d) very high

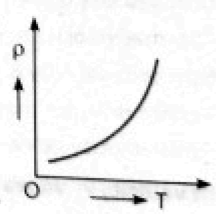
A fuse wire should melt a large current flows through it. Hence, it should have a very high resistance, so that very large amount of heat is produced due to which the fuse wire melts and breaks the connectivity of circuit from supply mains, because $H = I^2Rt \Rightarrow H \propto R$.

Q 43. The temperature (*T*) dependence of resistivity (ρ) of a semiconductor is represented by:

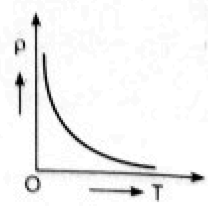
a. 

b. 

c. 

d. 

Ans. (c)



The resistivity of a semiconductor decreases with increase in temperature exponentially.

Q 44. We use alloy for making of resistors, because they have

Temp. coefficient	**Resistivity**
a. Low	Low
b. High	High
c. High	Low
d. Low	High

Ans. (a) Low, Low

Alloys have low resistivity and low temperature coefficiency.

Q 45. The temperature coefficient of resistance of an alloy used for making resistors is:

a. small and positive b. small and negative

c. large and positive d. large and negative

Ans. (a) small and positive

The temperature coefficient of resistance of an alloy used for making resistors is small and positive.

Q 46. The resistance of a heating element is 99 Ω at room temperature. What is the temperature of the element, if the resistance is found to be 116 Ω?

(Temperature coefficient of the material of the resistor is 1.7×10^{-4} °C^{-1})

a. 999.9°C b. 1005.3°C c. 1020.2°C d. 1037.1°C

Ans. (d) 1037.1°C

Here, $R_0 = 99\ \Omega, T_0 = 27°C$

$R_T = 116\ \Omega, \alpha = 1.7 \times 10^{-4}\ °C^{-1}$

∴ $R_T = R_0 [1 + \alpha (T - T_0)]$

∴ $\frac{R_T}{R_0} - 1 = \alpha (T - T_0)$

⇒ $\frac{116}{99} - 1 = \alpha (T - T_0)$

$$T - T_0 = \frac{1}{\alpha}\left[\frac{116 - 99}{99}\right] = \frac{17}{99\alpha} = \frac{1}{1.7 \times 10^{-4}} \times \frac{17}{99}$$

∴ $T - T_0 = \frac{10^5}{99} = 1010.10°C$

⇒ $T = 1010.1 + T_0 = 1010.1 + 27 = 1037.1°C$

Q 47. Identical piece of Ge and Cu are taken and cooled, then:

a. resistivity of both increases

b. resistivity of both decreases

c. resistivity of Cu increases and Ge decreases

d. resistivity of Cu decreases and Ge increases

Ans. (d) resistivity of Cu decreases and Ge increases

T!P

A piece of germanium (Ge) is a semiconductor while that of copper (Cu) is a metal.

For metals resistance decreases with increase in temperature while for semiconductor it increases.

Q 48. Which of the following is wrong? Resistivity of a conductor is:

a. independent of temperature

b. inversely proportional to temperature

c. independent of dimensions of conductor

d. less than resistivity of a semiconductor

Ans. (a) independent of temperature

Q 49. A wire has a resistance of 2.5 Ω at 28°C and a resistance of 2.9 Ω at 100°C. The temperature coefficient of resistivity of material of the wire is:

a. $1.06 \times 10^{-3}\ °C^{-1}$ b. $3.5 \times 10^{-2}\ °C^{-1}$

c. $2.22 \times 10^{-3}\ °C^{-1}$ d. $3.95 \times 10^{-2}\ °C^{-1}$

Ans. (c) $2.22 \times 10^{-3}\ °C^{-1}$

Here, $R_1 = 2.5\ \Omega, T_1 = 28°C$

$R_2 = 2.9\ \Omega$ and $T_2 = 100°C$

As $R_2 = R_1 [1 + \alpha (T_2 - T_1)]$

∴ $2.9 = 2.5 [1 + \alpha (100 - 28)]$

$\frac{2.9}{2.5} - 1 = 72\alpha$ or $\alpha = \frac{1}{72} \times \frac{2.9 - 2.5}{2.5}$

$= \frac{1}{72} \times \frac{0.4}{2.5} = 2.22 \times 10^{-3}\ °C^{-1}$

Q 50. Joule's law of heating effect can be expressed as:

a. $H = \frac{V^2}{R} t$ b. $H = \frac{I^2}{R} t$

c. $H = V^2 Rt$ d. $H = IRt$

Ans. (a) $H = \frac{V^2}{R} t$

Q 51. A current of 2 A flows in a wire offering a resistance of 10 Ω. Calculate the energy dissipated by the wire in 0.5 hours.

a. 72 Wh b. 72 kJ

c. 7200 J d. 72 kJh

Ans. (b) 72kJ

Here, $I = 2\text{A}, R = 10\ \Omega$

Energy dissipated $= I^2 Rt$

$= (2)^2 \times 10 \times (0.5 \times 3600)$

$= 72000$ J

$= 72$ kJ

Q 52. A bulb has a power of 200 W. What is the energy dissipated by it in 5 minutes?

a. 60 J b. 1000 J c. 60 kJ d. 1 kJ

Ans. (c) 60 kJ

Energy dissipated = Power × Time

$= 200 \times (5 \times 60)$

$= 60{,}000$ J $= 60$ kJ

Q 53. A boy has two spare light bulbs in his drawer. One is marked 240 V and 100 W and the other is marked 240 V and 60 W. He tries to decide which of the following assertions are correct?

a. The 60 W light bulb has more resistance and therefore burns less brightly

b. The 60 W light bulb has less resistance and therefore burns less brightly

c. The 100 W bulb has more resistance and therefore burns more brightly

d. The 100 W bulb has less resistance and therefore burns less brightly

Ans. (a) The 60 W light bulb has more resistance and therefore burns less brightly

When the same potential difference, that is the voltage, is applied as in houses.

$$\text{Power} = VI = \frac{V^2}{R}$$

The smaller resistance consumes greater power. Here, 100 W bulb has less resistance. It should glow more brightly. The 60 W bulb has more resistance and therefore statement (a) is correct.

Q 54. Two resistors R_1 and R_2 of 4 Ω and 6 Ω are connected in parallel across a battery. The ratio of power dissipated in them, $P_1 : P_2$ will be: *(CBSE 2020)*

a. 4 : 9 b. 3 : 2
c. 9 : 4 d. 2 : 3

Ans. (b) 3 : 2

$$\frac{P_1}{P_2} = \frac{\frac{V^2}{R_1}}{\frac{V^2}{R_2}}$$

$$\frac{P_1}{P_2} = \frac{R_2}{R_1} \Rightarrow \frac{6}{4} \Rightarrow 3:2$$

Q 55. Four wires of the same diameter are connected, in turn, between two points maintained at a constant potential difference. Their resistivities and lengths are; ρ and L (wire 1), 1.2 ρ and 1.2 L (wire 2), 0.9 ρ and 0.9 L (wire 3) and ρ and 1.5 L (wire 4). Rank the wires according to the rates at which energy is dissipated as heat, greatest first:

a. 4 > 3 > 1 > 2 b. 4 > 2 > 1 > 3
c. 1 > 2 > 3 > 4 d. 3 > 1 > 2 > 4

Ans. (d) 3 > 1 > 2 > 4

Resistance of a wire, $R = \frac{\rho l}{A}$

Rate of energy dissipated as heat is $H = \frac{V^2}{R} = \frac{V^2 A}{\rho l}$

For wire 1, $H_1 = \frac{V^2 A}{\rho L}$

For wire 2, $H_2 = \frac{V^2 A}{(1.2\rho)(1.2L)} = \frac{0.694 V^2 A}{\rho L} = 0.694 H_1$

For wire 3, $H_3 = \frac{V^2 A}{(0.9\rho)(0.9L)} = \frac{1.23 V^2 A}{\rho L} = 1.23 H_1$

For wire 4, $H_4 = \frac{V^2 A}{(\rho)(1.5L)} = \frac{0.666 V^2 A}{\rho L} = 0.666 H_1$

$\therefore H_3 > H_1 > H_2 > H_4$

Q 56. A heater coil is rated 100 W, 200 V. It is cut into two identical parts. Both parts are connected together in parallel, to the same source of 200 V. The energy liberated per second in the new combination is:

a. 100 J b. 200 J c. 300 J d. 400 J

Ans. (d) 400 J

Resistance of heater coil,

$$R = \frac{V^2}{P} = \frac{200 \times 200}{100} = 400\ \Omega$$

Resistance of either half part = 200 Ω

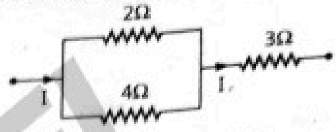
Equivalent resistance when both parts are connected in parallel,

$$R' = \frac{200 \times 200}{200 + 200} = 100\ \Omega$$

Energy liberated per second when combination is connected to a source of 200 V,

$$= \frac{V^2}{R'} = \frac{200 \times 200}{100} = 400\ J$$

Q 57. In the circuit shown in figure, heat developed across 2 Ω, 4 Ω and 3 Ω resistances are in the ratio of:



a. 2 : 4 : 3 b. 8 : 4 : 12
c. 4 : 8 : 27 d. 8 : 4 : 27

Ans. (d) 8 : 4 : 27

Current through 2 Ω, resistor $I_1 = \frac{2I}{3}$

Heat produced per second,

$$H_1 = I_1^2 \times 2 = \left(\frac{2I}{3}\right)^2 \times 2 = \frac{8I^2}{9}$$

Current through 4 Ω, resistor $I_2 = \frac{I}{3}$

Heat produced per second

$$H_2 = I_2^2 \times 4 = \left(\frac{I}{3}\right)^2 \times 4 = \frac{4I^2}{9}$$

Current through 3 Ω, resistor = I

Heat produced $H_3 = I^2 \times 3$

$$= 3I^2 = \frac{27I^2}{9}$$

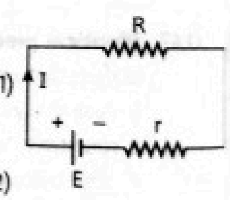
$\therefore H_1 : H_2 : H_3 = 8 : 4 : 27$

Q 58. A cell of emf E is connected with an external resistance R, the potential difference across cell is V. The internal resistance of cell will be:

a. $\frac{(E-V)R}{E}$ b. $\frac{(E-V)R}{V}$
c. $\frac{(V-E)R}{E}$ d. $\frac{(V-E)R}{E}$

Ans. (b) $\frac{(E-V)R}{V}$

Current drawn from cell,



$$I = \frac{E}{R+r} \quad \text{...(1)}$$

From Ohm's law, $V = IR$

$$\Rightarrow \quad I = \frac{V}{R} \quad \text{...(2)}$$

From eqs. (1) and (2), we have

$$\frac{V}{R} = \frac{E}{R+r}$$

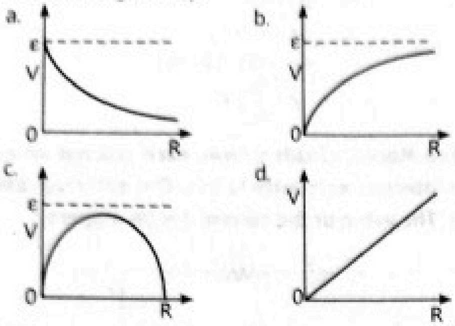
$$\Rightarrow \quad r = \left(\frac{E-V}{V}\right)R$$

Q 59. About internal resistance of a cell, the correct statement is that it is:

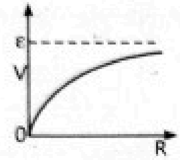
a. Constant for a given cell
b. Infinite
c. Finite and its value decreases with increase of time of use
d. Finite and its value increases with increase of time of use

Ans. (d) Finite and its value increases with increase of time of use

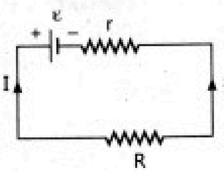
Q 60. A cell having an emf ε and internal resistance r is connected across a variable external resistance R. As the resistance R is increased, the plot of potential difference V across R is given by:



Ans. (b)



Current in the circuit, $I = \frac{\varepsilon}{R+r}$



Potential difference across R,

$$V = IR = \left(\frac{\varepsilon}{R+r}\right)R = \frac{\varepsilon}{\left(1+\frac{r}{R}\right)}$$

When $R = 0, V = 0$ or $R = \infty, V = \varepsilon$

Q 61. A battery of emf 15 V and internal resistance of 4 Ω is connected to a resistor. If the current in the circuit is 2 A and the circuit is closed. Resistance of the resistor and terminal voltage of the battery will be:

a. 2.5 Ω, 6 V b. 3.5 Ω, 6 V
c. 2.5 Ω, 7 V d. 3.5 Ω, 7 V

Ans. (d) 3.5 Ω, 7 V

Given, $\varepsilon = 15$ V, $r = 4\ \Omega$, $I = 2$ A

Now, for resistance of the resistors

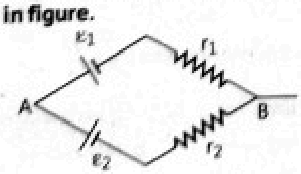
$$\varepsilon - Ir = V = IR; 15 - 2 \times 4 = 2 \times R; 15 - 8 = 2R$$

$$R = \frac{7}{2} = 3.5\ \Omega$$

Terminal voltage of battery,

$$V = IR = 2 \times 3.5 = 7\text{ V}$$

Q 62. Two batteries of emf ε_1 and ε_2 ($\varepsilon_2 > \varepsilon_1$) and internal resistances r_1 and r_2 respectively are connected in parallel as shown in figure. *(NCERT EXEMPLAR)*



a. The equivalent emf ε_{eq} of the two cells is between ε_1 and ε_2, *i.e.*, $\varepsilon_1 < \varepsilon_{eq} < \varepsilon_2$
b. The equivalent emf ε_{eq} is smaller than ε_1
c. The ε_{eq} is given by $\varepsilon_{eq} = \varepsilon_1 + \varepsilon_2$ always
d. ε_{eq} is independent of internal resistances r_1 and r_2

Ans. (a) The equivalent emf ε_{eq} of the two cells is between ε_1 and ε_2, *i.e.*, $\varepsilon_1 < \varepsilon_{eq} < \varepsilon_2$.

Q 63. What is the internal resistance of a 2.1 V cell which gives a current of 0.2 A through a resistance of 10 Ω?

a. 1 Ω b. 0.5 Ω c. 2 Ω d. 3 Ω

Ans. (b) 0.5 Ω

Current drawn from the cell,

$$I = \frac{\varepsilon}{R+r}$$

$$0.2 = \frac{2.1}{(10+r)}$$

$$2 + 0.2r = 2.1$$

$$0.2r = 0.1$$

$$r = 0.5\ \Omega$$

Q 64. A cell of emf E and internal resistance r is connected across a resistance R. If internal resistance is equal to R, then the potential difference between the terminals of the cell must be:

a. E b. $\frac{E}{2}$ c. $\frac{E}{4}$ d. $\frac{3E}{2}$

Ans. (b) $\frac{E}{2}$

We know that, $V = \frac{ER}{R+r}$

$$= \frac{ER}{R+R} \quad [\because R = r]$$

$$= \frac{ER}{2R} = \frac{E}{2}$$

Q 65. Two batteries of emfs 2 V and 1 V of internal resistances 1 Ω and 2 Ω respectively are connected in parallel. The effective emf of the combination is:

a. $\frac{3}{2}$ V b. $\frac{5}{3}$ V c. $\frac{3}{5}$ V d. 2 V

Ans. (d) 2 V

As, in parallel combination of cells,

$$E_{eff} = E_{max} = 2\text{ V}$$

Q 66. Current provided by a battery is maximum when

a. internal resistance is equal to external resistance
b. internal resistance is greater than external resistance
c. internal resistance is less than external resistance
d. None of the above

Ans. (a) internal resistance is equal to external resistance

Current provided by the battery is maximum when internal resistance equals to external resistance.

Q 67. A cell supplies a current of 0.9 A through a 2 Ω resistor and a current of 0.3 A through 7 Ω resistor. The internal resistance of the cell is:

a. 2.0 Ω b. 1.5 Ω
c. 1.0 Ω d. 0.5 Ω

Ans. (d) 0.5 Ω

Current drawn from the cell,

$$I = \frac{\varepsilon}{R+r}$$

$$0.9 = \frac{\varepsilon}{2+r}$$

or $\varepsilon = 0.9(2+r)$ ...(1)

Similarly, $0.3 = \frac{\varepsilon}{7+r}$

or $\varepsilon = 0.3(7+r)$ ...(2)

From eqs. (1) and (2), we get

$0.9(2+r) = 0.3(7+r)$

$3(2+r) = 7+r$

$\Rightarrow 6+3r = 7+r$

$\Rightarrow 2r = 1$

or $r = 0.5\ \Omega$

Q 68. The battery of a trunk has an emf of 24 V. If the internal resistance of the battery is 0.8 Ω. What is the maximum current that can be drawn from the battery?

a. 30 A b. 32 A
c. 33 A d. 34 A

Ans. (a) 30 A

Here, $\varepsilon = 24$ V and $r = 0.8\ \Omega$

For the maximum current from the battery

$\varepsilon = Ir$ $(\because R = 0)$

$\therefore I = \frac{\varepsilon}{r} = \frac{24}{0.8} = 30$ A

Q 69. A battery having 12 V emf and internal resistance 3 Ω is connected to a resistor. If the current in the circuit is 1 A, then the resistance of resistor and lost voltage of the battery when circuit is closed will be:

a. 7 Ω, 7 V b. 8 Ω, 8 V
c. 9 Ω, 9 V d. 9 Ω, 10 V

Ans. (c) 9 Ω, 9 V

Here, $\varepsilon = 12$ V, $r = 3\ \Omega$, $I = 1$ A, $V = IR = \varepsilon - Ir$

$\therefore R = \frac{\varepsilon - Ir}{I} = \frac{12 - 1\times 3}{1}$

$= 12 - 3 = 9\ \Omega$

and $V = IR = 1 \times 9 = 9$ V

Q 70. Five cells each of emf *E* and resistance *r* are connected in series. Due to oversight one cell is connected wrongly. The equivalent emf and internal resistance of the combination is:

a. $5E$ b. $2E$
c. $3E$ d. $4E$

Ans. (c) $3E$

Emf of the 5 identical cells of emf E are connected in series. Then the net emf of the combination should be $5E$. But, one of them is wrongly connected *i.e.*, with its polarity reversed. This cell will cancel the emf of another cell. Thus, equivalent number of cells in the combination $= E + E + E + E - E = 3E$. Net emf of the combination $= 3E$.

Q 71. Three identical cells, each of 4 V and internal resistance *r*, are connected in series to a 6Ω resistor. If the current flowing in the circuit is 2 A. The internal resistance of each cell is:

a. 0.11 Ω b. 0 Ω
c. 0.12 Ω d. 1.1 Ω

Ans. (b) 0 Ω

Total emf $= 3 \times 4 = 12$ V

Total resistance $= 6 + 3r$

Current in the circuit = 2 A

Using ohms law,

$2 = \frac{12}{(6+3r)}$

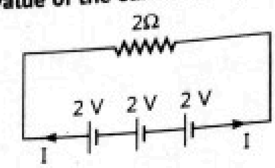
$2(6+3r) = 12$

$12 + 6r = 12$

$6r = 12 - 12 = 0$

$r = \frac{0}{6} = 0$

Q 72. In the electric circuit shown, each cell has an emf of 2 V and internal resistance is 1 Ω. The external resistance is 2 Ω. The value of the current *I* is (in ampere):



a. 2 b. 1.25
c. 0.4 d. 1.2

Ans. (d) 1.2

The current $= \frac{\text{net emf}}{\text{net resistance}}$

$I = \frac{2+2+2}{1+1+1+2}$

$= \frac{6}{5}$

$= 1.2$ A

Q 73. If *n* identical cells of emf ε and internal resistance *r* are connected in series, then the total emf and equivalent internal resistance of the combination will be:

a. $\varepsilon, \frac{r}{n}$ b. ε, nr c. $n\varepsilon, \frac{r}{n}$ d. $n\varepsilon, nr$

Ans. (d) $n\varepsilon, nr$

In series combination,

equivalent emf $= n\varepsilon$

Equivalent internal resistance $= nr$

Q 74. If *n* cells each of emf ε and internal resistance *r* are connected in parallel, then the total emf and internal resistances will be:

a. $\varepsilon, \frac{r}{n}$ b. ε, nr c. $n\varepsilon, \frac{r}{n}$ d. $n\varepsilon, nr$

Ans. (a) $\varepsilon, \frac{r}{n}$

In parallel combination,

Equivalent emf $= \varepsilon$

Equivalent internal resistance $= \frac{r}{n}$

Q 75. The basic laws for analyzing an electric circuit are:

a. Einstein's theory b. Newton's laws
c. Kirchhoff's laws d. Faraday's laws

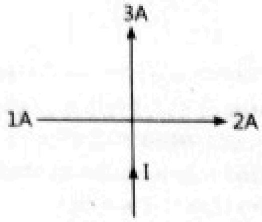
Ans. (c) Kirchhoff's laws

Q 76. Kirchhoff's first and second laws are respectively based on law of conservation of:

a. momentum and energy b. charge and energy
c. mass and energy d. None of the above

Ans. (b) charge and energy

Q 77. The value of current I in figure is:



a. 4 A
b. 6 A
c. 3 A
d. 5 A

Ans. (a) 4 A

From Kirchhoff's first law, in an electric circuit, the algebraic sum of the currents meeting at any junction is zero.

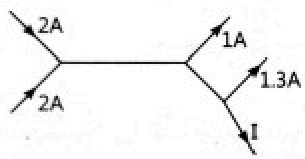
i.e., $\Sigma i = 0$

Taking inward direction of current as positive and outward as negative, we have

$$1\text{A} - 3\text{ A} - 2\text{ A} + I = 0$$

$$\Rightarrow \quad I = 4\text{ A}$$

Q 78. Figure shows currents in a part of an electric circuit, then current I is:



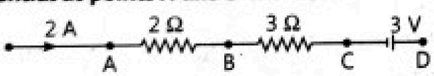
a. 1.7 A
b. 3.7 A
c. 1.3 A
d. 1 A

Ans. (a) 1.7 A

Applying Kirchhoff's first law.

$$I = 2 + 2 - 1 - 1.3 = 1.7\text{ A}$$

Q 79. In the given circuit the potential at point B is zero, the potential at points A and D will be:



a. $V_A = 4$ V; $V_D = 9$ V
b. $V_A = 3$ V; $V_D = 4$ V
c. $V_A = 9$ V; $V_D = 3$ V
d. $V_A = 4$ V; $V_D = 3$ V

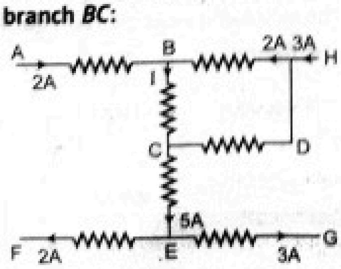
Ans. (d) $V_A = 4$ V; $V_D = 3$ V

$$V_A - V_B = 2 \times 2 = 4\text{ V}$$

$$\therefore V_A - 0 = 4\text{ V} \Rightarrow V_A = 4\text{ V} \qquad [\because V_B = 0]$$

As point D is connected to positive terminal of battery of emf 3 V and $V_B = 0$, $\therefore V_D = 3$ V

Q 80. In the circuit diagram, calculate the electric current through branch BC:



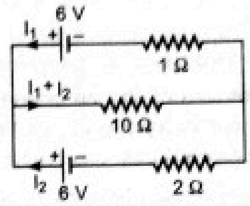
a. 4 A
b. 2 A
c. 5 A
d. 10 A

Ans. (a) 4 A

Applying KCL at point B,

$$I = 2\text{ A} + 2\text{ A} = 4\text{ A}$$

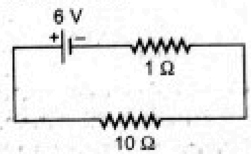
Q 81. Electric current through resistance 10 Ω, in the given circuit is:



a. 0 A
b. 0.5 A
c. 6/11 A
d. 2 A

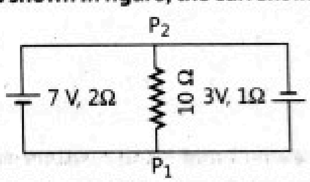
Ans. (c) 6/11 A

On simplifying the circuit.



$$I = \frac{V}{R} = \frac{6}{11}\text{ A}$$

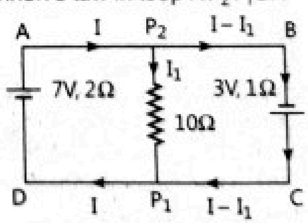
Q 82. A 7 V battery with internal resistance 2 Ω and a 3 V battery with internal resistance 1 Ω are connected to a 10 Ω resistor as shown in figure, the current in 10 Ω resistor is:



a. 0.27 A
b. 0.31 A
c. 0.031 A
d. 0.53 A

Ans. (c) 0.031 A

Using Kirchhoff's law in loop AP_2P_1DA



$$\therefore \quad 10I_1 + 2I - 7 = 0$$

$$10I_1 + 2I = 7 \qquad ...(1)$$

Using Kirchhoff's law in loop $P_2P_1CBP_2$

$$-3 + 1(I - I_1) - 10I_1 = 0$$

$$I - 11I_1 = 3; I = 3 + 11I_1 \qquad ...(2)$$

From eqs. (1) and (2), we get

$$10I_1 + 2(3 + 11I_1) = 7$$

$$\Rightarrow \quad 10I_1 + 6 + 22I_1 = 7$$

$$\therefore \quad 32I_1 = 1; I_1 = \frac{1}{32} = 0.031\text{ A}$$

Q 83. In a balanced Wheatstone's network, the resistances in arms Q and S are interchanged. As a result of this:

a. galvanometer and the cell must be interchanged to balance
b. galvanometer shows zero deflection
c. network is not balanced
d. network is still balanced

Ans. (c) network is not balanced

Q 84. Wheatstone bridge works on the principle of ....

a. full deflection b. partial deflection
c. no deflection d. null deflection

Ans. (d) null deflection

Q 85. WSB experiment is most sensitive, when:

a. all four resistance are approximately equal
b. one of the resistance is very high as compare to others
c. one of the resistance is very low as compare to others
d. any two resistances are equal to infinity

Ans. (a) all four resistance are approximately equal

Under balanced condition $\frac{P}{Q} = \frac{R}{S}$.

Q 86. In a Wheatstone's bridge, all the four arms have equal resistance R. If resistance of the galvanometer arm is also R, then equivalent resistance of the combination is:

a. R b. $2R$
c. $\frac{R}{2}$ d. $\frac{R}{4}$

Ans. (a) R

As $\frac{P}{Q} = \frac{R}{S}$, so resistance of the galvanometer can be omitted (P and Q are in series = $2R$, R and S are also in series = $2R$). Now the equivalent resistance = $\frac{2R \times 2R}{4R} = R$.

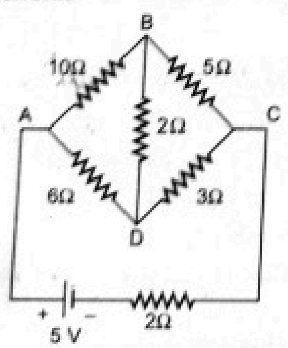
Q 87. In a Wheatstone bridge if the battery and galvanometer are interchanged, then the deflection in galvanometer will:

a. change in previous direction
b. not change
c. change in opposite direction
d. None of the above

Ans. (b) not change

The deflection in galvanometer will not be changed due to interchange of battery and the galvanometer.

Q 88. Determine the electric current through branch BD of the electric network:



a. 0.6 A b. 0 A
c. 1 A d. 10 A

Ans. (b) 0 A $\frac{P}{Q} = \frac{R}{S} \Rightarrow \frac{10}{5} = \frac{6}{3}$

As, bridge is balanced, current will be zero.

Q 89. Four resistances of 3 Ω, 3 Ω, 3 Ω and 4 Ω respectively are used to a form of a Wheatstone bridge. The 4 Ω resistance is short circuited with a resistance R in order to get bridge balanced. The value of R will be:

a. 10 Ω b. 11 Ω
c. 12 Ω d. 13 Ω

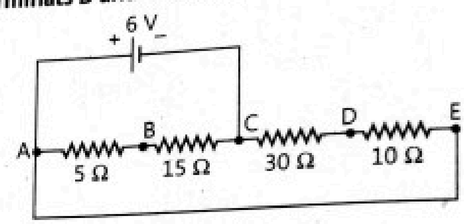
Ans. (c) 12 Ω

The bridge will be balanced when the shunted resistance is of the value of 3 Ω

$\therefore \quad 3 = \frac{4 \times R}{4 + R};\ 12 + 3R = 4R$

$\therefore \quad R = 12\ \Omega$

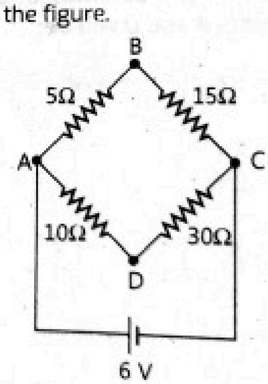
Q 90. Four resistors are connected as shown in the figure. A 6 V battery of negligible resistance is connected across terminals A and C. The potential difference across terminals B and D will be:



a. Zero b. 1.5 V
c. 2 V d. 3 V

Ans. (a) Zero

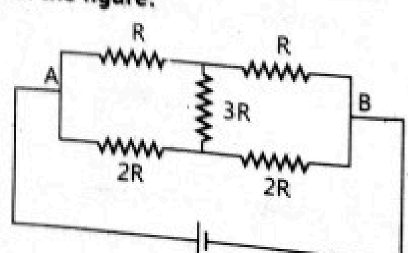
The given figure is a circuit of balanced Wheatstone bridge as shown in the figure.



Points B and D would be at the same potential.

i.e., $V_B - V_D = 0$ V

Q 91. Consider the following statements regarding the network shown in the figure:



1. The equivalent resistance of the network between points A and B is $\left(\frac{4}{3}R\right)$.

2. The current in resistor $3R$ is zero.

3. The potential difference across R is equal to the potential difference across $2R$.

Which of the above statement(s) is/are correct?

a. 1 only b. 2 only
c. 2 and 3 d. 1, 2 and 3

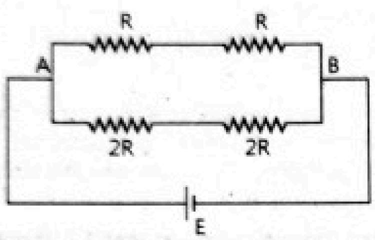
Ans. (d) 1, 2 and 3

The given network represent a Wheatstone bridge

$$\because \quad \frac{R}{2R} = \frac{R}{2R}$$

The resistance $3R$ is ineffective.

The equivalent circuit reduces to the circuit shown in the figure.



Equivalent Resistance,

$$R_{eq} = \frac{2R \times 4R}{2R + 4R} = \frac{8R^2}{6R} = \frac{4R}{3}$$

So, option (1) is correct.

As Wheatstone bridge is balanced, no current flows through $3R$, *i.e.*, current in $3R$ is zero.

So, option (2) is correct.

Voltage across parallel resistances is same, so option (3) is also correct.

Q 92. Meter bridge is application of:

a. Kirchhoff's current law
b. Kirchhoff's voltage law
c. balance Wheatstone bridge
d. Both a. and b.

Ans. (c) balance Wheatstone bridge

Q 93. The resistances in left and right gap of a meter bridge are 20 Ω and 30 Ω respectively. When the resistance in the left gap is reduced to half its value, the balance point shifts by:

a. 15 cm to the right b. 15 cm to the left
c. 20 cm to the right d. 20 cm to the left

Ans. (b) 15 cm to the left

Using $$\frac{R_1}{l} = \frac{R_2}{100 - l} \quad ...(1)$$

Put $R_1 = 20\ \Omega$ and $R_2 = 30\ \Omega$ in eq. (1), we get

$$\frac{20}{l} = \frac{30}{100 - l}$$

$$\Rightarrow \quad 2000 - 20l = 30l$$

$$\Rightarrow \quad 50l = 2000$$

$$\Rightarrow \quad l = 40 \text{ cm}$$

Let the new balance point lies at a distance l'.

Put $R_1 = 10\ \Omega \left(\frac{20}{2}\right)$ and $R_2 = 30\ \Omega$ in eq. (1), we get

$$\frac{10}{l'} = \frac{30}{100 - l'}$$

$$\Rightarrow \quad 1000 - 10l' = 30l'$$

$$\Rightarrow \quad 40l' = 1000$$

$$\Rightarrow \quad l' = 25 \text{ cm}$$

As $l' < l$, so balance point shift towards left.

Shift in balance point $= l - l' = 40 - 25 = 15$ cm

Q 94. A resistance R is to be measured using a meter bridge. Student chooses the standard resistance S to be 100 Ω. He finds the null point at $l_1 = 2.9$ cm. He is told to attempt to improve the accuracy. Which of the following is a useful way? *(NCERT EXEMPLAR)*

a. He should measure l_1 more accurately
b. He should change S to 1000 Ω and repeat the experiment
c. He should change S to 3 Ω and repeat the experiment
d. He should give up hope of a more accurate measurement with a meter bridge

Ans. (c) He should change S to 3 Ω and repeat the experiment

As the meter bridge is balanced,

$$\therefore \quad \frac{R}{S} = \frac{l_1}{(100 - l_1)} \text{ or } R = \frac{Sl_1}{(100 - l_1)}$$

$$= \frac{(100\ \Omega)(2.9 \text{ cm})}{(100 - 2.9) \text{ cm}} \approx 3\ \Omega$$

The accuracy of measuring R can be improved, if S and R are of the same order, *i.e.*, S should be changed to 3 Ω.

Q 95. In a meter bridge experiment, the ratio of the left gap resistance to right gap resistance is 2 : 3, the balance point from left is:

a. 60 cm b. 50 cm c. 40 cm d. 20 cm

Ans. (c) 40 cm

$$\frac{P}{Q} = \frac{l_1}{100 - l_1} \text{ or } \frac{2}{3} = \frac{l_1}{100 - l_1}$$

or $$5l_1 = 200 \text{ or } l_1 = 40 \text{ cm}$$

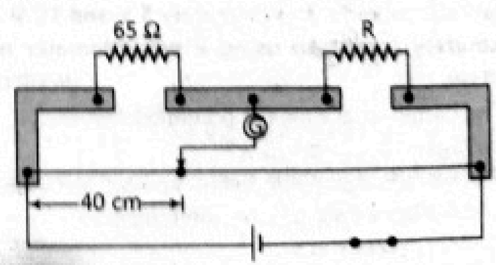
Q 96. In a metre bridge experiment, resistance box (with $R = 2\ \Omega$) is connected in the left gap and the unknown resistance S in the right gap. If balancing length be 40 cm, calculate value of S.

a. 2 Ω b. 3 Ω c. 4 Ω d. 2.5 Ω

Ans. (b) 3 Ω

$$\frac{2}{40} = \frac{S}{100 - 40} \Rightarrow S = 3\ \Omega$$

Q 97. What is the value of unknown resistance R, if galvanometer shows null deflection in the given meter bridge set up?



a. 97.5 Ω b. 105 Ω
c. 150 Ω d. 110 Ω

Ans. (a) 97.5 Ω

For null deflection in meter bridge,

$$\frac{R_1}{R_2} = \frac{l}{(100 - l)}$$

$$\therefore \quad \frac{65}{R} = \frac{40}{100 - 40} = \frac{40}{60}$$

$$R = 65 \times \frac{60}{40} = 97.5\ \Omega$$

Q 98. A potentiometer can measure emf of a cell because: *(CBSE 2020)*

a. the sensitivity of potentiometer is large
b. no current is drawn from the cell at balance
c. no current flows in the wire of potentiometer at balance
d. internal resistance of cell is neglected

Ans. (c) no current flows in the wire of potentiometer at balance

Q 99. For measurement of potential difference, a potentiometer is preferred over voltmeter because:

a. potentiometer is more sensitive than voltmeter
b. the resistance of potentiometer is less than voltmeter
c. potentiometer is cheaper than voltmeter
d. potentiometer does not take current from the circuit

Ans. (d) potentiometer does not take current from the circuit

Q 100. With a certain cell, the balance point is obtained at 65 cm from the end of a potentiometer wire. With another cell whose emf differs from that of the first by 0.1 V, the balance point is obtained at 60 cm. Then the emf of each cell is:

a. 1.2 V and 1.5 V respectively
b. 2.1 V and 2.2 V respectively
c. 1.3 V and 1.2 V respectively
d. 5.1 V and 5.2 V respectively

Ans. (c) 1.3 V and 1.2 V respectively

We know that,

$$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$

According to question, $E_2 = E_1 - 0.1$

$$\therefore \quad \frac{E_1}{E_1 - 0.1} = \frac{65}{60}$$

$$\frac{E_1}{E_1 - 0.1} = \frac{13}{12}$$

$$12E_1 = 13E_1 - 1.3$$

$$E_1 = +1.3\ V$$

$$E_2 = 1.3 - 0.1 = 1.2\ V$$

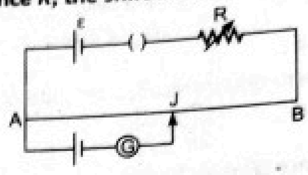
Q 101. Two cells of emf's approximately 5 V and 10 V are to be accurately compared using a potentiometer of length 400 cm. *(NCERT EXEMPLAR)*

a. The battery that runs the potentiometer should have voltage of 8 V
b. The battery of potentiometer can have a voltage of 15 V and R adjusted so that the potential drop across the wire slightly exceeds 10 V
c. The first portion of 50 cm of wire itself should have potential drop of 10 V
d. Potentiometer is usually used for comparing resistances and not voltages

Ans. (b) The battery of potentiometer can have a voltage of 15 V and R adjusted so that the potential drop across the wire slightly exceeds 10 V

The balance point can be obtained only if the potential difference across the wire is greater than the emf's to be compared (or measured). Therefore, option (b) is correct.

Q 102. AB is a wire of potentiometer with the increase in the value of resistance R, the shift in the balance point J will be:



a. towards B
b. towards A
c. remains constant
d. first towards B, then back towards A

Ans. (a) towards B

Due to increase in resistance R the current through the wire will decrease and hence the potential gradient also decreases, which results in increase in balancing length. So J will shift towards B.

Q 103. In a potentiometer a cell of emf 1.5 V gives a balanced point at 32 cm length of the wire. If the cell is replaced by another cell, then the balance point shifts to 65.0 cm, then the emf of second cell is:

a. 3.05 V b. 2.05 V
c. 4.05 V d. 6.05 V

Ans. (a) 3.05 V

Here, in the balance condition of potentiometer

$$\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2}$$

or $\varepsilon_1 = 1.5\ V,\ l_1 = 32\ cm,\ l_2 = 65\ cm$

$$\therefore \quad \varepsilon_2 = \varepsilon_1 \times \frac{l_2}{l_1} = 1.5 \times \frac{65}{32} = 3.05\ V$$

Q 104. For a cell of emf 2 V, a balance is obtained for 50 cm of the potentiometer wire. If the cell is shunted by a 2 Ω resistor and the balance is obtained across 40 cm of the wire, then the internal resistance of the cell is:

a. 1 Ω b. 0.5 Ω
c. 1.2 Ω d. 2.5 Ω

Ans. (b) 0.5 Ω

$$r = R\left(\frac{l_1 - l_2}{l_2}\right) = 2 \times \left(\frac{50 - 40}{40}\right) = 0.5\ \Omega$$

Q 105. In a potentiometer the balancing with a cell is at length of 220 cm. On shunting the cell with a resistance of 3 Ω balance length becomes 130 cm. What is the internal resistance of this cell?

a. 4.5 Ω b. 7.8 Ω
c. 6.3 Ω d. 2.08 Ω

Ans. (d) 2.08 Ω

Here, $l_1 = 220\ cm,\ l_2 = 130\ cm,\ R = 3\ \Omega$

∴ Internal resistance,

$$r = \left(\frac{l_1 - l_2}{l_2}\right) R = \left(\frac{220 - 130}{130}\right) \times 3 = 2.08\ \Omega$$

Assertion and Reason Type Questions

Directions (Q.Nos. 106 to 133): In the following questions, astatement of Assertion (A) is followed by a statement of Reason (R). Mark the correct choice as:

a. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A)
b. Both Assertion (A) and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A)
c. Assertion (A) is true but Reason (R) is false
d. Assertion (A) is false and Reason (R) is also false

Q 106. Assertion (A): In a simple battery circuit the point of lowest potential is positive terminal of the battery.

Reason (R): The current flows towards the point of the higher potential as it flows in such a circuit from the negative to the positive terminal.

Ans. (d) It is quite clear that in a battery circuit, the point of lowest potential is the negative terminal of the battery and the current flows from higher potential to lower potential.

Q 107. Assertion (A): Electrons which constitute the current are negatively charged.

Reason (R): Current carrying wire is negatively charged.

Ans. (c) Electrons that constitute current are negatively charged. A wire carrying current is not charged. Inside the wire the number of electrons equal to the number of protons, at any instant. Therefore the conductor is neutral. The current in the conductor is due to the flow of electrons from the negative terminal to the positive terminal.

Q 108. Assertion (A): Current can be represented with an arrow.

Reason (R): Current is a vector quantity.

Ans. (c) Current is a scalar quantity. Although we represent current with an arrow.

Q 109. Assertion (A): The current in a wire is due to flow of free electrons in a definite direction.

Reason (R): A current carrying wire should have non-zero charge.

Ans. (c) The current in a wire is due to flow of free electrons in a definite direction. But the number of protons in the wire at any instant is equal to number of electrons and charge on electrons is equal and opposite to that of proton. Hence, net charge on the wire is zero.

Q 110. Assertion (A): Electric field outside the conducting wire which carries a constant current is zero.

Reason (R): Net charge on conducting wire is zero.

Ans. (a) When current flows through a conductor, it always remains uncharged, hence no electric field is produced outside it.

Q 111. Assertion (A): There is no current in the metals in the absence of electric field.

Reason (R): Motion of free electron is random.

Ans. (a) It is clear that **electrons move in all directions** haphazardly in metals. When an electric field is applied, each free electron acquire a drift velocity. There is a net flow of charge, which constitute current. In the absence of electric field this is impossible and hence, there is no current.

Q 112. Assertion (A): Current flows in a conductor only when there is an external electric field within the conductor.

Reason (R): The drift velocity of the electrons is directly proportional to the electric field.

Ans. (a) In the absence of electric field, the electrons move randomly in all directions. Hence, there is no net motion of electrons and no current flow in the conductor. But in the presence of electric field, electrons moves in a particular direction. Each electron experiences a force in the direction opposite to that of the electric field and moves from the negative end to the positive end of the conductor. Thus there is a current flow.

The drift velocity, $\vec{v}_d = -\frac{e}{m}\vec{E}\tau$ i.e., $\vec{v}_d \propto \mu\vec{E}$.

Q 113. Assertion (A): Bending a wire does not effect electrical resistance.

Reason (R): Resistance of wire is proportional to resistivity of material.

Ans. (a) Resistance of wire $R = \rho\frac{l}{A}$ where ρ is resistivity of material which does not depend on the geometry of wire. Since, when wire banded, resistivity, length and area of cross-section do not change, therefore resistance of wire also remain same.

Q 114. Assertion (A): The resistance of a conductor decreases with increase in cross-sectional area.

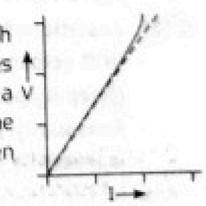
Reason (R): On increasing the cross-sectional area of a conductor, more current will flow through the conductor.

Ans. (a) Increasing the cross-sectional area increases the space available for electrons to flow, which decreases the resistance of the conductor.

Q 115. Assertion (A): For good conductors, the I-V graph is a perfect straight line inclined to current axis.

Reason (R): By Ohm's law, voltage across the ends of a conductor is directly proportional to the resistance of the conductor.

Ans. (d) The given graph shows the V-I graph of a good conductor. Ohm's law states that, current flowing through a conductor is directly proportional to the voltage between the ends of a given conductor, i.e., $V \propto I$,



or $V = RI$

where, the constant of proportionality R is called the resistance of the conductor.

Q 116. Assertion (A): The drift velocity of electrons in a metallic wire will decrease, if the temperature of the wire is increased.

Reason (R): On increasing temperature, conductivity of metallic wire decreases.

Ans. (b) On increasing temperature of wire, the kinetic energy of free electrons increase and so they collide more rapidly with each other and hence their drift velocity decreases. Also when temperature increases, resistivity increase and resistivity is inversely proportional to conductivity of material.

Q 117. Assertion (A): Drift velocity of electrons is independent of time.

Reason (R): Electrons are accelerated in the presence of electric field.

Ans. (b) Drift velocity is the average velocity of electrons in presence of electric field, which is independent of time.

Q 118. Assertion (A): The electric bulbs glows immediately when switch is on.

Reason (R): The drift velocity of electrons in a metallic wire is very high.

Ans. (c) In a conductor there are large number of free electrons. When we close the circuit, the electric field is established instantly with the speed of electromagnetic wave which cause electron drift at every portion of the circuit. Due to which the current is set up in the entire circuit instantly. The current which is set up does not wait for the electrons flow from one end of the conductor to the another end. It is due to this reason, the electric bulb glows immediately when switch is on.

Q 119. Assertion (A): The drift velocity of electrons in a metallic wire will decrease, if the temperature of the wire is increased.

Reason (R): On increasing temperature, conductance of metallic wire decreases.

Ans. (b) On increasing temperature of wire the kinetic energy of free electrons increase and so they collide more rapidly with each other and hence their drift velocity decreases. Also when temperature increases, resistance increase and resistance is inversely proportional to conductivity of material.

Q 120. Assertion (A): If we bend an insulated conducting wire, the resistance of the wire increases.

Reason (R): The drift velocity of electrons in bent wire decreases.

Ans. (d) Bending will not increase the resistance of the conducting wire. Also drift velocity of electron is independent of bending of conductor.

Q 121. Assertion (A): If the length of the conductor is doubled, the drift velocity will become half of the original value. (Keeping potential difference unchanged.)

Reason (R): At constant potential difference, drift velocity is inversely proportional to the length of the conductor.

Ans. (a) Drift velocity of free electrons is given by,

$$v_d = \frac{eE}{m}\tau$$

where, $E = \frac{\text{Potential difference}}{\text{length}} = \frac{V}{l}$

$$\therefore \quad v_d = \frac{eV}{ml}\tau$$

i.e., $v_d \propto \frac{1}{l}$ where, $\frac{eV\tau}{m}$ is constant.

It mean if l is doubled, the drift velocity will become half of the original value.

Q 122. Assertion (A): The current flowing through a conductor is directly proportional to the drift velocity.

Reason (R): As the drift velocity increases the current flowing through the conductor decreases.

Ans. (c) Consider a conductor of length l and area of cross-section A. Time taken by the free electrons to cross the conductor,

$t = l / v_d$.

Hence, current, $I = \frac{q}{t} = \frac{Al \times ne}{l / v_d}$

or $\quad I = Anev_d$

or $\quad I \propto v_d$

Thus current is directly proportional to drift velocity.

Q 123. Assertion (A): Ohm's law is not valid, if current depends on voltage non-linearly.

Reason (R): Ohm's law is a fundamental law of nature.

Ans. (c) Ohm's law is not a fundamental law of nature. It fails in the following conditions:

(i) voltage depends on current non linearly.

(ii) the relation between voltage and current depends on the sign of voltage for the same absolute value of voltage.

(iii) the relation between voltage and current is not unique.

Q 124. Assertion (A): The resistivity of a semiconductor increases with temperature.

Reason (R): The atoms of a semiconductor vibrate with larger amplitude at higher temperatures thereby increasing its resistivity.

Ans. (d) Resistivity of a semiconductor decreases with the temperature. The atoms of a semiconductor vibrate with larger amplitudes at higher temperatures thereby increasing it's conductivity not resistivity.

Q 125. Assertion (A): Electric appliances with metallic body have three connections, whereas an electric bulb has a two pin connection.

Reason (R): Three pin connections reduce heating of connecting wires.

Ans. (c) The metallic body of the electrical appliances is connected to the third pin which is connected to the earth. This is a safety precaution and avoids eventual electric shock. By doing this the extra charge flowing through the metallic body is passed to earth and avoid shocks. There is nothing such as reducing of the heating of connecting wires by three pin connections.

Q 126. Assertion (A): Material used in the construction of a standard resistance is constantan or manganin.

Reason (R): Temperature coefficient of constantan is very small.

Ans. (a) These alloys (constantan or manganin) are used for making standard resistance because they possess high resistivity and low temperature coefficient of resistance

Q 127. Assertion (A): The temperature coefficient of resistance is always positive only for metals.

Reason (R): On increasing the temperature, the resistance of metals and alloys increases.

Ans. (b) The value of temperature coefficient of resistance is positive only for metals and alloys and is negative for semiconductors and insulators.

Q 128. Assertion (A): Some electric appliances have three pins, even though, if we remove the top pin, it will continue working.

Reason (R): The third pin is used only as a safety device.

Ans. (a)

Q 129. Assertion (A): Heater wire must have high resistance and high melting point.

Reason (R): If resistance is high, the electric conductivity will be less.

Ans. (b) Heater wire must have high resistance and high melting point, because in series current remains same, therefore according to Joule's law $H = i^2Rt / 4.2$, heat produced is high if R is high. Melting point must be high, so that wire may not melt with increase in temperature.

Q 130. Assertion (A): Electromotive force is a force which helps the electrons to flow and produce current.

Reason (R): Electromotive force is independent of the voltage across the cell.

Ans. (d) Electromotive force is not a force, it is the voltage difference between the two terminals of a source in open circuit.

Q 131. Assertion (A): Kirchhoff's junction rule can be applied to a junction of several lines or a point in a line.

Reason (R): When steady current is flowing, there is no accumulation of charges at any junction or at any point in a line.

Ans. (a)

Q 132. Assertion (A): In meter bridge experiment, a high resistance is always connected in series with a galvanometer.

Reason (R): As resistance increases current through the circuit increases.

Ans. (c) The resistance of the galvanometer is fixed. In meter bridge experiments, to protect the galvanometer from a high current, high resistance is connected to the galvanometer in order to protect it from damage.

Q 133. Assertion (A): Potentiometer is used only to compare potential differences.

Reason (R): The potentiometer draws current from the voltage source being measured.

Ans. (d) Potentiometer is a device used to compare potential differences. Since the method involves a condition of no current flow, the device can be used to measure potential difference, internal resistance of a cell and compare emf's of two sources. Potentiometer draws no current from the voltage source being measured.

Case Study Based QUESTIONS

Case Study 1

According to Ohm's law, the current flowing through a conductor is directly proportional to the potential difference across the ends of the conductor *i.e.*, $I \propto V \Rightarrow \frac{V}{I} = R$, where R is resistance of the conductor. Electrical resistance of a conductor is the obstruction posed by the conductor to the flow of electric current through it. It depends upon length, area of cross-section, nature of material and temperature of the conductor. We can write, $R \propto \frac{l}{A}$ or $R = \rho\frac{l}{A}$, where ρ is electrical resistivity of the material of the conductor.

Read the above passage carefully and give the answer of the following questions.

Q. 1. Dimensions of electric resistance is:

a. $[ML^2T^{-2}A^{-2}]$ b. $[ML^2T^{-3}A^{-2}]$
c. $[M^{-1}L^{-2}T^{-1}A]$ d. $[M^{-1}L^2T^2A^{-1}]$

Ans. (b) $[ML^2T^{-3}A^{-2}]$

Q. 2. If 1μA current flows through a conductor when potential difference of 2V is applied across its ends, then the resistance of the conductor is:

a. $2 \times 10^6\ \Omega$ b. $3 \times 10^5\ \Omega$
c. $1.5 \times 10^5\ \Omega$ d. $5 \times 10^7\ \Omega$

Ans. (a) $2 \times 10^6\ \Omega$

$$R = \frac{V}{I} = \frac{2}{10^{-6}} = 2 \times 10^6\ \Omega$$

Q. 3. Specific resistance of a wire depends upon:

a. length b. cross-sectional area
c. mass d. None of these

Ans. (d) None of these

Specific resistance depends upon the nature of material and is independent of mass and dimensions of the material.

Q. 4. The slope of the graph between potential difference and current through a conductor is:

a. a straight line b. curve
c. first curve then straight line
d. first straight line then curve

Ans. (a) a straight line

Q. 5. The resistivity of the material of a wire 1.0 m long, 0.4 mm in diameter and having a resistance of 2.0Ω is

a. $1.57 \times 10^{-6}\ \Omega m$ b. $5.25 \times 10^{-7}\ \Omega m$
c. $7.12 \times 10^{-5}\ \Omega m$ d. $2.55 \times 10^{-7}\ \Omega m$

Ans. (d) $2.55 \times 10^{-7}\ \Omega m$

$l = 1.0$ m; $D = 0.4$ mm $= 4 \times 10^{-4}$ m

$R = 2\ \Omega$

$$A = \frac{\pi D^2}{4} = \frac{\pi \times (4 \times 10^{-4})^2}{4} = 4\pi \times 10^{-8}\ m^2$$

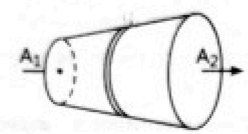
Now, $$\rho = \frac{RA}{l} = \frac{2 \times 4\pi \times 10^{-8}}{1} = 2.55 \times 10^{-7}\ \Omega m$$

Case Study 2

The flow of charge in a particular direction constitutes the electric current. Current is measured in Ampere. Quantitatively, electric current in a conductor across an area held perpendicular to the direction of flow of charge is defined as the amount of charge is flowing across that area per unit time.

Current density at a point in a conductor is the ratio of the current at that point in the conductor to the area of cross-section of the conductor of that point.

The given figure shows a steady current flows in a metallic conductor of non-uniform cross-section. Current density depends inversely on area, so, here $J_1 > J_2$, as $A_1 < A_2$.



When a constant current is flowing through a conductor of non-uniform cross-section, electron density does not depend upon the area of cross-section, while current density, drift velocity and electric field all vary inversely with area of cross-section.

Read the above passage carefully and give the answer of the following questions.

Q 1. What is the current flowing through a conductor, if one million electrons are crossing in one millisecond through a cross-section of it?

a. 2.5×10^{-10} A
b. 1.6×10^{-10} A
c. 7.5×10^{-9} A
d. 8.2×10^{-11} A

Ans. (b) 1.6×10^{-10} A

$$q = 10^6 \times 1.6 \times 10^{-19} \text{ C}$$
$$= 1.6 \times 10^{-13} \text{ C}$$
$$t = 10^{-3} \text{ s}$$
$$I = \frac{q}{t} = \frac{1.6 \times 10^{-13}}{10^{-3}} = 1.6 \times 10^{-10} \text{ A}$$

Q 2. SI unit of electric current is:

a. Cs b. Ns^{-2} c. Cs^{-1} d. $C^{-1}s^{-1}$

Ans. (c) Cs^{-1}

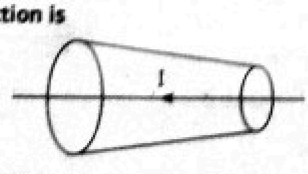
Q 3. A steady current flows in a metallic conductor of non-uniform cross-section. Which of these quantities is constant along the conductor?

a. Electric field
b. Drift velocity
c. Current
d. Current density

Ans. (c) Current

The current flowing through a conductor of non-uniform cross-section remain same in the whole of the conductor.

Q 4. A constant current *I* is flowing along the length of a conductor of variable cross-section as shown in the figure. The quantity which does not depend upon the area of cross-section is



a. electron density
b. current density
c. drift velocity
d. electric field

Ans. (a) electron density

Q 5. When a current of 40 A flows through a conductor of area 10 m^2, then the current density is:

a. 4 A/m^2 b. 1 A/m^2 c. 2 A/m^2 d. 8 A/m^2

Ans. (a) 4 A/m^2

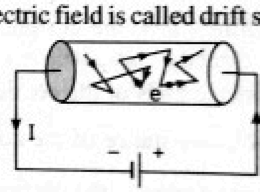
Given $I = 40$ A; $A = 10$ m^2

∴ Current density, $J = \frac{I}{A}$

or $J = \frac{40}{10} = 4 \text{ A/m}^2$

Case Study 3

Metals have a large number of free electrons nearly 10^{28} per cubic metre. In the absence of electric field, average terminal speed of the electrons in random motion at room temperature is of the order of 10^5 ms^{-1}. When a potential difference V is applied across the two ends of a given conductor, the free electrons in the conductor experiences a force and are accelerated towards the positive end of the conductor. On their way, they suffer frequent collisions with the ions/atoms of the conductor and lose their gained kinetic energy. After each collision, the free electrons are gain accelerated due to electric field, towards the positive end of the conductor and lose their gained kinetic energy in the next collision with the ions/atoms of the conductor. The average speed of the free electrons with which they drift towards the positive end of the conductor under the effect of applied electric field is called drift speed of the electrons.



Read the above passage carefully and give the answer of the following questions.

Q 1. Magnitude of drift velocity per unit electric field is

a. current density
b. current
c. resistivity
d. mobility

Ans. (d) mobility

Mobility is defined as the magnitude of drift velocity per unit electric field.

$$\text{Mobility, } \mu = \frac{|v_d|}{E}$$

Q 2. The drift speed of the electrons depends on:

a. dimensions of the conductor
b. number density of free electrons in the conductor
c. Both a. and b.
d. Neither a. nor b.

Ans. (c) Both a. and b.

Drift velocity, $v_d = \frac{I}{neA}$

where the symbols have their usual meanings.

Q 3. We are able to obtain fairly large currents in a conductor because:

a. the electron drift speed is usually very large

b. the number density of free electrons is very high and this can compensate for the low values of the electron drift speed and the very small magnitude of the electron charge

c. the number density of free electrons as well as the electron drift speds are very large and these compensate for the very small magnitude of the electron charge

d. the very small magnitude of the electron charge has to be divided by the still smaller product of the number density and drift speed to get the electric current

Ans. (b) the number density of free electrons is very high and this can compensate for the low values of the electron drift speed and the very small magnitude of the electron charge

$$I = neAv_d$$

v_d is of order of few ms^{-1}, $e = 1.6 \times 10^{-19}$ C

A is of the order of mm^2, so a large I is due to a large value of n in conductors.

Q 4. Drift speed of electrons in a conductor is very small *i.e.*, $i = 10^{-4}$ ms^{-1}. The electric bulb glows immediately. When the switch is closed because:

a. drift velocity of electron increases when switch is closed

b. electrons are accelerated towards the negative end of the conductor

c. the drifting of electrons takes place at the entire length of the conductor

d. the electrons of conductor move towards the positive end and protons of conductor move towards negative end of the conductor

Ans. (c) the drifting of electrons takes place at the entire length of the conductor

When we close the circuit, an electric field is established instantly with the speed of electromagnetic wave which causes electrons to drift at every portion of the circuit, due to which the current is set up in the entire circuit instantly. The current which is set up does not wait for electrons to flow from one end of the conductor to another. Thus, the electric bulb glows immediately when switch is closed.

Q 5. The number density of free electrons in a copper conductor is 8.5×10^{28} m^{-3}. How long does an electron take to drift from one end of a wire 3.0 m long to its other end? The area of cross-section of the wire is 2.0×10^{-6} m^2 and it is carrying a current of 3.0 A.

a. 8.1×10^4 s b. 2.7×10^4 s

c. 9×10^3 s d. 3×10^3 s

Ans. (b) 2.7×10^4 s

Here, number density of free electrons, $n = 8.5 \times 10^{28}$ m^{-3}

Area of cross-section of a wire, $A = 2.0 \times 10^{-6}$ m^2

Length of wire, $l = 3.0$ m

Current, $I = 3.0$ A

The drift velocity of an electron is

$$v_d = \frac{I}{neA} \quad ...(1)$$

The time taken by the electron to drift from one end to other end of the wire is

$$t = \frac{l}{v_d} = \frac{lneA}{I} \quad \text{[Using eq. (1)]}$$

$$= \frac{(3.0\,m)(8.5 \times 10^{28}\,m^{-3})(1.6 \times 10^{-19}\,C)(2.0 \times 10^{-6}\,m^2)}{(3.0\,A)}$$

$$= 2.7 \times 10^4 \text{ s}$$

Case Study 4

The resistance of a conductor at temperature t° C is given by $R_t = R_0(1 + \alpha t)$

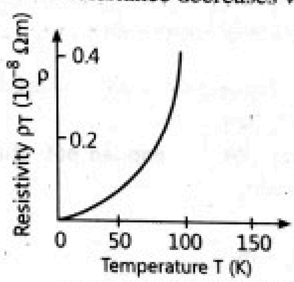
where R_t is the resistance at t° C, R_0 is the resistance at 0°C and α is the characteristics constants of the material of the conductor.

Over a limited range of temperatures, that is not too large. The resistivity of a metallic conductor is approximately given by $\rho_t = \rho_0(1 + \alpha t)$.

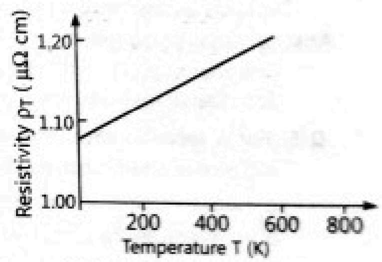
where, α is the temperature coefficient of resistivity. Its unit is K^{-1} or $°C^{-1}$.

For metals, α is positive *i.e.*, resistance increases with rise in temperature.

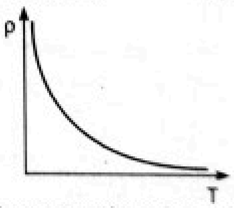
For insulators and semiconductors, α is negative *i.e.*, resistance decreases with rise in temperature.



Resistivity ρ_T of copper as a function of temperature T



Resistivity ρ_T of nichrome as a function of temperature T



Temperature dependence of the resistivity of a typical semiconductor

Read the above passage carefully and give the answer of the following questions.

Q 1. Fractional increase in resistivity per unit increase in temperature is defined as

a. resistivity

b. temperature coefficient of resistivity

c. conductivity

d. drift velocity

Ans. (b) temperature coefficient of resistivity

Temperature coefficient of resistivity is defined as the fractional increase in resistivity per unit increase in temperature.

Q 2. The material whose resistivity is insensitive to temperature is

a. silicon b. copper c. silver d. nichrome

Ans. (d) nichrome

Nichrome (which is an alloy of nickel, iron and chromium) exhibits a very weak dependence of resistivity with temperature.

Q 3. The temperature coefficient of the resistance of a wire is 0.00125 per °C. At 300 K its resistance is 1 Ω. The resistance of wire will be 2 Ω at

a. 1154 K b. 1100 K c. 1400 K d. 1127 K

Ans. (d) 1127 K

Using, $R_T = R_0(1+\alpha T)$

$\therefore \quad \dfrac{R_{T_2}}{R_{T_1}} = \dfrac{R_0(1+\alpha T_2)}{R_0(1+\alpha T_1)} = \dfrac{2}{1} = \dfrac{(1+\alpha T_2)}{(1+\alpha \times 300)}$

$\Rightarrow \quad 2 + \alpha \times 600 = 1 + \alpha\, T_2$

$\Rightarrow \quad 1 = \alpha\,(T_2 - 600)$

$\Rightarrow \quad \dfrac{1}{0.00125} = (T_2 - 600)$

$\Rightarrow \quad 800°\text{C} = T_2 - 600$

$T_2 = 800 - 273 + 600$

$T_2 = 1127\text{ K}$

Q 4. The temperature coefficient of resistance of an alloy used for making resistors is

a. small and positive b. small and negative

c. large and positive d. large and negative

Ans. (a) small and positive

The temperature coefficient of resistance of an alloy used for making resistors is small and positive.

Q 5. For a metallic wire, the ratio V/I (V = applied potential difference and I = current flowing) is

a. independent of temperature

b. increases as the temperature rises

c. decreases as the temperature rises

d. increases or decreases as temperature rises depending upon the metal

Ans. (b) increases as the temperature rises

The resistance of a metallic wire at temperature t°C is given by

$$R_t = R_0(1+\alpha t)$$

where, α is the temperature coefficient of resistance and R_0 is the resistance of a wire at 0°C.

For metals, α is positive. Hence, resistance of a wire increases with increase in temperature.

Also, from Ohm's law

$$\frac{V}{I} = R$$

Hence, on increasing the temperature, the ratio $\frac{V}{I}$ increases.

Case Study 5

In physics, an electric power measure of the rate of electrical energy transfer by an electric circuit per unit time. It is denoted by P and measured using the SI unit of power is the watt or one joule per second. Electric power is commonly supplied by sources such as electric batteries and produced by electric generators.

The formula for electric power is given by $P = VI$

where, P is the power, V is the potential difference in the circuit, I is the electric current

Power can also be written as

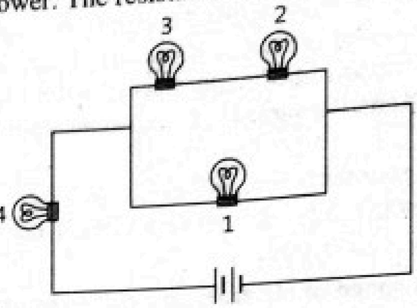
$$P = I^2R \text{ and } P = V^2/R$$

The above two expressions are got by using Ohm's law, where, voltage, current and resistance are related by the following relation

$$V = IR$$

where, R is the resistance in the circuit, V is the potential difference in the circuit, I is the electric current.

The given figure shows four bulbs 1, 2, 3 and 4, consume same power. The resistance of bulb 1 is 36Ω.



Read the above passage carefully and give the answer of the following questions.

Q 1. What is the resistance of the bulb 3?

a. 4 Ω b. 9 Ω

c. 18 Ω d. 12 Ω

Ans. (b) 9 Ω

The bulbs 2 and 3 are in series, current through them is same.

$\therefore \quad I_2 = I_3 = I_b$ (say)

Now, bulb 1 and combination of 2 and 3 are in parallel.

$\therefore \quad V_1 = (V_2 + V_3) = V$ (say)

Since, all bulbs consumes same power.

$\therefore \quad P_2 = P_3 \Rightarrow I_b^2R_2 = I_b^2R_3$

$\Rightarrow \quad R_2 = R_3$

So, $\quad V_2 = V_3 = \dfrac{V}{2}$

Now, $\quad P_1 = \dfrac{V_1^2}{R_1} = \dfrac{V^2}{36}$

and $\quad P_3 = \dfrac{V_3^2}{R_3} = \dfrac{V^2}{4R_3}$

$\because \quad P_1 = P_3$

$\therefore \quad \dfrac{V^2}{36} = \dfrac{V^2}{4R_3} \Rightarrow R_3 = 9\ \Omega$

Q 2. What is the resistance of bulb 4?

a. 4 Ω b. 8 Ω

c. 9 Ω d. 18 Ω

Ans. (a) 4 Ω

Total current through R_1

$$I_o = \frac{R_2 + R_3}{R_1 + (R_2 + R_3)} I$$

$$= \frac{18}{36+18} = \frac{18}{54} I = \frac{I}{3}$$

Also, $I_4 = I$

Since, $P_1 = P_4 \Rightarrow I_G^2 R_1 = I_4^2 R_4$

$\Rightarrow \left(\frac{I}{3}\right)^2 \times 36 = I^2 R_4$

which implies sign $R_4 = 4\ \Omega$

Q 3. If power of each bulb is 4 W, then the total current flowing through the circuit is:

a. 1 A b. 2 A c. 4 A d. 12 A

Ans. (a) 1 A

Given that $P_4 = 4$ W

$P_4 = I_4^2 R_4$

or $P_4 = I^2 R_4$ $(\because I_4 = I)$

or $I = 1$ A

Q 4. What is the equivalent resistance of the circuit?

a. 12 Ω b. 8 Ω c. 18 Ω d. 16 Ω

Ans. (d) 16 Ω

$$R_{eq} = R_4 + \frac{R_1(R_2 + R_3)}{R_1 + R_2 + R_3}$$

$$= 4 + \frac{36(9+9)}{36+9+9} = 16\ \Omega$$

Q 5. What is the voltage output of the battery, if the power of each bulb is 4 W?

a. 16 V b. 12 V

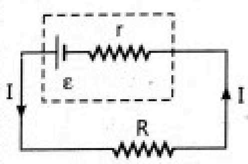
c. 24 V d. 18 V

Ans. (a) 16 V

$\varepsilon = I R_{eq} = 16$ V

Case Study 6

Emf of a cell is the maximum potential difference between two electrodes of the cell when no current is drawn from the cell. Internal resistance is the resistance offered by the electrolyte of a cell when the electric current flows through it. The internal resistance of a cell depends upon the following factors; (i) distance between the electrodes (ii) nature and temperature of the electrolyte (iii) nature of electrodes (iv) area of electrodes.



For a freshly prepared cell, the value of internal resistance is generally low and goes on increasing as the cell is put to more and more use. The potential difference between the two electrodes of a cell in a closed circuit is called terminal potential difference and its value is always less than the emf of the cell in a closed circuit. It can be written as $V = \varepsilon - Ir$.

Read the above passage carefully and give the answer of the following questions.

Q 1. The terminal potential difference of two electrodes of a cell is equal to emf of the cell when:

a. $I \neq 0$ b. $I = 0$

c. Both a. and b. d. Neither a. nor b.

Ans. (b) $I = 0$

Q 2. A cell of emf ε and internal resistance r gives a current of 0.5 A with an external resistance of 12 Ω and a current of 0.25 A with an external resistance of 25 Ω. What is the value of internal resistance of the cell?

a. 5 Ω b. 1 Ω c. 7 Ω d. 3 Ω

Ans. (b) 1 Ω

As $I = \frac{\varepsilon}{R + r}$

In first case, $I = 0.5$ A; $R = 12\ \Omega$

$$0.5 = \frac{\varepsilon}{12 + r} \Rightarrow \varepsilon = 6.0 + 0.5r \quad ...(1)$$

In second case, $I = 0.25$ A; $R = 25\ \Omega$

$$\varepsilon = 6.25 + 0.25r \quad ...(2)$$

From eqs. (1) and (2), $r = 1\ \Omega$

Q 3. Choose the wrong statement.

a. Potential difference across the terminals of a cell in a closed circuit is always less than its emf

b. Internal resistance of a cell decrease with the decrease in temperature of the electrolyte

c. Potential difference versus current graphs for a cell is a straight line with a –ve slope

d. Terminal potential difference of the cell when it is being charged is given as $V = \varepsilon + Ir$

Ans. (b) Internal resistance of a cell decrease with the decrease in temperature of the electrolyte

Q 4. An external resistance R is connected to a cell of internal resistance r, the maximum current flows in the external resistance, when:

a. $R = r$ b. $R < r$ c. $R > r$ d. $R = 1/r$

Ans. (a) $R = r$

Current in the circuit $I = \frac{\varepsilon}{R + r}$

Power delivered to the resistance R is

$$P = I^2 R = \frac{E^2 R}{(R + r)^2}$$

It is maximum when $\frac{dP}{dR} = 0$

$$\frac{dP}{dR} = \varepsilon^2 \left[\frac{(r+R)^2 - 2R(r+R)}{(r+R)^4}\right] = 0$$

or $(r + R)^2 = 2R(r + R)$ or $R = r$

Q 5. If external resistance connected to a cell has been increased to 5 times, the potential difference across the terminals of the cell increases from 10 V to 30 V. Then, the emf of the cell is:

a. 30 V b. 60 V c. 50 V d. 40 V

Ans. (b) 60 V

For first case, $\frac{\varepsilon}{R + r} = \frac{10}{R}$ ...(1)

For second case, $\frac{\varepsilon}{5R + r} = \frac{30}{5R}$ ...(2)

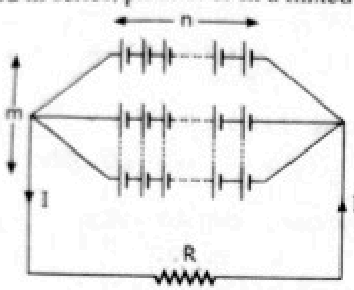
Dividing eq. (1) by eq. (2), we get, $r = 5R$

From eq. (1), $\frac{\varepsilon}{R + 5R} = \frac{10}{R}$

$\varepsilon = 60$ V

Case Study 7

A single cell provides a feeble current. In order to get a higher current in a circuit, we often use a combination of cells. A combination of cells is called a battery. Cells can be joined in series, parallel or in a mixed way.



Two cells are said to be connected in series when negative terminal of one cell is connected to positive terminal of the other cell and so on. Two cells are said to be connected in parallel, if positive terminal of each cell is connected to one point and negative terminal of each cell connected to the other point. In mixed grouping of cells, a certains number of identical cells are joined in series, and all such rows are then connected in parallel with each other.

Read the above passage carefully and give the answer of the following questions.

Q 1. To draw the maximum current from a combination of cells, how should the cells be grouped?

a. Parallel
b. Series
c. Mixed grouping
d. Depends upon the relative values of internal and external resistances

Ans. (d) Depends upon the relative values of internal and external resistances

Q 2. The total emf of the cells when n identical cells each of emf ε are connected in parallel is:

a. $n\varepsilon$ b. $n^2\varepsilon$ c. ε d. $\frac{\varepsilon}{n}$

Ans. (c) ε

For parallel combination of n cells,

$$\varepsilon_{eq} = \varepsilon$$

Q 3. 4 cells each of emf 2 V and internal resistance of 1 Ω are connected in parallel to a load resistor of 2 Ω. Then the current through the load resistor is

a. 2 A b. 1.5 A c. 1 A d. 0.888 A

Ans. (d) 0.888 A

$$I = \frac{m\varepsilon}{mR + r}, m = \text{number of cells} = 4$$

$$\varepsilon = 2 \text{ V}, R = 2\ \Omega, r = 1\ \Omega$$

$$I = \frac{8}{8+1} = \frac{8}{9} = 0.888 \text{ A}$$

Q 4. If two cells out of n number of cells each of internal resistance 'r' are wrongly connected in series, then total resistance of the cell is

a. $2nr$ b. $nr - 4r$ c. nr d. r

Ans. (b) $nr - 4r$

Q 5. Two identical non-ideal batteries are connected in parallel. Consider the following statements.

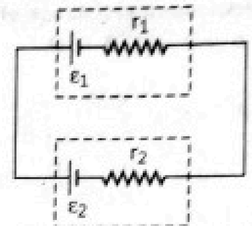
(i) The equivalent emf is smaller than either of the two emfs.

(ii) The equivalent internal resistance is smaller than either of the two internal resistances.

a. Both (i) and (ii) are correct
b. (i) is correct but (ii) is wrong
c. (ii) is correct but (i) is wrong
d. Both (i) and (ii) are wrong

Ans. (c) (ii) is correct but (i) is wrong

Let two cells of emf's ε_1 and ε_2 and of internal resistances r_1 and r_2 respectively are connected in parallel.



The equivalent emf is given by

$$\varepsilon_{eq} = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2} \quad ...(1)$$

The equivalent internal resistance is given by

$$\frac{1}{r_{eq}} = \frac{1}{r_1} + \frac{1}{r_2}$$

or $$r_{eq} = \frac{r_1 r_2}{r_1 + r_2} \quad ...(2)$$

Let us consider, two cells connected in parallel of same emf ε and same internal resistance r.

From eq. (1), we get

$$\varepsilon_{eq} = \frac{\varepsilon r + \varepsilon r}{r + r} = \varepsilon$$

From eq. (2), we get

$$r_{eq} = \frac{r^2}{r + r} = \frac{r}{2}$$

Case Study 8

Kirchhoff's circuit laws are two equalities that deal with the current and potential difference in the lumped element model of electrical circuits. They were first described in 1845 by German physicist Gustav Kirchhoff.

Kirchhoff's Current Law

This law states that, for any node in an electrical circuit, the sum of currents flowing into that node is equal to the sum of currents flowing out of that node.

Kirchhoff's Voltage Law

The directed sum of the potential differences (voltages) around any closed loop is zero.

Read the above passage carefully and give the answer of the following questions:

Q 1. Kirchhoff's current law is conservation of:

a. charge b. energy c. potential d. momentum

Ans. (a) charge

Q 2. Kirchhoff's current law can be written as:

a. $\Sigma V = 0$ b. $\Sigma I = 0$ c. $\Sigma R = 0$ d. $\Sigma q = 0$

Ans. (b) $\Sigma I = 0$

Q 3. Kirchhoff's voltage law is the conservation of:

a. energy
b. charge
c. current
d. momentum

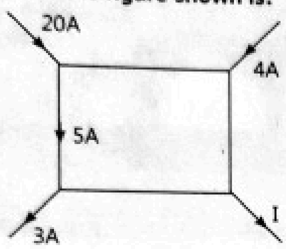
Ans. (a) energy

Q 4. Kirchhoff's voltage law is applied over:

a. closed circuit loop
b. at a circuit node
c. across battery
d. None of these

Ans. (a) closed circuit loop

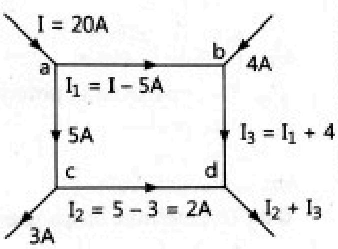
Q 5. The value of *I* in the figure shown is:



a. 19 A
b. 21 A
c. 4 A
d. 8 A

Ans. (b) 21 A

Using Kirchhoff's first law:



At junction *a*:

$I_1 = 20 - 5 = 15$ A

At junction *b*:

$I_3 = I_1 + 4$

$\therefore \quad I_3 = 15 + 4 = 19$ A

At junction *c*:

$I_2 = 5 - 3 = 2$ A

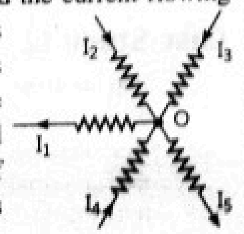
At junction *d*:

$I = I_2 + I_3$

$= 2\text{ A} + 19\text{ A} = 21\text{ A}$

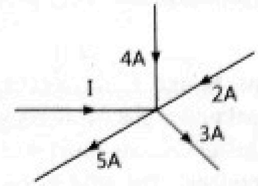
Case Study 9

In 1942, a German physicist Kirchhoff's extended Ohm's law to complicated circuits and gave two laws, which enable us to determine current in any part of such a circuit. According to Kirchhoff's first rule, the algebraic sum of the currents meeting at a junction in a closed electric circuit is zero. The current flowing in a conductor towards the junction is taken as positive and the current flowing away from the junction is taken as negative. According to Kirchhoff's second rule, in a closed loop, the algebraic sum of the emf's and algebraic sum of the products of current and resistance in the various emf of the loop is zero. While traversing a loop, if negative pole of the cell is encountered first, then its emf is negative, otherwise positive.



Read the above passage carefully and give the answer of the following questions:

Q 1. The value of current *I* in the given circuit is:



a. 4.5 A b. 3.7 A c. 2.0 A d. 2.5 A

Ans. (c) 2.0 A

According to Kirchhoff's junction law

$(+I) + (+4\text{ A}) + (+2\text{ A}) + (-5\text{ A}) + (-3\text{ A}) = 0$

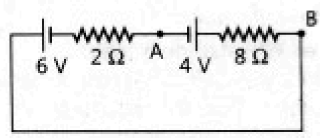
$I + 6\text{ A} - 8\text{ A} = 0$ or $I = 2$ A

Q 2. Point out the right statements about the validity of Kirchhoff's Junction rule.

a. The current flowing towards the junction are taken as positive
b. The currents flowing away from the junction are taken as negative
c. Bending or reorienting the wire does not change the validity of Kirchhoff's Junction rule
d. All of the above

Ans. (d) All of the above

Q 3. Potential difference between *A* and *B* in the circuit shown here is



a. 4 V b. 5.6 V c. 2.8 V d. 6 V

Ans. (b) 5.6 V

Apply KVL in the given circuit,

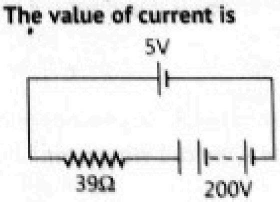
$6 - 8I - 4 - 2I = 0$

or $\quad 2 - 10I = 0$

or $\quad I = \frac{2}{10} = 0.2$ A

$V_{AB} = 4 + I \times 8 = 4 + 0.2 \times 8 = 5.6$ V

Q 4. A 5 V battery of negligible internal resistance is connected across a 200 V battery and a resistance of 39 Ω as shown in the figure. The value of current is



a. 5 A b. 3 A c. 4 A d. 7.8 A

Ans. (a) 5 A

Apply KVL,

$-39I - 200 + 5 = 0 \Rightarrow 39I = 195 \Rightarrow I = 5$ A

Q 5. Between any two points in a circuit, the sum of all .... is the same through any pathway.

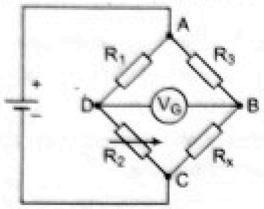
a. charge
b. current
c. resistance
d. potential difference

Ans. (d) potential difference

According to Kirchhoff's voltage law, between any two points in a circuit, the sum of all voltage drop is the same through any pathway.

Case Study 10

A Wheatstone bridge is an electrical circuit used to measure an unknown electrical resistance by balancing two legs of a bridge circuit, one leg of which includes the unknown component. The primary benefit of the circuit is its ability to provide extremely accurate measurements.



The resistance is adjusted until the bridge is "balanced" and no current flows through the galvanometer. At this point, the voltage between the two mid-points (B and D) will be zero.

Therefore the ratio of the two resistances in the known leg is equal to the ratio of the two resistances in the unknown leg.

Read the above passage carefully and give the answer of the following questions:

Q 1. In balanced Wheatstone bridge:

a. potential at points B and D remain same

b. large current flows through the circuit

c. battery becomes over heated

d. resistances become small

Ans. (a) potential at points B and D remain same

A Wheatstone bridge is said to be balanced if no current flows through V_G

Q 2. Wheatstone bridge is used to measure:

a. unknown current b. unknown voltage

c. unknown charge d. unknown resistance

Ans. (d) unknown resistance

The ratio of the two resistances in the known leg is equal to the ratio of the two resistances in the unknown leg.

Q 3. Wheatstone bridge is implemented in lab using

a. ammeter b. voltmeter

c. meter bridge d. potentiometer

Ans. (c) meter bridge

Wheatstone bridge is based on the principal of meter bridge.

Q 4. Condition for balanced Wheatstone bridge:

a. $R_1/R_2 = R_3/R_x$ b. $R_3 = R_1 \times R_x$

c. $R_1 = R_3 \times R_x$ d. None of these

Ans (a) $R_1/R_2 = R_3/R_x$

The ratio of the two resistances in the known leg is equal to the ratio of the two resistances in the unknown leg.

Q 5. Wheatstone bridge is analogous to:

a. cantilevel b. simple level system

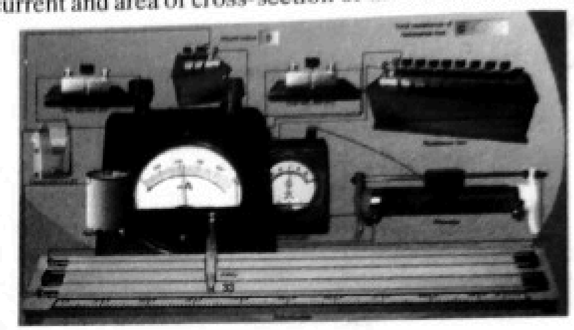
c. gear train d. mechanical clutch

Ans. (b) simple level system

The best suited option is simple level system.

Case Study 11

Potentiometer: Potentiometer is a device which is used to find out the emf of any cell and it is also used to find the potential difference across any two points on a conductor correctly. In this device as long wire of manganin or constantan, copper strips, binding screws etc. are used. The principle of potentiometer is given as, the decrease in potential across any part of the wire is directly proportional to the length of that part of wire, provided the current and area of cross-section of the wire remain same.



Read the above passage carefully and give the answer of the following questions:

Q 1. Potentiometer (Rheostat) is used to find out

a. emf b. potential difference

c. Both a. and b. d. None of these

Ans. (c) Both a. and b.

Q 2. The wire used in potentiometer is made of the material:

a. constantan b. gold

c. iron d. silver

Ans. (a) constantan

Q 3. The metallic strips used in potentiometer are made of:

a. copper b. iron

c. gold d. manganin

Ans. (a) copper

Q 4. The decrease in potential across the wire is proportional to the length of the wire

a. directly b. inversely

c. Both a. and b. d. None of these

Ans. (a) directly

Q 5. The potentiometer will give accurate result, if the area of cross-section of the wire

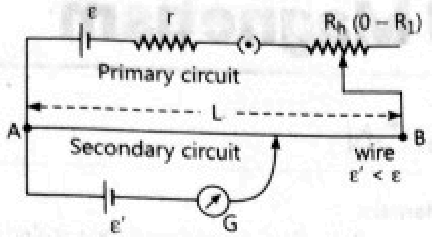
a. increases b. decrease

c. remain same d. None of these

Ans. (c) remain same

Case Study 12

Potentiometer is an apparatus used for measuring the emf of a cell or potential difference between two points in an electrical circuit accurately. It is also used to determine the internal resistance of a primary cell. The potentiometer is based on the principle that, if V is the potential difference across any portion of the wire of length l and resistance R, then $V \propto l$ or $V = kl$ where k is the potential gradient. Thus, potential difference across any portion of potentiometer wire is directly proportional to length of the wire of that portion. The potentiometer wire must be uniform. The resistance of potentiometer wire should be high.



Read the above passage carefully and give the answer of the following questions:

Q 1. Which one of the following is true about potentiometer?

a. Its sensitivity is low

b. It measures the emf of a cell very accurately

c. It is based on deflection method

d. None of the above

Ans. (b) It measures the emf of a cell very accurately

Q 2. A current of 1.0 mA is flowing through a potentiometer wire of length 4 cm and of resistance 4 Ω. The potential gradient of the potentiometer wire is

a. 10^{-3} Vm^{-1} b. 10^{-5} Vm^{-2}

c. 2×10^{-3} Vm^{-1} d. 4×10^{-3} Vm^{-1}

Ans. (a) 10^{-3} Vm^{-1}

Given, $I = 1.0$ mA $= 10^{-3}$ A; $R = 4\ \Omega$; $L = 4$ m

Potential drop across potentiometer wire,

$$V = IR = 10^{-3} \times 4 \text{ V}$$

Potential gradient, $k = \frac{V}{L} = \frac{4 \times 10^{-3}}{4} = 10^{-3}$ Vm^{-1}

Q 3. Sensitivity of a potentiometer can be increased by:

a. decreasing potential gradient along the wire

b. increasing potential gradient along the wire

c. decreasing current through the wire

d. increasing current through the wire

Ans. (a) decreasing potential gradient along the wire

Q 4. A potentiometer is an accurate and versatile device to make electrical measurements of emf because the method involves

a. potential gradient

b. a condition of no current flow through the galvanometer

c. a combination of cells, galvanometer and resistances

d. cells

Ans. (b) a condition of no current flow through the galvanometer

A potentiometer is an accurate and versatile device to make electrical measurements of emf because the method involves a condition of no current flow through the galvanometer. It can be used to measure potential difference, internal resistance of a cell and compare emf's of two sources.

Q 5. In a potentiometer experiment, the balancing length is 8m, when the two cells E_1 and E_2 are joined in series. When the two cells are connected in opposition the balancing lengths is 4 m. The ratio of emf of two cells (E_1 / E_2) is

a. 1 : 2 b. 2 : 1

c. 1 : 3 d. 3 : 1

Ans. (d) 3 : 1

$$\frac{E_1}{E_2} = \frac{l_1 + l_2}{l_1 - l_2} = \frac{8 + 4}{8 - 4} = \frac{12}{4} = \frac{3}{1}$$

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CHAPTER 4

Moving Charges and Magnetism

Fastrack REVISION

- **Magnetic Field:** Just as static charge produces an electric field a moving charge or current through conductor produces a magnetic Field ($\vec{B}$).
- It is the space around a conductor carrying current or the space around a magnet in which its magnetic effect can be felt.
- Magnetic field is also called as magnetic induction or magnetic flux density.
- S.I. unit of $\vec{B}$ is tesla (T) or weber/metre^2.

The direction of $\vec{B}$ is determined by Fleming's left-hand rule.

- **Magnetic Force**

$$F = qvB\sin\theta$$

or

$$|\vec{F}| = q|\vec{v} \times \vec{B}|$$

- **Fleming's Left Hand Rule:** It states that if we stretch the first finger, the central finger and thumb of left hand are mutually perpendicular to each other such that the first finger points in the direction of magnetic field and second finger shows the direction of electric current then the thumb represents the direction of force experienced by the charged particle.
- **Motion in a Magnetic Field:** The particle will describe a circle if v and B are perpendicular to each other.

If velocity has a component along B, the particle will produce helical motion.

- **Lorentz Force:** The force experienced by a charged particle moving in a space where both electric and magnetic fields exist is called Lorentz force.

$$\vec{F} = q[\vec{E} + (\vec{v} \times \vec{B})]$$

- **Magnetic Force on a Current Carrying Conductor**

$$\vec{F} = IBl\sin\theta$$

- **Biot-Savart Law:** Magnetic field due to a current element,

$$dB = \frac{\mu_0}{4\pi}\frac{idl\sin\theta}{r^2}$$

where, μ_0 = Permeability of free space and $\mu_0 = 4\pi \times 10^{-7}$ wb/Am

- **Magnetic Field at a Point in Circular Loop**

$$\vec{B} = \frac{\mu_0 IR^2}{2(R^2 + x^2)^{3/2}}$$

- **Magnetic Field at the Centre of the Coil**

$$\vec{B} = \frac{\mu_0 NI}{2R}\vec{r}$$

- **Similarities and Dis-similarities between the Biot-Savart's Law and Coulomb's Law**
  - **Similarities**
    - (i) Both the laws are for long range, since in both the laws, the field at a point varies inversely as the square of distance from the source to point of observation.
    - (ii) Both the fields obey superposition principle.
  - **Dis-similarities**
    - (i) The electrostatic field is produced by a scalar source, *i.e.*, 'q' and the magnetic field is produced by a vector source $Id\vec{l}$.
    - (ii) The electrostatic field is acting along the displacement vector. The magnetic field is acting perpendicular to the plane *i.e.*, along direction of $Id\vec{l} \times \vec{r}$.
    - (iii) Coulomb's law is independent of angle, whereas the Biot-Savart's law is angle dependent.
- **Relation between μ_0, ε_0 and c**

$$\varepsilon_0\mu_0 = 4\pi\varepsilon_0\left(\frac{\mu_0}{4\pi}\right) = \left(\frac{1}{9 \times 10^9}\right)(10^{-7}) = \frac{1}{(3 \times 10^8)^2} = \frac{1}{c^2}$$

- **Ampere's Circuital Law:** It states that the line integral of magnetic field around a closed path is equal to μ_0 times the total current I threading the closed path.

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I$$

- **Solenoid :** A solenoid consists of an insulated long wire closely wound in the form of a helix. Its length is very large as compared to its diameter.
- **Magnetic Field due to a Solenoid**

$$B = \mu_0 nI$$

- **Toroid:** The toroid is a hollow circular ring on which a large number of turns of a insulated metallic wire are closely wound.

$$B = \mu_0 nI$$

Here, $n = \frac{N}{2\pi r}$

- **Torque on a Current Loop, Magnetic Dipole**

$$\tau = NIBA\sin\theta$$

Further, $\tau = mB\sin\theta$, where m is the magnetic moment of the current loop.

- **Moving Coil Galvanometer:** Moving coil galvanometer is an instrument used for detection and measurement of small electric currents.

Principle: It is based on the principle that when a current carrying coil is placed in a magnetic field, it experiences a torque.

$$I \propto \phi$$

$$\phi = \left(\frac{NAB}{K}\right)I$$

where, ϕ = angle of deflection and K = torsional constant of the spring.

- **Current Sensitivity:** It is defined as the deflection produced in the galvanometer when a unit current flows through it.

$$\frac{\phi}{I} = \frac{nAB}{K}$$

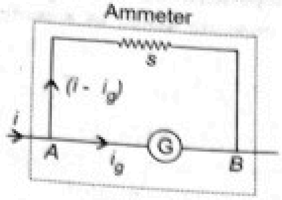
- **Voltage Sensitivity**

$$\frac{\phi}{V} = \left(\frac{nAB}{K}\right)\frac{1}{R}$$

- A galvanometer can be converted into an ammeter by using a low resistance wire in parallel with the galvanometer.

$(R \equiv 0)$

Now, effective resistance of ammeter will be

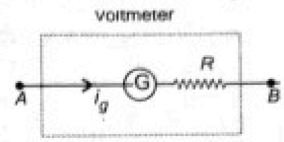


$$\frac{1}{R_A}=\frac{1}{G}+\frac{1}{S}$$

$$R_A=\frac{GS}{G+S}$$

- A galvanometer can be converted into a voltmeter by connecting a high resistance wire in series with the galvanometer. $(R=\infty)$

Effective resistance of volmeter will be $R_V=G+R$



Objective TYPE QUESTIONS

Multiple Choice Questions

Q 1. The magnetic effect of electric current was first noticed by:

a. Andre Ampere b. Hendrik Antoon Lorentz

c. Hans Christian Oersted d. Michael Faraday

Ans. (c) Hans Christian Oersted

Q 2. The laws obeyed by electricity and magnetism were unified and formulated by:

a. J.C. Bose b. James Maxwell

c. G. Marconi d. Hans Christian Oersted

Ans. (b) James Maxwell

Q 3. Radio waves were produced by .... and ....

a. James Maxwell, J.C. Bose

b. Lorentz, G. Marconi

c. E.O. Lawrence, M.S. Livingstone

d. J.C. Bose, G. Marconi

Ans. (d) J.C. Bose, G. Marconi

Q 4. When a magnetic compass needle is carried nearby to a straight wire carrying current, then:

(I) the straight wire cause a noticeable deflection in the compass needle.

(II) the alignment of the needle is tangential to an imaginary circle with straight wire as its centre and has a plane perpendicular to the wire.

a. (I) is correct

b. (II) is correct

c. Both (I) and (II) are correct

d. Neither (I) nor (II) is correct.

Ans. (c) Both (I) and (II) are correct.

Q 5. A current or a field going into the plane of the paper is depicted by a/an ....

a. cross b. dot

c. both a. and b. d. arrow

Ans. (a) cross

Q 6. A current carrying wire is held over a magnetic needle, such that electric current is passed through it from south to north direction. Then the north pole of the needle will be deflected towards :

a. east b. west c. north d. south

Ans. (b) west.

Using the right-hand thumb rule, it can be concluded that the magnetic field due to current carrying conductor is in west direction. Hence, north pole of the needle will be deflected towards west.

Q 7. When a magnetic field is applied on a stationary electron, it:

a. remains stationary

b. spins about its own axis

c. moves in the direction of the field

d. moves perpendicular to the direction of the field

Ans. (a) remains stationary

The electrons remains stationary because magnetic force act on moving charge.

Q 8. Which one of the following is not correct about Lorentz force?

a. In presence of electric field $\vec{E}(r)$ and magnetic field $\vec{B}(r)$ the force on a moving electric charge is $\vec{F}=q[\vec{E}(r)+\vec{v}\times\vec{B}(r)]$.

b. The force, due to magnetic field on a negative charge is opposite to that on a positive charge.

c. The force due to magnetic field becomes zero if velocity and magnetic field are parallel or anti-parallel.

d. For a static charge the magnetic force is maximum.

Ans. (d) For a static charge the magnetic force is maximum.

If charge is not moving then the magnetic force is zero.

Since $\vec{F}_m=q(\vec{v}\times\vec{B})$

As $\vec{v}=0$, for stationary charge $\therefore \vec{F}_m=0$

Q 9. The magnetic force $\vec{F}$ on a current carrying conductor of length l in an external magnetic field $\vec{B}$ is given by:

a. $\frac{I\times\vec{B}}{\vec{l}}$ b. $\frac{\vec{l}\times\vec{B}}{I}$

c. $I(\vec{l}\times\vec{B})$ d. $I^2\,\vec{l}\times\vec{B}$

Ans. (c) $I(\vec{l}\times\vec{B})$

Q 10. An alpha particle is moving perpendicular to the uniform magnetic field of 0.5 T with the velocity 3×10^5 ms^{-1}. What is the work done by the particle?

a. 1.5×10^5 J b. Infinity

c. 3 J d. Zero

Ans. (d) Zero.

Q 11. A 2.5 m long straight wire having mass of 500 g is suspended in mid air by a uniform horizontal magnetic field B. If a current of 4 A is passing through the wire then the magnitude of the field is (Take $g = 10\ m\ s^{-1}$):

a. 0.5 T b. 0.6 T c. 0.25 T d. 0.8 T

Ans. (a) 0.5 T

Here, $m = 500\ g = 0.5\ kg, I = 4\ A, l = 2.5\ m$

As $F = IlB \sin\theta$

$mg = IlB \sin 90°$, $(\because \theta = 90° \text{ and } F = mg)$

$\therefore B = \dfrac{mg}{Il} = \dfrac{0.5 \times 10}{4 \times 2.5} = 0.5\ T$

Q 12. A conductor of length 20 cm carries a current of 1 A is kept at an angle with the magnetic field of 4 T. Find the angle between the conductor and the magnetic field if it experiences a force of 0.4 N.

a. 0° b. 30°

c. 60° d. 90°

Ans. (b) 30°.

$F = IlB \sin\theta$

or $\sin\theta = \dfrac{F}{IlB} = \dfrac{0.4}{1 \times \frac{20}{100} \times 4} = \dfrac{1}{2}$

$\Rightarrow \theta = 30°$

Q 13. The magnetic force per unit length on a wire carrying a current of 10 A and making an angle of 45° with the direction of a uniform magnetic field of 0.20 T is:

a. $2\sqrt{2}\ Nm^{-1}$ b. $\dfrac{2}{\sqrt{2}}\ Nm^{-1}$

c. $\dfrac{\sqrt{2}}{2}\ Nm^{-1}$ d. $4\sqrt{2}\ Nm^{-1}$

Ans. (b) $\dfrac{2}{\sqrt{2}}\ Nm^{-1}$

$I = 10\ A, \theta = 45°, B = 0.2\ T$

$\therefore F = IlB \sin\theta$

$\therefore \dfrac{F}{l} = IB \sin 45° = 10 \times 0.2 \times \dfrac{1}{\sqrt{2}} = \dfrac{2}{\sqrt{2}}\ N\ m^{-1}$

Q 14. Which one of the following is correct statement about magnetic forces?

a. Magnetic forces always obey Newton's third law

b. Magnetic forces do not obey Newton's third law

c. For very high current, magnetic forces obey Newton's third law

d. Inside low magnetic field, magnetic forces obey Newton's third law

Ans. (b) Magnetic forces do not obey Newton's third law.

Q 15. If the velocity of charged particle has both perpendicular and parallel components while moving through a magnetic field, what is the path followed by a charged particle?

a. Circular b. Elliptical c. Linear d. Helical

Ans. (d) Helical

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The component of velocity perpendicular to magnetic field gives a circular path whereas the component parallel to magnetic field gives a straight line path. Thus overall, the particle traces a helical path.

Q 16. Two charged particles traverse identical helical paths in a completely opposite sense in a uniform magnetic field $\vec{B} = B_0 \hat{k}$.

a. They have equal z-components of momenta.

b. They must have equal charges.

c. They necessarily represent a particle-antiparticle pair.

d. The charge to mass ratio satisfy:

$$\left(\frac{e}{m}\right)_1 + \left(\frac{e}{m}\right)_2 = 0$$

Ans. (d) The charge to mass ratio satisfy:

$$\left(\frac{e}{m}\right)_1 + \left(\frac{e}{m}\right)_2 = 0$$

In the present situation the charge to mass ratio (e/m) of these two particles is same and charges on them are of opposite character. Hence, the situation given in option (d) holds good.

Q 17. A charged particle is moving in a circle of radius R with constant speed v, under the influence of a uniform magnetic field. The time period of motion:

a. depends on both R and v

b. depends on v and not on R

c. depends on R and not on v

d. is independent of both R and v

Ans. (d) is independent of both R and v.

T!P

Time period of one revolution, $T = \dfrac{2\pi m}{qB}$

Q 18. A charged particle enters a magnetic field H with its initial velocity making an angle of 45° with H. The path of the particle will be:

a. a straight line b. a circle

c. an ellipse d. a helix

Ans. (d) a helix.

T!P

When $\vec{v}$ and $\vec{H}$ are not perpendicular or parallel, the charged particle moves in a helical path.

Q 19. If a charged particle enters a magnetic field, then it will:

a. always experience a force by the magnetic field

b. never experience any force

c. experience a force, if it is moving at right angles to the field

d. experience a force, if it is moving parallel to the field

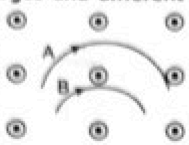
Ans. (c) experience a force, if it is moving at right angles to the field.

Q 20. A charge q moving in a staight line is accelerated by a potential difference V. It enters a uniform magnetic field B, perpendicular to its path. Then the radius of the circular path in which it travels will be:

a. $\sqrt{\dfrac{2mV}{qB^2}}$ b. $\sqrt{\dfrac{mV}{qB^2}}$ c. $\sqrt{\dfrac{qB^2}{2mV}}$ d. $\sqrt{\dfrac{qB^2}{mV}}$

Ans. (a) $\sqrt{\dfrac{2mV}{qB^2}}$

Q 21. Two particles A and B with same charges and different masses (m_A and m_B respectively) are moving in a plane inside uniform magnetic field which is perpendicular to the plane. The speed of the particles are v_A and v_B respectively and the trajectories are as shown in figure. Then:



a. $m_A v_A < m_B v_B$ b. $m_A v_A > m_B v_B$
c. $m_A < m_B$ and $v_A < v_B$ d. $m_A = m_B$ and $v_A < v_B$

Ans. (b) $m_A v_A > m_B v_B$

Radius of circular path,

$$r_A = \frac{m_A v_A}{qB} \text{ and } r_B = \frac{m_B v_B}{qB}$$

According to question, $r_A < r_B$

$$\therefore \quad \frac{m_A v_A}{qB} > \frac{m_B v_B}{qB} \text{ or } m_A v_A > m_B v_B$$

Q 22. What uniform magnetic field applied perpendicular to a beam of electrons moving at 1.3×10^6 ms^{-1}, is required to make the electrons travel in a circular arc of radius 0.35 m?

a. 2.1×10^{-5} G b. 6×10^{-5} T
c. 2.1×10^{-5} T d. 6×10^{-5} G

Ans. (c) 2.1×10^{-5} T.

Radius, $r = \frac{mv}{qB}$ or $B = \frac{mv}{qr}$

$$= \frac{9.1 \times 10^{-31} \times 1.3 \times 10^6}{1.6 \times 10^{-19} \times 0.35}$$

$$= 2.1 \times 10^{-5} \text{ T}$$

Q 23. A charged particle is moving on circular path with velocity v in a uniform magnetic field B, if the velocity of the charged particle is doubled and strength of magnetic field is halved, then radius becomes:

a. 8 times b. 4 times c. 2 times d. 16 times

Ans. (b) 4 times.

As $Bqv = \frac{mv^2}{r}$ or $r = \frac{mv}{Bq}$

According to the question, $v' = 2v$ and $B' = \frac{B}{2}$

$$\therefore \quad r' = \frac{mv'}{B'q} = \frac{m(2v)}{(B/2)q} = \frac{4mv}{Bq} = 4r$$

Q 24. A A deuteron of kinetic energy 50 keV is describing a circular orbit of radius 0.5 m in a plane perpendicular to the magnetic field $\vec{B}$. The kinetic energy of the proton that describes a circular orbit of same radius and inside same $\vec{B}$ is:

a. 25 keV b. 50 keV c. 200 keV d. 100 keV

Ans. (d) 100 keV

$$KE = \frac{q^2B^2r^2}{2m}$$

$$\Rightarrow \quad KE \propto \frac{1}{m} \Rightarrow KE = 100 \text{ keV}$$

Q 25. Two α-particles have the ratio of their velocities as 3 : 2 on entering the magnetic field. If they move in different circular paths, then the ratio of the radii of their paths is:

a. 2 : 3 b. 3 : 2 c. 9 : 4 d. 4 : 9

Ans. (b) 3 : 2

As $qvB = \frac{mv^2}{r}$

$$\therefore \quad r = \frac{mv}{qB} \Rightarrow r \propto v \text{ or } \frac{r_A}{r_B} = \frac{v_A}{v_B} = \frac{3}{2}$$

Q 26. An electron of energy 1800 eV describes a circular path in magnetic field of flux density 0.4 T. The radius of path is ($q = 1.6 \times 10^{-19}$ C, $m_e = 9.1 \times 10^{-31}$ kg)

a. 2.58×10^{-4} m b. 3.58×10^{-4} m
c. 2.58×10^{-3} m d. 3.58×10^{-3} m

Ans. (b) 3.58×10^{-4} m.

$$E = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{2E}{m}} \quad (\because m_e = m)$$

$$r = \frac{mv}{Be} = \frac{m}{Be}\sqrt{\frac{2E}{m}} = \frac{\sqrt{2mE}}{Be}$$

$$r = \frac{\sqrt{2 \times 1800 \times 1.6 \times 10^{-19} \times 9.1 \times 10^{-31}}}{1.6 \times 10^{-19} \times 0.4}$$

$$= 3.58 \times 10^{-4} \text{ m}$$

Q 27. An electron having momentum 2.4×10^{-23} kg m s^{-1} enters a region of uniform magnetic field of 0.15 T. The field vector makes an angle of 30° with the initial velocity vector of the electron. The radius of the helical path of the electron in the field shall be:

a. 2 mm b. 1 mm c. $\frac{\sqrt{3}}{2}$ mm d. 0.5 mm

Ans. (d) 0.5 mm.

The radius of the helical path of the electron in the uniform magnetic field is

$$r = \frac{mv_\perp}{eB} = \frac{mv\sin\theta}{eB}$$

$$= \frac{(2.4 \times 10^{-23} \text{ kg m s}^{-1}) \times \sin 30°}{(1.6 \times 10^{-19} \text{ C}) \times (0.15 \text{ T})}$$

$$= 5 \times 10^{-4} \text{ m} = 0.5 \times 10^{-3} \text{ m} = 0.5 \text{ mm}.$$

Q 28. A charged particle is released from a rest in a region, having steady and uniform electric and magnetic fields. If the two fields are parallel to each other, then the path of the particle will be:

a. ellipse b. circle c. helix d. straight line

Ans. (d) straight line

Here, $\theta = 0$

So, force due to magnetic field, $F_m = 0$

Hence, there is no effect of magnetic field on moving charged particle. So the particle will move due to electrostatic force only and follow straight line path.

Q 29. A charged particle moves along a circle under the action of magnetic and electric fields, then this region of space may have:

a. $E = 0, B = 0$ b. $E = 0, B \neq 0$
c. $E \neq 0, B = 0$ d. $E \neq 0, B \neq 0$

Ans. (b) $E = 0, B \neq 0$.

A charged particle moves in a straight line under the action of an electric field whereas it moves in a circular path under the action of a magnetic field. Thus, for the particle moving in a circular path, $E = 0, B \neq 0$.

Q 30. A charged particle with charge 'q', enters a region of constant, uniform and mutually orthogonal fields E B, with velocity v perpendicular to both E and B. The particle comes out without any change in magnitude or direction of its velocity. Then:

a. $\vec{v} = \frac{\vec{E}\times\vec{B}}{E^2}$ b. $\vec{v} = \frac{\vec{E}\times\vec{B}}{B^2}$ c. $\vec{v} = \frac{\vec{B}\times\vec{E}}{E^2}$ d. $\vec{v} = \frac{\vec{B}\times\vec{E}}{B^2}$

Ans. (b) $\vec{v} = \frac{\vec{E}\times\vec{B}}{B^2}$

Force acting on a particle under both electric and magnetic field is $\vec{F} = q\vec{E} + q(\vec{v}\times\vec{B}) = 0$ (since neither direction nor magnitude changes)

Taking cross product with $\vec{B}$ on both sides.

$$0 = q\vec{E}\times\vec{B} + q(\vec{v}\times\vec{B})\times\vec{B}$$

$$= q\vec{E}\times\vec{B} + q(\vec{v}\cdot\vec{B})\vec{B} - \vec{v}B^2$$

$$\vec{v} = \vec{E}\times\vec{B}/B^2 \qquad (\because \vec{v}\cdot\vec{B} = 0)$$

Q 31. Biot-Savart law indicates that the moving electrons (velocity $\vec{v}$) produce a magnetic field $\vec{B}$ such that:

(NCERT EXEMPLAR)

a. $\vec{B}\perp\vec{v}$ b. $\vec{B}\parallel\vec{v}$

c. it obeys inverse cube law.

d. it is along the line joining the electron and point of observation.

Ans. (a) $\vec{B}\perp\vec{v}$

Magnetic field produced by charges moving with velocity $\vec{v}$, at a distance r is $\vec{B} = \left(\frac{\mu_0}{4\pi}\right)\cdot q\frac{\vec{v}\times\hat{r}}{r^2}$.

Therefore $\vec{B}\perp\vec{v}$.

Q 32. For the magnetic field to be maximum due to a small element of current carrying conductor at a point, the angle between the element and the line joining the element to the given point must be:

a. 0° b. 90° c. 180° d. 45°

Ans. (b) 90°

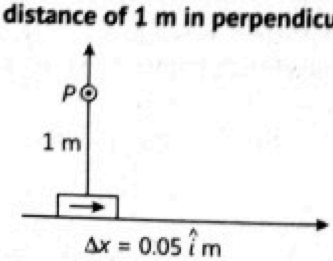
The magnetic field due to small element of current carrying conductor of length l is given by

$$dB = \frac{\mu_0}{4\pi}\frac{idl\sin\theta}{r^2}$$

This value will be maximum when

$$\sin\theta = 1 = \sin 90° \Rightarrow \theta = 90°$$

Q 33. An element of $0.05\,\hat{i}$ m is placed at the origin as shown in figure which carries a large current of 10 A. The magnetic field at a distance of 1 m in perpendicular direction is:



a. 4.5×10^{-8} T b. 5.5×10^{-8} T

c. 5.0×10^{-8} T d. 7.5×10^{-8} T

Ans. (c) 5.0×10^{-8} T

$$dB = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$$

Here, $dl = \Delta x = 0.05$ m, $I = 10$ A, $r = 1$ m

$\sin\theta = \sin 90° = 1$

$\therefore$ $dB = 10^{-7}\times\frac{10\times0.05\times1}{(1)^2}$

$= 0.50\times10^{-7} = 5.0\times10^{-8}$ T

Q 34. The magnitude of the magnetic field of a long straight wire carrying a current of 1 A at a distance of 2 cm is:

a. 10^{-5} T b. 10^{-7} T c. 2×10^{-7} T d. 2×10^{-5} T

Ans. (a) 10^{-5} T

Here, $I = 1$ A, $x = 2$ cm $= 0.02$ cm

Magnetic field, $B = \frac{\mu_0 I}{2\pi x}$

$= \frac{4\pi\times10^{-7}\times1}{2\pi\times0.02} = 100\times10^{-7} = 10^{-5}$ T.

Q 35. A straight wire of diameter 1 mm carries a current of 1 A. It is replaced by another wire of diameter 2 mm, carrying same current. The strength of the magnetic field is:

a. twice the former value

b. one half of the former value

c. same as the former value

d. one quarter of the former value

Ans. (c) same as the former value

We know that, $B = \frac{\mu_0 I}{2\pi x}$

The field due to current carrying wire is independent of the diameter of the wire.

Q 36. A current loop in a magnetic field:

a. experiences a torque whether the field is uniform or non-uniform in all orientations

b. can be in equilibrium in one orientation

c. can be equilibrium in two orientations, both the equilibrium states are unstable

d. can be in equilibrium in two orientations, one stable while the other is unstable.

Ans. (d) can be in equilibrium in two orientations, one stable while the other is unstable.

Q 37. A circular coil of radius a carries an electric current. The magnetic field due the coil at a point on the axis of the coil located at a distance r from centre of the coil, such that $r >> a$ varies:

a. $\frac{1}{r}$ b. $\frac{1}{r^2}$ c. $\frac{1}{r^3}$ d. $\frac{1}{r^{3/2}}$

Ans. (c) $\frac{1}{r^3}$

$$B = \frac{\mu_0 I a^2}{2(a^2+r^2)^{3/2}} = \frac{\mu_0 I a^2}{2r^3} \text{ for } r^2 + a^2 \approx r^2.$$

Q 38. A circular loop of radius 3 cm is having a current of 12.5 A. The magnitude of magnetic field at a distance of 4 cm on its axis is:

a. 5.65×10^{-5} T b. 5.27×10^{-5} T

c. 6.54×10^{-5} T d. 9.20×10^{-5} T

Ans. (a) 5.65×10^{-5} T

$$B = \frac{\mu_0 I R^2}{2(R^2+x^2)^{3/2}}$$

Here, $I = 12.5\text{ A}, R = 3\text{ cm} = 3\times10^{-2}\text{ m}$

$x = 4\text{ cm} = 4\times10^{-2}\text{ m}$

$\therefore \quad B = \frac{4\pi\times10^{-7}\times12.5\times(3\times10^{-2})^2}{2[(3\times10^{-2})^2+(4\times10^{-2})^2]^{3/2}} = 5.65\times10^{-5}\text{ T}.$

Q 39. A straight wire carrying a current of 13 A is bent into a semi-circular arc of radius 2 cm as shown in figure. The magnetic field is 1.5×10^{-4} T at the centre of arc, then the magnetic field due to straight segment is:

a. 1.5×10^{-4} T
b. 2.5×10^{-4} T
c. zero
d. 3×10^{-4} T

Ans. (c) zero.

Since dl and r for each element of the straight segments are parallel. Therefore

$$\vec{dl}\times\vec{r} = 0$$

Hence, B is also zero.

Q 40. A wire in the form of a circular loop, of one turn carrying a current, produces magnetic induction B at the centre. If the same wire is looped into a coil of two turns and carries the same current, the new value of magnetic induction at the centre is:

a. B b. $2B$ c. $4B$ d. $8B$

Ans. (c) $4B$.

$$B = \frac{\mu_0 I}{2r}, B' = \frac{\mu_0(2)I}{2(r/2)} = 4B$$

Q 41. A long wire carries a steady current. It is bent into a circle of one turn and the magnetic field at the centre of the coil is B. It is then bent into a circular loop of smaller radius, having 'n' turns. The magnetic field at the centre of the coil will be:

a. nB b. n^2B c. $2nB$ d. $2n^2B$

Ans. (b) n^2B.

Magnetic field at the centre of this wire,

$$B = \frac{\mu_0 I}{2R} \quad ...(1)$$

The same wire is bent into a circular loop of 'n' turns.

New radius is given by,

$$n\times2\pi r = 2\pi R \Rightarrow r = \frac{R}{n}$$

Thus, magnetic field at the centre of this loop $= \frac{\mu_0 nI}{2r}$

$$= \frac{\mu_0 nI}{2R}\times n = n^2\frac{\mu_0 I}{2R} = n^2B \quad \text{(from (1))}$$

Q 42. A circular coil of wire consisting of 100 turns each of radius 9 cm carries a current of 0.4 A. The magnitude of magnetic field at the centre of the coil is:

a. 2.4×10^{-4} T
b. 3.5×10^{-4} T
c. 2.79×10^{-4} T
d. 3×10^{-4} T

Ans. (c) 2.79×10^{-4} T.

Here $N = 100$

$R = 9\text{ cm} = 9\times10^{-2}$ m and $I = 0.4$ A

Now, $B = \frac{\mu_0 NI}{2R} = \frac{2\pi\times10^{-7}\times100\times0.4}{9\times10^{-2}}$

$= \frac{2\times3.14\times0.4}{9}\times10^{-3} = 0.279\times10^{-3}\text{ T} = 2.79\times10^{-4}\text{ T}$

Q 43. The magnitude of the magnetic field at the centre of the tightly wound 150 turn coil of radius 12 cm carrying a current of 2 A is:

a. 18 G
b. 19.7 G
c. 15.7 G
d. 17.7 G

Ans. (c) 15.7 G

Here, $N = 150, R = 12\text{ cm} = 12\times10^{-2}\text{ m}, I = 2\text{ A}$

$\therefore \quad B = \frac{\mu_0 NI}{2R} = \frac{4\pi\times10^{-7}\times150\times2}{2\times12\times10^{-2}} = 1.57\times10^{-3}\text{ T}$

$= 1.57\times10^{-3}\text{ T} = 15.7\times10^{-4}\text{ T} = 15.7\text{ G}$

Q 44. A tightly wound 90 turn coil of radius 15 cm has a magnetic field of 4×10^{-4} T at its centre. The current flowing through it is:

a. 1.06 A
b. 2.44 A
c. 3.44 A
d. 4.44 A

Ans. (a) 1.06 A

Here, $N = 90$

$R = 15\text{ cm} = 15\times10^{-2}\text{ m}, B = 4\times10^{-4}\text{ T}$

$\because \quad B = \frac{\mu_0 NI}{2R}$

$\therefore \quad I = \frac{2RB}{N\mu_0} = \frac{2\times15\times10^{-2}\times4\times10^{-4}}{4\pi\times10^{-7}\times90} = 1.06\text{ A}$

Q 45. A circular current loop of magnetic moment M is in an arbitrary orientation in an external magnetic field $\vec{B}$. The work done to rotate the loop by 30° about an axis prependicular to its plane is: *[NCERT EXEMPLAR]*

a. MB
b. $\sqrt{3}\frac{MB}{2}$
c. $\frac{MB}{2}$
d. zero

Ans. (d) zero

Rotation of loop by 30° about an axis perpendicular to its plane does not change the angle between magnetic moment and magnetic field. Hence, no work is done.

Q 46. A current carrying circular loop of radius R is placed in the X-Y plane with centre at the origin. Half of the loop with $x > 0$ is now bent so that it now lies in the Y-Z plane. *[NCERT EXEMPLAR]*

a. The magnitude of magnetic moment now diminishes.
b. The magnetic moment does not change.
c. The magnitude of $\vec{B}$ at $(0, 0, z)$, $z >> R$ increases.
d. The magnitude of $\vec{B}$ at $(0, 0, z)$, $z >> R$ is unchanged.

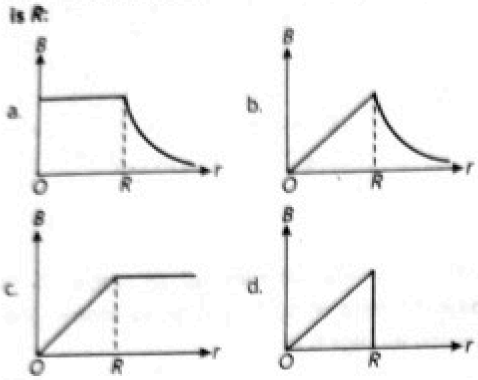
Ans. (c) The magnitude of $\vec{B}$ at $(0, 0, z)$, $z >> R$ increases.

Q 47. Ampere's circuital law is given by:

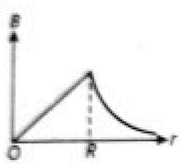
a. $\oint\vec{H}\cdot\vec{dl} = \mu_0 I_{enc}$
b. $\oint\vec{B}\cdot\vec{dl} = \mu_0 I_{enc}$
c. $\oint\vec{B}\cdot\vec{dl} = \mu_0 J$
d. $\oint\vec{H}\cdot\vec{dl} = \mu_0 J$

Ans. (b) $\oint\vec{B}\cdot\vec{dl} = \mu_0 I_{enc}$

Q 48. The correct plot of the magnitude of magnetic field $\vec{B}$ vs distance r from centre of the wire is, if the radius of wire is R:



Ans. (b)



The magnetic field from the centre of wire of radius R is given by

$B = \left(\frac{\mu_0 I}{2R^2}\right) r$ (for $r < R$) $\Rightarrow B \propto r$ and $B = \frac{\mu_0 I}{2\pi r} (r > R) \Rightarrow B \propto \frac{1}{r}$

From this description, we can say that the graph (b) is a correct representation.

Q 49. A current I flows along the length of an infinitely long, straight thin walled pipe. Then:

a. the magnetic field is same at all points, inside the pipe but not zero
b. the magnetic field at any point inside the pipe is zero
c. the magnetic field is zero only on the axis of the pipe
d. the magnetic field is different at different points inside the pipe

Ans. (b) the magnetic field at any point inside the pipe is zero.
Using Ampere circuital law over a circular loop of any radius less than the radius of the pipe, we can see that net current inside the loop is zero.
Hence, magnetic field at every point inside the loop will be zero.

Q 50. A long straight wire in the horizontal plane carries a current of 75 A in north to south direction, magnitude and direction of field B at a point 3 m east of the wire is:

a. 4×10^{-6} T, vertical up b. 5×10^{-6} T, vertical down
c. 5×10^{-6} T, vertical up d. 4×10^{-6} T, vertical down

Ans. (c) 5×10^{-6} T, vertical up.
From Ampere circuital law

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{enc}$$
$$B \times 2\pi R = \mu_0 I_{enc}$$
$$B = \frac{\mu_0 I_{enc}}{2\pi R} = 2 \times 10^{-7} \times \frac{75}{3} = 5 \times 10^{-6} \text{ T}$$

The direction of field at the given point will be vertical up determined by the screw rule or right-hand rule.

Q 51. An electric current passes through a long straight wire. At a distance of 4 cm from the wire, the magnetic field is B. The magnetic field at 12 cm from the wire would be:

a. $B/6$ b. $B/3$ c. $B/4$ d. $B/2$

Ans. (b) $B/3$

In a long straight wire,

$$B = \frac{\mu_0 I}{2\pi r} \Rightarrow B \propto \frac{1}{r}$$
$$\therefore \frac{B}{B_1} = \frac{r_2}{r_1} \Rightarrow \frac{B}{B_1} = \frac{12}{4} = 3$$
$$\Rightarrow B = 3B_1 \text{ or } B_1 = B/3.$$

Q 52. Ampere circuital law is used to find the:

a. direction of current
b. direction of magnetic field
c. direction of magnetic motion of conductor
d. magnitude of current

Ans. (b) direction of magnetic field.

Q 53. A solid cylindrical wire of radius R carries a current I. The ratio of magnetic field at points which are located at $R/2$ and $2R$ distance away from the axis of the wire is:

a. 1 : 1 b. 1 : 2 c. 2 : 1 d. 1 : 4

Ans. (a) 1 : 1.

We know that, $B_{out} = \frac{\mu_0 I}{2\pi r} (r > R)$

Here, $r = 2R$

$$\therefore B_{out} = \frac{\mu_0 I}{2\pi \times 2R} = \frac{\mu_0 I}{4\pi R} \quad ...(i)$$

Also, $B_{in} = \frac{\mu_0 I r}{2\pi R^2} (r < R)$

Here, $r = R/2$

$$\therefore B_{in} = \frac{\mu_0 I R/2}{2\pi R^2} = \frac{\mu_0 I}{4\pi R} \quad ...(ii)$$

Required ratio, $\frac{B_{in}}{B_{out}} = \frac{1}{1}$.

Q 54. An electron is projected with uniform velocity along the axis of a current carrying long solenoid. Which of the following is true? *[NCERT EXEMPLAR]*

a. The electron will be accelerated along the axis.
b. The electron path will be circular about the axis.
c. The electron will experience a force at 45° to the axis and hence execute a helical path.
d. The electron will continue to move with uniform velocity along the axis of the solenoid.

Ans. (d) The electron will continue to move with uniform velocity along the axis of the solenoid.

Q 55. A solenoid has 1000 turns per metre length. If a current of 5 A is flowing through it, then magnetic field inside the solenoid is:

a. $2\pi \times 10^{-3}$ T b. $2\pi \times 10^{-5}$ T
c. $4\pi \times 10^{-3}$ T d. $4\pi \times 10^{-5}$ T

Ans. (a) $2\pi \times 10^{-3}$ T

$$B = \mu_0 nI = 4\pi \times 10^{-7} \times 5 \times 1000 = 2\pi \times 10^{-3} \text{ T}.$$

Q 56. A solenoid coil of 200 turns/m is carrying a current of 3 A. The length of the solenoid is 0.2 m and has a diameter of 1 cm. The magnitude of the magnetic field inside the solenoid is:

a. $12\pi \times 10^{-5}$ T b. $24\pi \times 10^{-5}$ T
c. $12\pi \times 10^{-4}$ T d. $48\pi \times 10^{-6}$ T

Ans. (b) $24\pi \times 10^{-5}$ T.

$$B = \mu_0 nI$$
$$= 4\pi \times 10^{-7} \times 200 \times 3 = 24\pi \times 10^{-5} \text{ T}$$

Q 57. A solenoid of 1.5 m length and 4.0 m diameter possesses 10 turns/cm. A current of 5 A is flowing through it. The magnetic induction of axis inside the solenoid is:

a. $2\pi \times 10^{-3}$ T
b. $2\pi \times 10^{-5}$ T
c. $2\pi \times 10^{-3}$ G
d. $2\pi \times 10^{-5}$ G

Ans. (a) $2\pi \times 10^{-3}$ T

Magnetic field, $B = \mu_0 nI = 4\pi \times 10^{-7} \times 5 \times 1000$
$= 2\pi \times 10^{-3}$ T
($\because n = 10$ turns/cm or $n = 1000$ turns/m)

Q 58. A solenoid of length 0.6 m has a radius of 2 cm and is made up of 600 turns. If it carries a current of 4 A, then the magnitude of the magnetic field inside the solenoid is:

a. 6.024×10^{-3} T
b. 8.024×10^{-3} T
c. 5.024×10^{-3} T
d. 7.024×10^{-3} T

Ans. (c) 5.024×10^{-3} T.

Here, $n = \frac{600}{0.6} = 1000$ turns/m, $I = 4$ A

$l = 0.6$ m, $r = 0.02$ m $\because \frac{l}{r} = 30$ i.e., $l >> r$

Hence, we can use long solenoid formula, then

$\therefore \quad B = \mu_0 nI = 4\pi \times 10^{-7} \times 10^3 \times 4 = 50.24 \times 10^{-4}$
$= 5.024 \times 10^{-3}$ T.

Q 59. A solenoid of length 50 cm, having 100 turns carries a current of 2.5 A. The magnetic field at one end of the solenoid is:

a. 3.14×10^{-4} T
b. 6.28×10^{-4} T
c. 1.57×10^{-4} T
d. 9.42×10^{-4} T

Ans. (a) 3.14×10^{-4} T

Here, $I = 2.5$ A, $l = 50$ cm $= 0.50$ m

and $n = \frac{100}{0.50} = 200\ \text{m}^{-1}$

$\therefore \quad B = \frac{\mu_0 nI}{2} = \frac{4\pi \times 10^{-7} \times 200 \times 2.5}{2} = 3.14 \times 10^{-4}$ T.

Q 60. In which form the field lines inside the infinite solenoid are present?

a. Perpendicular straight lines
b. Circular lines
c. Ellipsoidal lines
d. Parallel straight lines

Ans. (d) Parallel straight lines.

Q 61. The magnetic field generated along the axis of a solenoid is proportional to:

a. its length.
b. square of current flowing in it.
c. number of turns per unit length.
d. reciprocal of its radius.

Ans. (c) number of turns per unit length.

Q 62. A long solenoid has magnetic field strength of 3.14×10^{-2} T inside it when a current of 5A passes through it. The number of turns in 1m length of the solenoid is:

a. 1000 b. 3000 c. 10000 d. 5000

Ans. (d) 5000.

We know that, $B = \mu_0 nI$

$\Rightarrow \quad n = \frac{B}{\mu_0 I} = \frac{3.14 \times 10^{-2}}{4\pi \times 10^{-7} \times 5}$

$= \frac{3.14 \times 10^{-2} \times 10^7}{4 \times 3.14 \times 5} = \frac{10^5}{20} = 5000$

Q 63. The magnitude of magnetic induction for a current carrying toroid of uniform cross-section is:

a. uniform over the whole cross-section
b. maximum at the centre of cross-section
c. maximum on the outer edge
d. maximum on the inner edge.

Ans. (a) uniform over the whole cross-section.

Q 64. Which one of the following statements is correct?

a. The magnetic field in the open space inside the toroid is constant.
b. The magnetic field in the open space exterior to the toroid is constant.
c. The magnetic field inside the core of toroid is constant.
d. The magnetic field inside the core of toroid is zero.

Ans. (c) The magnetic field inside the core of toroid is constant.

Q 65. A toroid having 200 turns carries a current of 1A. The average radius of the toroid is 10 cm. The magnetic field at any point in the open space inside the toroid is:

a. 4×10^{-3} T
b. zero
c. 0.5×10^{-3} T
d. 3×10^{-3} T

Ans. (b) zero.

Magnetic field $\vec{B}$ at any point inthe open space inside the toroid is zero, because the amperean loop enclose net current equals zero.

Q 66. The current in the windings on a toroid is 2.0 A. There are 400 turns and the mean circumferential length is 40 cm. If the inside magnetic field is 1.0 T, the relative permeability is near to:

a. 100 b. 200 c. 300 d. 400

Ans. (d) 400.

Magnetic field, $B = \frac{\mu_0 \mu_r NI}{2\pi r}$

$1.0 = \frac{4\pi \times 10^{-7} \times \mu_r \times 400 \times 2}{40 \times 10^{-2}}$

$\Rightarrow \quad \mu_r \approx 400$

Q 67. The two parallel conductors carry equal currents in the same direction. What is the nature of the force acting between them?

a. Repulsive
b. Attractive
c. Can not predict
d. No force

Ans. (c) Attractive.

T!P

Parallel currents attract and anti-parallel currents repel in nature.

Q 68. Two thin, long parallel wires, separated by a distance (d) carry a current of i A in the same direction. They will:

a. attract each other with a force per unit length of $\mu_0 i^2/(2\pi d)$
b. repel each other with a force per unit length of $\mu_0 i^2/(2\pi d)$
c. attract each other with a force per unit length $\mu_0 i^2/(2\pi d^2)$
d. repel each other with a force of per unit length $\mu_0 i^2/(2\pi d^2)$

Ans. (a) attract each other with a force per unit length of $\mu_0 i^2/(2\pi d)$.

Q 69. If distance between two current carrying wires is doubled, then force between them is:

a. halved b. doubled c. tripled d. quadrupled

Ans. (a) halved.

The force acting on one wire due to currents through two wires is inversely proportional to the distance between them. Thus, the force become half if the distance between the wires is doubled.

Q 70. Two parallel wires 2m apart carry currents of 2A and 5A respectively in same direction, the force per unit length acting between the two wires is:

a. 2×10^{-6} N/m b. 3×10^{-6} N/m
c. 1×10^{-6} N/m d. 4×10^{-6} N/m

Ans. (c) Given, $I_1 = 2$ A, $I_2 = 5$ A, $d = 2$ m

$$\therefore \quad f = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{d} = 10^{-7}\times\frac{2\times2\times5}{2} = 1\times10^{-6}\text{ N/m}$$

Q 71. A conductor of length 2 m carrying current 2A is held parallel to an infinitely long conductor carrying current of 12 A at a distance of 100 mm, the force on small conductor is:

a. 8.6×10^{-5} N b. 6.6×10^{-5} N
c. 7.6×10^{-5} N d. 9.6×10^{-5} N

Ans. (d) 9.6×10^{-6} N

Here, $I_1 = 2$ A, $I_2 = 12$ A, $d = 100$ mm $= 0.1$ m, $l = 2$ m

Now total force on length l of small conductor

$$F = \frac{\mu_0}{4\pi}\times\frac{2I_1I_2}{d}l = \frac{10^{-7}\times2\times2\times12\times2}{0.1} = 9.6\times10^{-5}\text{ N}$$

Q 72. Two wires are kept parallel and carry equal currents separated by 2 cm apart, They experience an attractive force of 16×10^{-5} newton per unit length, find the current flowing in the two wires.

a. 16×10^{-5} A b. 16 A
c. 4 A d. 1 A

Ans. (c) 4 A.

Here $I_1 = I_2 = I$, $F = 16\times10^{-5}$ N/m, $d = 2$ cm

$$F = \frac{\mu_0 2I_1I_2}{4\pi d} = \frac{\mu_0}{4\pi}\frac{2I^2}{d}$$

$$16\times10^{-5} = 10^{-7}\times\frac{2\times I^2}{2\times10^{-2}}$$

$$\Rightarrow \quad I^2 = \frac{16\times10^{-5}}{10^{-5}} = 16 \Rightarrow I = 4\text{ A.}$$

Q 73. Two long straight wires carrying the same current and separated by a distance r, exert force F per unit length on each other. If the current is decreased to $I/2$ and separation between them is increased to $2r$, then force will become:

a. $8F$ b. $2F$ c. $F/2$ d. $F/8$

Ans. (d) $F/8$.

It is given that $I_1 = I_1 = I$

$$\therefore \quad \text{Force, } F = \frac{\mu_0}{4\pi}\frac{2I^2}{r} \quad ...(1)$$

Now, $I' = I/2$ and $r = 2r$

$$\text{So New force } F' = \frac{\mu_0}{4\pi}\frac{2(I/2)^2}{2r} = \frac{\mu_0}{4\pi}\frac{2I^2}{8r}$$

$$= \frac{1}{8}\left(\frac{\mu_0}{4\pi}\frac{2I^2}{r}\right) = \frac{1}{8}F \quad \text{(from eq.(1))}$$

Q 74. A current carrying loop is placed in a non-uniform magnetic field. It will experience:

a. a force of repulsion b. a force of attraction
c. a torque but no force d. a force and a torque

Ans. (d) a force and a torque.

Q 75. The magnetic moment of a current I carrying circular coil of radius r and number of turns N varies as:

a. $\frac{1}{r^2}$ b. $\frac{1}{r}$ c. r d. r^2

Ans. (d) r^2.

Magnetic Moment, $M = NIA = NI\pi r^2$

$$\Rightarrow \quad M \propto r^2.$$

Q 76. A small circular flexible loop of wire of radius r carries a current I. It is placed in a uniform magnetic field B. The tension in the loop will be doubled if:

a. I is doubled b. B is halved
c. r is doubled d. both B and I are doubled

Ans. (a) I is doubled.

$M = IA$ when I is doubled, M is doubled.

Also, $\tau = MB\sin\theta$, when M is doubled, torque is doubled, hence tension is doubled.

Q 77. A 200 turn closely wound circular coil of radius 15 cm carries a current of 4 A. The magnetic moment of this coil is:

a. 36.5 Am^2 b. 56.5 Am^2
c. 66.5 Am^2 d. 108 Am^2

Ans. (b) 56.5 A m^2.

The magnetic moment is given by

$$|\vec{M}| = NIA = NI\pi r^2 = 200\times4\times3.14\times(15\times10^{-2})^2$$

$$= 200\times4\times3.14\times15\times15\times10^{-4} = 56.5\text{ Am}^2.$$

Q 78. The magnetic moment associated with a circular coil of 35 turns and radius 25 cm, if it carries a current of 11 A is:

a. 72.2 A m^2 b. 70.5 A m^2
c. 74.56 A m^2 d. 75.56 A m^2

Ans. (d) 75.56 A m^2.

Given, $N = 35$, $r = 25$ cm $= 25\times10^{-2}$ m, $I = 11$A

Then magnetic moment associated with this circular coil

$$M = NIA = NI\pi r^2 = 35\times11\times3.14\times(25\times10^{-2})^2$$

$$= 75.56\text{ A m}^2.$$

Q 79. The correct statement about magnetic moment is:

a. it is a vector quantity
b. its unit is Am^2
c. its dimensions are $[M^0 L^2 T^0 A^1]$
d. All of the above

Ans. (d) All of the above.

Q 80. A circular coil of one turn and area A carrying a current has a magnetic dipole moment M. The current through the coil is:

a. MA b. $\frac{A}{M}$ c. $\frac{M}{A}$ d. $\frac{M}{A^2}$

Ans. (c) $\frac{M}{A}$.

We know that $M = NIA$

$$\Rightarrow \quad I = \frac{M}{NA} = \frac{M}{1\times A} \quad \text{(Given that } N = 1)$$

$$\Rightarrow \quad I = \frac{M}{A}.$$

Q 81. Two wires of same length are shaped into a square and a circle if they carry same current, ratio of magnetic moment is:

a. $2:\pi$ b. $\pi:2$ c. $\pi:4$ d. $4:\pi$

Ans. (c) $\pi : 4$.

According to question,

Perimeter of square should be equal to circumference of circle

$\therefore$ $4a = 2\pi r \Rightarrow a = \pi r/2$ ...(1)

Magnetic moment of square wire,

$M_1 = I(A_1) = \frac{I\pi^2 r^2}{4}$ (from eq. (1)) ...(2)

Magnetic moment of circular wire,

$M_2 = I(A_2) = I\pi r^2$ ...(3)

Required ratio, $\frac{\mu_1}{\mu_2} = \frac{I\pi^2 r^2}{4} \times \frac{1}{I\pi r^2} = \frac{\pi}{4}$

Q 82. An electron having charge *e* moves in a circular orbit of radius *r*, with frequency ν. The magnetic moment associated with the orbital motion of the electron is:

a. $\pi\nu e r^2$ b. $\pi\nu r^2/e$ c. $\pi\nu\frac{e}{\nu}$ d. $\pi e\frac{r^2}{\nu}$

Ans. (a) $\pi\nu e r^2$.

Magnetic Moment, $M = IA$

We know that, $I = \frac{\text{charge}}{\text{time}}$ and time $= \frac{1}{\text{frequency}}$

$\therefore$ $I = \text{charge} \times \text{frequency} = e\nu$

$\Rightarrow$ $M = e\nu A = e\nu(\pi r^2)$

$= \pi\nu e r^2$

Q 83. A current carrying loop is placed in a uniform magnetic field. The torque acting on it does depend upon:

a. area of loop b. value of current

c. magnetic field d. All of these

Ans. (d) All of these.

Q 84. A current carrying loop is free to turn in a uniform magnetic field. The loop will then come to quilibrium when its place is inclined at:

a. 90° to the direction of field b. 0° to the direction of field

c. 45° to the direction of field d. 135° to the direction of field

Ans. (b) 0° to the direction of field.

A stable equilibrium is when the net torque on the loop is minimum. It is when the magnetic moment of the loop is along the direction of field, *i.e.*, $\theta = 0°$

$\Rightarrow$ $\tau = MB\sin\theta = MB\sin 0° = 0$.

Q 85. A rectangular coil of wire carrying a current is kept in a uniform magnetic field. The torque acting on the coil will be maximum when:

a. the plane of the coil is perpendicular to the field

b. the normal to the plane of the coil is parallel to the field

c. the normal to the plane of the coil is perpendicular to the field

d. the plane of the coil is making an angle of 45° with the field

Ans. (c) the normal to the plane of the coil is perpendicular to the field.

$\vec{\tau} = \vec{M} \times \vec{B}$

$= niAB\sin\theta$

So, $\sin\theta$ is maximum when $\theta = 90°$

and θ is normal between normal of plane of coil and field.

So, the normal to the plane of the coil should be perpendicular to the field to produce maximum torque.

Q 86. A rectangular loop carrying a current is placed in a uniform magnetic field *B*. The area enclosed by the loop is *A*. If there are *n* turns in the loop, the torque acting on the loop is given by:

a. $ni(\vec{A} \times \vec{B})$ b. $ni(\vec{A} \cdot \vec{B})$ c. $\frac{i(\vec{A} \times \vec{B})}{n}$ d. $\frac{i(\vec{A} \cdot \vec{B})}{n}$

Ans. (a) $ni(\vec{A} \times \vec{B})$.

$\vec{\tau} = \vec{M} \times \vec{B}$

$= ni(\vec{A} \times \vec{B})$ $(\because \vec{M} = ni\vec{A})$

Q 87. A circular coil of 70 turns and radius 5 cm carrying a current of 8 A is suspended vertically in a uniform horizontal magnetic field of magnitude 1.5 T. The field lines make an angle of 30° with the normal of the coil then the magnitude of the counter torque that must be applied to prevent the coil from turning is:

a. 33 N m b. 3.3 N m c. 3.3×10^{-2} N m d. 3.3×10^{-4} N m

Ans. (b) 3.3 N m.

Given, $N = 70, r = 5$ cm

$= 5 \times 10^{-2}$ m, $I = 8$ A

$B = 1.5$ T, $\theta = 30°$.

The counter torque to prevent the coil from turning will be equal and opposite to the torque acting on the coil.

$\therefore$ $\tau = NIAB\sin\theta = NI\pi r^2 B\sin 30°$

$= 70 \times 8 \times 3.14 \times (5 \times 10^{-2})^2 \times 1.5 \times \frac{1}{2}$

$= 3.297$ N m $= 3.3$ N m

Q 88. A circular coil of 25 turns and radius 12 cm is placed in a uniform magnetic field of 0.5 T normal to the plane of the coil. If the current in the coil is 6 A then total torque acting on the coil is:

a. zero b. 3.4 N m c. 3.8 N m d. 4.4 N m

Ans. (a) zero.

The torque acting on the coil

$|\vec{\tau}| = |\vec{M} \times \vec{B}| = MB\sin\theta$

Here the circular coil is placed normal to the direction of magnetic field then the angle between the direction of magnetic moment $(\vec{M})$ and magnetic field $(\vec{B})$ is zero, then

$\tau = MB\sin\theta = MB\sin 0° = 0 \therefore \tau = 0$

Q 89. The final torque on a coil having magnetic moment 25 Am^2 in a 5 T uniform external magnetic field, if the coil rotates through an angle of 60° under the influence of the magnetic field is:

a. 216.5 N m b. 108.25 N m

c. 102.5 N m d. 258.1 N m

Ans. (b) 108.25 N m.

$|\vec{\tau}| = |\vec{M} \times \vec{B}| = mB\sin\theta$

Here, $M = 25$ A m^2; $\theta = 60°$; $B = 5$ T

$\therefore$ $\tau = 25 \times 5 \times \sin 60°$

or $\tau = 125 \times \frac{\sqrt{3}}{2} = 108.25$ N m.

Q 90. The magnitude of torque experienced by a square coil of side 1.2 cm which consists of 25 turns and carries a current 10 A suspended vertically and the normal to the plane of coil makes an angle of 30° with the direction of a uniform horizontal magnetic field of magnitude 0.9 T is:

a. 1.6 Nm b. 1.2 Nm
c. 1.4 Nm d. 1.8 Nm

Ans. (a) 1.6 Nm.

$$\tau = NIAB\sin\theta$$

Here, $N = 25, I = 10\text{ A}, B = 0.9\text{ T}, \theta = 30°$

$A = a^2 = 12\times10^{-2}\times12\times10^{-2} = 144\times10^{-4}\text{ m}^2$

$\therefore \tau = 25\times10\times144\times10^{-4}\times0.9\times\sin30° = 1.6\text{ N m}.$

Q 91. The magnetic moment (μ_e) is directly proportional to orbital angular momentum (l), connected by a constant called the ....

a. Planck's constant b. nuclear susceptibility
c. Gyromagnetic ratio d. chemical shift

Ans. (c) Gyromagnetic ratio.

Q 92. The numerical value of Gyromagnetic ratio for an electron is given by:

a. $8.8\times10^{-12}\text{ C kg}^{-1}$ b. $8.8\times10^{10}\text{ C kg}^{-1}$
c. $1.6\times10^{-19}\text{ C kg}^{-1}$ d. $6.67\times10^{11}\text{ C kg}^{-1}$

Ans. (b) $8.8\times10^{10}\text{ C kg}^{-1}$.

The gyromagnetic ratio is a constant.

For any charged particle its value is given by $\frac{\mu_l}{l} = \frac{e}{2m}$

For electron $m = m_e = 9.1\times10^{-31}\text{ kg}, e = 1.6\times10^{-19}\text{ C}$,

$$\therefore \frac{\mu_l}{l} = \frac{1.6\times10^{-19}}{2\times9.1\times10^{-31}} = 8.8\times10^{10}\text{ C kg}^{-1}.$$

Q 93. What is the correct value of Bohr magneton?

a. $8.99\times10^{-24}\text{ A m}^2$ b. $9.27\times10^{-24}\text{ A m}^2$
c. $5.66\times10^{-24}\text{ A m}^2$ d. $9.27\times10^{-28}\text{ A m}^2$

Ans. (b) $9.27\times10^{-24}\text{ A m}^2$.

Bohr Magneton

$$(\mu_l)_{min} = \mu_B = \frac{e}{4\pi m_e}h$$

Here, $e = 1.6\times10^{-19}\text{ C}, h = 6.64\times10^{-34}\text{ J s}$

$m_e = 9.1\times10^{-31}\text{ kg}$

$$\therefore \mu_B = \frac{1.60\times10^{-19}\times6.64\times10^{-34}}{4\times3.14\times9.1\times10^{-31}}$$

$$= 9.27\times10^{-24}\text{ A m}^2$$

Q 94. In a moving coil galvanometer the deflection (ϕ) on the scale by a pointer attached to the spring is:

a. $\left(\frac{NA}{kB}\right)I$ b. $\left(\frac{N}{kAB}\right)I$ c. $\left(\frac{NAB}{k}\right)I$ d. $\left(\frac{NAB}{kI}\right)$

Ans. (c) $\left(\frac{NAB}{k}\right)I$.

Since magnetic torque on the coil, $\tau = NIAB$

This torque is balanced by counter torque

$$\therefore k\phi = NIAB \text{ or } \phi = \left(\frac{NAB}{k}\right)I$$

where k is torsional constant. It is a scalar quantity having dimension of torque or energy *i.e.*, $[ML^2T^{-2}]$.

Q 95. A galvanometer is said to be sensitive, if it gives a:

a. small deflection for a small current
b. small deflection for a large current
c. large deflection for a large current
d. large deflection for a small current

Ans. (d) large deflection for a small current.

Q 96. In a moving coil galvanometer, the magnetic pole pieces are made cylindrical and a soft iron core is placed at the centre of the coil, the purpose for doing so is:

a. to make the magnetic field strong
b. to make the magnetic field strong and radial
c. to make the magnetic field uniform
d. to make the magnetic field strong and uniform

Ans. (b) to make the magnetic field strong and radial.

Q 97. A moving coil type of galvanometer is based upon the principle that:

a. coil carrying current experiences a torque in magnetic field.
b. a coil carrying current produces a magnetic field
c. a coil carrying current experiences impulse in a magnetic field
d. a coil carrying current experiences a force in a magnetic field

Ans. (a) coil carrying current experiences a torque in magnetic field.

Q 98. Which of the following expressions are applicable to the moving coil galvanometer?

a. $\vec{F}_m = q(\vec{V}\times\vec{B})$ b. $B = B_0\tan\theta$
c. $\vec{\tau} = \vec{M}\times\vec{B}$ d. None of these

Ans. (c) $\vec{\tau} = \vec{M}\times\vec{B}$.

Q 99. The sensitivity of a galvanometer will increase if:

a. radius of coil is increased
b. number of turns in coil is decreased
c. radius of coil is decreased
d. a strong field is used

Ans. (a) radius of coil is increased.

Q 100. What is the shape of magnet in moving coil galvanometer to make the radial magnetic field?

a. Concave b. Horse shoe magnet
c. Convex d. None of these

Ans. (a) Concave.

Q 101. A small cylindrical soft iron piece is kept in galvanometer so that:

a. a radial uniform magnetic field is produced
b. a uniform magnetic field is produced
c. there is a steady deflection of the coil
d. All of the above

Ans. d. All of the above.

Q 102. Which of the following material is used in making the core of a moving coil galvanometer?

a. Copper b. Nickel
c. Iron d. Both a. and b.

Ans. (c) Iron.

Q 103. Among the following which can not be used to increase the voltage sensitivity of the galvanometer?

a. By increasing the area of the coil
b. By increasing the magnetic field
c. By decreasing the couple per unit twist
d. By increasing the number of turns

Ans. (d) By increasing the number of turns

Q 104. If the current sensitivity of a galvanometer is doubled, then its voltage sensitivity will be:

a. doubled b. halved c. unchanged d. four times

Ans. (c) unchanged

Q 105. A moving coil galvanometer can be converted into an ammeter by:

a. introducing a shunt resistance of large value in series.
b. introducing a shunt resistance of small value in parallel.
c. introducing a resistance of small value in series.
d. introducing a resistance of large value in parallel.

Ans. (b) introducing a shunt resistance of small value in parallel.

Q 106. Current sensitivity of a moving coil galvanometer is 5 div/mA and its voltage sensitivity is 20 div/V. The resistance of the galvanometer is ....

a. 25 Ω b. 250 Ω c. 40 Ω d. 500 Ω

Ans. (b) 250 Ω

$$\text{Resistance} = \frac{\text{Current sensitivity}}{\text{Voltage sensitivity}} = \frac{5000\text{ div/A}}{20\text{ div/A}} = 250\ \Omega$$

Q 107. A galvanometer of resistane 70 Ω is converted to an ammeter by a shunt resistance r_s = 0.03 Ω. The value of its resistance will become:

a. 0.025 Ω b. 0.022 Ω c. 0.035 Ω d. 0.030 Ω

Ans. (d) 0.030 Ω.

$$R = \frac{R_G r_s}{R_G + r_s}$$

Here, $R_G = 70\ \Omega, r_s = 0.03\ \Omega$

$$\therefore \quad R = \frac{70 \times 0.03}{70 + 0.03} = 0.02998 = 0.030\ \Omega$$

Q 108. If the galvanometer current is 10 mA, resistance of the galvanometer is 40 Ω and shunt of 2 Ω is connected to the galvanometer, the maximum current which can be measured by this ammeter is:

a. 0.21 A b. 2.1 A c. 210 A d. 21 A

Ans. (a) 0.21 A.

$$I = \left(\frac{r_s + R_G}{r_s}\right) I_g = \left(\frac{2+40}{2}\right) \times 0.01 = 0.21\text{ A}$$

Q 109. A galvanometer of resistance 40 Ω gives a deflection of 5 divisions per mA. There are 50 divisions on the scale. The maximum current that can pass through it when a shunt resistance of 2 Ω is connected is:

a. 210 mA b. 155 mA
c. 420 mA d. 75 mA

Ans. (a) 210 mA.

$$I_g = \frac{50}{5} = 10\text{ mA}; R_G = 40\ \Omega, r_s = 2\ \Omega$$

Maximum current,

$$I = \frac{R_G + r_s}{r_s} \times I_g = \frac{(40+2) \times 10}{2} = 210\text{ mA}$$

Q 110. In an ammeter, 10% of main current is passing through the galvanometer. If the resistance of the galvanometer is G, then the shunt resistance will be:

a. 9G b. G/9 c. 90G d. G/90

Ans. (b) G/9.

Given, $I_g = 0.1I,\ R_G = G$

Shunt Resistance, $r_s = \dfrac{I_g R_G}{I - I_g} = \dfrac{(0.1I)G}{I - 0.1I} = \dfrac{0.1IG}{0.9I} = \dfrac{G}{9}$

Q 111. The conversion of a moving coil galvanometer into a voltmeter is done by:

a. introducing a resistance of large value in series
b. introducing a resistance of small value in parallel
c. introducing a resistance of large value in parallel
d. introducing a resistance of small value in series.

Ans. (a) introducing a resistance of large value in series.

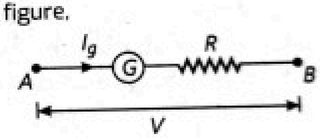
Q 112. A galvanometer of resistance 10 Ω gives full-scale deflection when I mA current passes through it. The resistance required to convert it into a voltmeter reading upto 2.5 V is:

a. 24.9 Ω b. 249 Ω c. 2490 Ω d. 24900 Ω

Ans. (c) 2490 Ω.

Here, $I_g = 1\text{ mA} = 1 \times 10^{-3}\text{ A}, R_G = 10\ \Omega$
$V = 2.5\text{ V}$

From the figure,

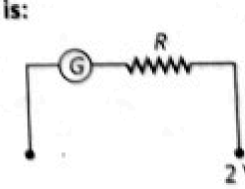


$$V = I_g(R_G + R) \text{ or } R = \frac{V}{I_g} - R_G$$

Substituting the given values, we get,

$$R = \frac{2.5\text{ V}}{1 \times 10^{-3}\text{ A}} - 10\ \Omega = 2500\ \Omega - 10\ \Omega = 2490\ \Omega$$

Q 113. A volmeter which can measure 2 V is constructed by using a galvanometer of resistance 12 Ω and that produces maximum deflection for the current of 2 mA, then the resistance *R* is:



a. 888 Ω b. 988 Ω c. 898 Ω d. 999 Ω

Ans. (b) 988 Ω.

$$R = \frac{V}{I_g} - R_G$$

Putting $V = 2\text{ V}, I_g = 2\text{ MA} = 2 \times 10^{-3}\text{ A}, R_G = 12\ \Omega.$

$$\therefore \quad R = \frac{2}{2 \times 10^{-3}} - 12 = 1000 - 12 = 988\ \Omega$$

Assertion and Reason Type Questions

Directions (Q.Nos. 114 to 139): In the following questions, astatement of Assertion (A) is followed by a statement of Reason (R). Mark the correct choice as:

a. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A)
b. Both Assertion (A) and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A)
c. Assertion (A) is true but Reason (R) is false
d. Assertion (A) is false and Reason (R) is also false

Q 114. Assertion (A): Magnetic field lines always form closed loops.
Reason (R): Moving charges or currents produce a magnetic field.

Ans. (b)

Q 115. Assertion (A): If an electron is not deflected while passing through a certain region of space, then only possibility is that there is no magnetic region.
Reason (R): Force is inversely proportional to the magnetic field applied.

Ans. (d) In this case we can not be sure about the absence of the magnetic field because if the electron moving parallel to the direction of magnetic field, the angle between velocity and applied magnetic field is zero ($F = 0$). Then also electron passes without deflection. Also $F = eVB\sin\theta \Rightarrow F \propto B$

Q 116. Assertion (A): Magnetic field interacts with a moving charge and not with a stationary charge.
Reason (R): A moving charge produces a magnetic field.

Ans. (a) A moving charge experiences a force in magnetic field. It is because of interaction of two magnetic fields, one of which is produced due to motion of charge and other in which charge is moving.

Q 117. Assertion (A): An electron and proton enters a magnetic field with equal velocities, then, the force experienced by proton will be more than electron.
Reason (R): The mass of proton is 1999 times more than the mass of electron.

Ans. (d) The force experienced by a charge particle in a magnetic field is given by,

$$\vec{F} = q(\vec{v} \times \vec{B})$$

which is independent of mass. As q, v and B are same for both the electron and proton, hence both will experience same force.

Q 118. Assertion (A): Magnetic lines of force form continuous closed loops.
Reason (R: Magnetic poles always occur in pairs as north pole and south pole.

Ans. (a) Magnetic poles exist in pairs. It is not possible to isolate a north pole or a south pole. Magnetic field lines start from the north pole and go to the south pole and return to the north pole. They form continuous closed loops.

Q 119. Assertion (A): If a charged particle is moving on a circular path in a perpendicular magnetic field, the momentum of the particle is not changing.
Reason (R): Velocity of the particle in not changing in the magnetic field.

Ans. (d) When a charged particle is moving on a circular path in a magnetic field, the magnitude of velocity does not change but direction of velocity is changing every moment. Hence velocity is changing, so momentum ($m\vec{v}$) is also changing.

Q 120. Assertion (A): When force is zero, the charged particle follows linear path.
Reason (R): A charged particle enters in a uniform magnetic field, whose velocity makes an angle θ with magneticd field will cover a linear path.

Ans. (c) When charged particle enters the uniform field they makes angle θ with the field. Then its path is decided by combined effect of two component of velocity. $v\cos\theta$ parallel to the field. Due to the parallel field the charge will follow a linear path and due to the perpendicular component ($v\sin\theta$) of the field will be circular. This results in a helical path whose axis is parallel to the parallel component of the field.

Q 121. Assertion (A): When a charged particle moves perpendicular to magnetic field then its kinetic energy and momentum gets affected.
Reason (R): Force changes velocity of charged particle.

Ans. (d) When a charged particle moves perpendicular to magnetid field, it experiences a force which changes the direction of motion of the particle without changing the magnitude of velocity of the particle. Hence, kinetic energy remains constant but momentum of electron changes.

Q 122. Assertion (A): The energy of charged particle moving in a uniform magnetic field does not change.
Reason (R): Work done by magnetic field on the charge is zero.

Ans. (a) The force on a charged particle moving in a uniform magnetic field always acts in direction perpendicular to the direction of motion of the charge. As work done by magnetic field on the charge is zero, [$W = FS\cos\theta$], so the energy of the charged particle does not change.

Q 123. Assertion (A): The kinetic energy of a charged particle moving in a uniform magnetic field does not change.
Reason (R): In a uniform magnetic field no force acts on the charge particle.

Ans. (c) When a charged particle is moving in a uniform magnetic field, it experiences a force in a direction perpendicular to its direction of motion. Due to which the speed of the charged particle remains unchanged and hence its kinetic energy remains same.

Q 124. Assertion (A): When the observation point lies along the length of the current element, magnetic field is zero.
Reason (R): Magnetic field close to current element is zero.

Ans. (c) Since $dB \propto \sin\theta$, where θ is angle between the direction of the flow of current and the line joining the elementary portion to the observation point which is zero in this case, so the magnetidc field is also zero (because $\sin\theta$ is equal to zero).

Q 125. Assertion (A): A direct current flows through a metallic rod, produce magnetic field only outside the rod.

Reason (R): There is no flow of charge carriers inside the rod.

Ans. (d) In the case of metallic rod, the charge carriers flow through whole of the cross section. Therefore, the magnetic field exists both inside as well as outside. However magnetic field inside the rod will go on decreasing as we go towards the axis.

Q 126. Assertion (A): The magnetic field intensity at the centre of a circular coil carrying current changes, if the current through the coil is doubled.

Reason (R): The magnetic field intensity is dependent on current in conductor.

Ans. (a) The magnetic field at the centre of circular coil is given by,

$$B = \frac{\mu_0}{4\pi}\frac{2\pi nI}{a}$$

So if current through coil is doubled then magnetic field is $B' = 2B$.

The magnetic field also get doubled. The magnetic field is directly proportional to the current in conductor.

Q 127. Assertion (A): A circular loop carrying current lies in *XY* plane with its center at origin having a magnetic flux in negative *Z*-axis.

Reason (R): Magnetic flux direction is independent of the direction of current in the conductor.

Ans. (c) The direction of magnetic field due to current carrying conductor can be found by applying right hand thumb rule or right hand palm rule. When electric current is passed through a circular conductor, the magnetic field lines near the center of the conductor are almost straight lines. Magnetic flux direction is determined only by the direction of current.

Q 128. Assertion (A): Ampere's circuital law holds for steady currents which do not fluctuate with time.

Reason (R): Ampere's circuital law is similar to that of Biot-savart's law.

Ans. (b)

Q 129. Assertion (A): A current *I* flows along the length of an infinitely long straight and thin walled pipe. Then the magnetic field at any point inside the pipe is zero.

Reason (R): $\oint \vec{B}.d\vec{l} = \mu_0 I$

Ans. (a)

Q 130. Assertion (A): Magnetic field due to current carrying solenoid is independent of its length and cross-sectional area.

Reason (R): The magnetic field inside the solenoid is uniform.

Ans. Magnetic field due to a solenoid having n number of turns per metre and carrying current I is $B = \mu_0 nI$ which is independent of the length and area of cross section of the solenoid.

The magnetic field inside the solenoid is uniform.

Q 131. Assertion (A): Magnetic field lines can be entirely confined within the core of a toroid, but not within a straight solenoid.

Reason (R): The magnetic field inside the solenoid is uniform.

Ans. (b) Magnetic field lines can be entirely confined to the core of a toroid because toroid has no ends. It can confine the field within its core. A straight solenoid has two ends. If the entire flux were confined between these ends, the flux throughout the cross-section at each end would be non-zero.

Q 132. Assertion (A): The magnetic field at the ends of a very long current carrying solenoid is half of that at the centre.

Reason (R): If the solenoid is sufficiently long, the field within it is uniform.

Ans. (b) The magnetic field of a solenoid is given by,

$$B = \frac{1}{2}\mu_0 nI[\cos\theta_1 - \cos\theta_2]$$

For a very long current carrying solenoid, the magnetic field at the ends of a very long solenoid is given by,

$$B = \frac{1}{2}\mu_0 nI = \frac{1}{2} \times \text{Magnetic field at the centre.}$$

$$[\because \theta_1 = 90°, \theta_2 = 180°]$$

Q 133. Assertion (A): If two long wires, hanging freely are connected to a battery in series, they come closer to each other.

Reason (R): Force of attraction acts between the two wires carrying current.

Ans. (d) When two long parallel wires are connected to a battery in series, they carry currents in opposite directions, hence they repel each other.

Q 134. Assertion (A): When current is represented by a straight line, the magnetic field will be circular.

Reason (R): According to Fleming's left hand rule, direction of force is parallel to the magnetic field.

Ans. (c) When current is straight, it means the current is passing through a straight conductor, the magnetic field produced due to current through a straight conductor is in the form of concentric circular magnetic lines of force whose centres lie on the linear conductor and are in a plane perpendicular to the plane of linear conductor. It means the magnetic field is circular.

Q 135. Assertion (A): Two parallel conducting wires carrying currents in opposite direction, come close to each other.

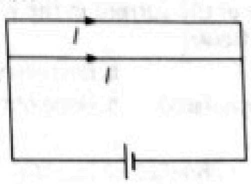
Reason (R): Parallel currents repel and anti-parallel currents attract.

Ans. (d) Since in the two parallel wires the flow of current is in opposite directions they repel each other, so they will move apart. Parallel currents attract and anti-parallel currents repel.

Q 136. Assertion (A): When two long parallel wires, hanging freely are connected in parallel to a battery, they come closer to each other.

Reason (R): Wires carrying current in opposite direction repel each other.

Ans. (b) The wires are parallel to each other but the direction of current in it is in same direction so they attract each other. If the current in the wires is in opposite direction then wires repel each other. When the currents are in opposite directions, the magnetic forces are reversed and the wires repels each other.



Q 137. Assertion (A): Torque on the coil is the maximum, when coil is suspended in a radial magnetic field.
Reason (R): The torque tends to rotate the coil on its own axis.

Ans. (b) The torque on the coil in a magnetic field is given by $\tau = nIBA\cos\theta$

For radial field, the coil is set with its plane parallel to the direction of the magnetic field B, then $\theta = 0°$ and $\cos\theta = 1$.

$\Rightarrow$ Torque $= nIBA(1) = nIBA$ (maximum).

Q 138. Assertion (A): Magnetic moment is measured in joule/tesla or amp m^2.

Reason (R): Joule/tesla is equivalent to amp m^2.

Ans. (a) Magnetic moment $= \frac{\text{Joule}}{\text{tesla}} = \frac{W}{B} = \frac{W}{F/qv} = \frac{Wqv}{F}$

$$= \frac{[ML^2T^{-2}][AT][LT^{-1}]}{[MLT^{-2}]}$$

$$= [AL^2] = \text{amp m}^2$$

Q 139. Assertion (A): The net magnetic force on a current carrying loop in a uniform magnetic field is zero but torque may or may not be zero.

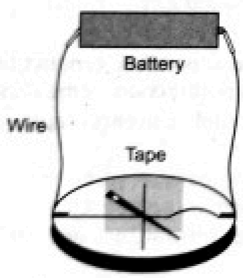
Reason (R): Torque on a current carrying coil in a magnetic field is given by $\vec{\tau} = nI(\vec{A} \times \vec{B})$.

Ans. (b)

Case Study Based QUESTIONS

Case Study 1

In 1820, A Danish physicist, Hans Christian Oersted, discovered that there is a relationship between electricity and magnetism. By setting up a compass through a wire carrying an electric current, Oersted showed that moving electrons can create a magnetic field. Oersted found that, for a straight wire carrying a steady current (DC), the magnetic field lines encircle the current-carrying wire. The magnetic field lines lie in a plane perpendicular to the wire. If the direction of the current is reversed, the direction of the magnetic force reverses. The strength of the field is directly proportional to the magnitude of the current. The strength of the field at any point is inversely proportional to the distance of the point from the wire.



Read the given passage carefully and give the answer of the following questions.

Q 1. Who was the first to discover the relation between electric and magnetid field?

a. H.C. Oersted
b. Charles William Oersted
c. Charles Maxwell
d. Andre Marie Ampere

Ans. (a) H.C. Oersted.
Hans Christian Oersted discovered that there is a relationship between electricity and magnetism.

Q 2. If magnitude of the current in the wire increases, strength of magnetid field:

a. increases
b. decreases
c. remains unchanged
d. None of these

Ans. (a) increases.

$B \propto I$

Q 3. Which of the following statements is true?

a. There is no relationship between electricity and magnetism
b. An electric current produces a magnetid field
c. A compass is not affected by electricity
d. A compass is not affected by a magnet

Ans. (b) An electric current produces a magnetid field.
Magnetism is related to electricity according to Oersted.

Q 4. A compass needle is placed below a straight conducting wire. If current is passing through the conducting wire from north to south, then the deflection of the compass is:

a. towards west
b. towards east
c. keeps oscillating in east-west direction
d. no deflection

Ans. (b) towards east.
By using Ampere's right-hand rule

Q 5. Charges at rest can produce:

a. static electric field
b. magnetic field
c. induced current
d. conventional current

Ans. (a) static electric field.
Charges at rest can produce static electric field.

Case Study 2

A charged particle moving in a magnetic field experiences a force that is proportional to the strength of the magnetic field, the component of the velocity that is perpendicular to the magnetic field and the charge of the particle.

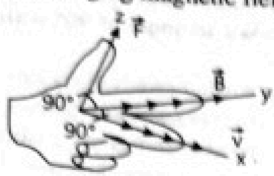
This force is given by $\vec{F} = q(\vec{v} \times \vec{B})$ where q is the electric charge of the particle, v is the instantaneous velocity of the particle, and B is the magnetic field (in Tesla).

The direction of force is determined by the rules of cross product of two vectors.

Force is perpendicular to both velocity and magnetic field.

Its direction is same as $\vec{v} \times \vec{B}$ if q is positive and opposite to $\vec{v} \times \vec{B}$ if q is negative.

The force is always perpendicular to both the velocity of the particle and the magnetic field that created it. Because the magnetic force is always perpendicular to the motion, the magnetic field can do no work on an isolated charge. It can only do work indirectly, via the electric field generated by a changing magnetic field.



Read the given passage carefully and give the answer of the following questions.

Q 1. When a magnetic field is applied on a stationary electron, it:

a. remains stationary

b. spins about its own axis

c. moves in the direction of the field

d. moves perpendicular to the direction of the field.

Ans. (a) remains stationary

For stationary electron, $\vec{v}=0$

$\therefore$ Force on the electron $\vec{F}_m = -e(\vec{v}\times\vec{B}) = 0$

Q 2. A proton is projected with a uniform velocity v along the axis of a current carrying solenoid, then:

a. the proton will be accelerated along the axis

b. the proton path will be circular about the axis

c. the proton moves along helical path

d. the proton will continue to move with velocity v along the axis.

Ans. (d) the proton will continue to move with velocity v along the axis.

Force on the proton, $\vec{F}_B = -e(\vec{v}\times\vec{B})$

Since, $\vec{v}$ is parallel to $\vec{B}$

$\therefore \quad \vec{F}_B = 0$

Hence proton will continue to move with velocity v along the axis of solenoid.

Q 3. A charged particle experiences magnetic force in the presence of magnetic field. Which of the following statement is correct?

a. The particle is stationary and magnetid field is perpendicular.

b. The particle is moving and magnetic field is perpendicular to the velocity.

c. The particle is stationary and magnetic field is parallel.

d. The particle is moving and magnetic field is parallel to velocity.

Ans. (b) The particle is moving and magnetic field is perpendicular to the velocity.

Magnetic force on the charged particle q is

$\vec{F}_m = q(\vec{v}\times\vec{B})$ or $F_m = qvB\sin\theta$

Where θ is the angle between $\vec{v}$ and $\vec{B}$.

Out of the given cases, only in case (b) it will experience the force while in other cases it will experience no force.

Q 4. A charge q moves with a velocity $2\ \text{m s}^{-1}$ along X-axis in a uniform magnetic field $\vec{B} = (\hat{i}+2\hat{j}+3\hat{k})$ T, then charge will experience a force:

a. in ZY-plane

b. along $-Y$ axis

c. along $+Z$ axis

d. along $-Z$ axis

Ans. (a) in ZY-plane

$\vec{F} = q(\vec{v}\times\vec{B})$

$= q[2\hat{i}\times(\hat{i}+2\hat{j}+3\hat{k})] = (4q)\hat{k} - (6q)\hat{j}$

Q 5. Moving charge will produce:

a. electric field only

b. magnetic field only

c. both electric and magnetic field

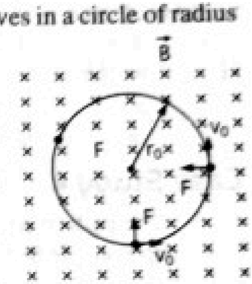
d. None of the above

Ans. (c) both electric and magnetic field

When an electric charge is moving both electric and magnetic fields are produced, whereas a static charge produces only electric field.

Case Study 3

An electron with speed $v_0 << c$ moves in a circle of radius r_0 in a uniform magnetic field. This electron is able to traverse a circular path as magnetic field is perpendicular to the velocity of the electron. A force acts on the particle perpendicular to both $\vec{v}_0$ and $\vec{B}$. This force continuously deflects the particle sideways without changing its speed and the particle will move along a circle perpendicular to the field. The time required for one revolution of the electron is T_0.



Read the given passage carefully and give the answer of the following questions.

Q 1. If the speed of the electron is now doubled to $2v_0$. The radius of the circle will change to:

a. $4r_0$ b. $2r_0$ c. r_0 d. $r_0/2$

Ans. (b) $2r_0$

As, $r_0 = \dfrac{mv}{qB} \Rightarrow r' = \dfrac{m(2v_0)}{qB} = 2r_0$

Q 2. If $v_0 = 2v_0$, then the time required for one revolution of the electron will change to:

a. $4T_0$ b. $2T_0$ c. T_0 d. $T_0/2$

Ans. (c) T_0

As, $T = \dfrac{2\pi m}{qB}$

Thus, it remains same as it is independent of velocity.

Q 3. A charged particle is projected in a magnetic field $\vec{B} = (2\hat{i}+4\hat{j})\times 10^2$ T. The acceleration of the particle is found to be $\vec{a} = (x\hat{i}+2\hat{j})\ \text{m s}^{-2}$. Find the value of x.

a. $4\ \text{m s}^{-2}$ b. $-4\ \text{m s}^{-2}$ c. $-2\ \text{m s}^{-2}$ d. $2\ \text{m s}^{-2}$

Ans. (b) $-4\ \text{m s}^{-2}$

As $F \perp B$

Hence, $a \perp B$

$\therefore \quad \vec{a}\cdot\vec{B} = 0$

$\Rightarrow (x\hat{i}+2\hat{j})\cdot(2\hat{i}+4\hat{j}) = 0$

$2x + 8 = 0 \Rightarrow x = -4\ \text{m s}^{-2}$

Q 4. If the given electron has a velocity not perpendicular to B, then trajectory of the electron is:

a. straight line b. circular c. helical d. zig-zag

Ans. (c) helical

If the charged particle has a velocity not perpendicular to $\vec{B}$, then component of velocity along $\vec{B}$ remains unchanged as the motion along the $\vec{B}$ will not be affected by $\vec{B}$.

Then, the motion of the particle in a plane perpendicular to $\vec{B}$ is as before circular one. Thereby, producing helical motion.

Q 5. If this electron of charge (e) is moving parallel to uniform magnetic field with constant velocity v, the force acting on the electron is:

a. Bev b. $\frac{Be}{v}$ c. $\frac{B}{ev}$ d. zero

Ans. (d) zero

The force on electron $F = qvB\sin\theta$

As the electron is moving parallel to B

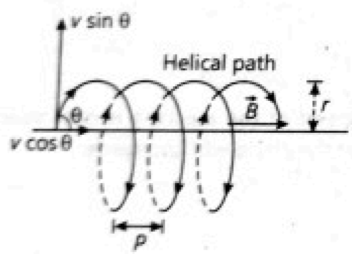
So, $\theta = 0°$

$\Rightarrow \quad qvB\sin 0° = 0$

Case Study 4

The path of a charged particle in magnetic field depends upon angle between velocity and magnetic field.

If velocity $\vec{v}$ is at angle θ to $\vec{B}$, component of velocity parallel to magnetic field ($v\cos\theta$) is responsible for circular motion, thus the charge particle moves in a helical path.



The plane of the circle is perpendicular to the magnetic field and the axis of the helix is parallel to the magnetic field. The charged particle moves along helical path touching the line parallel to the magnetic field passing through the starting point after each rotation.

Radius of circular path is $r = \frac{mv\sin\theta}{qB}$

Hence the resultant path of the charged particle will be a helix, with its axis along the direction of $\vec{B}$ as shown in figure.

Read the given passage carefully and give the answer of the following questions.

Q 1. When a positively charged particle enters into a uniform magnetic field with uniform velocity, its trajectory can be (i) a straight line (ii) a circle (iii) a helix.

a. (i) only b. (i) or (ii)

c. (i) or (iii) d. any oneof (i), (ii) and (iii)

Ans. (d) any one of (i), (ii) and (iii)

Q 2. Two charged particles A and B having the same charge, mass and speed enter into a magnetic field in such a way that the initial path of A makes an angle of 30° and that of B makes an angle of 90° with the field. Then the trajectory of:

a. B will have smaller radius of curvature than that of A

b. both will have the same curvature

c. A will have smaller radius of curvature than that of B

d. both will move along the direction of their original velocities.

Ans. (a) B will have smaller radius of curvature than that of A

Using, $qvB\sin\theta = \frac{mv^2}{r}$

$r \propto \frac{1}{\sin\theta}$ for the same values of m, v, q and B

$\therefore \quad \frac{r_A}{r_B} = \frac{\sin 90°}{\sin 30°} = 2$ or $r_A = 2r_B$ or $r_B < r_A$

Q 3. An electron having momentum 2.4×10^{-23} kg m/s enters a region of uniform magnetic field of 0.15 T. The field vector makes an angle of 30° with the initial velocity vector of the electron. The radius of the helical path of the electron in the field shall be:

a. 2 mm b. 1mm c. $\frac{\sqrt{3}}{2}$ mm d. 0.5 mm

Ans. (d) 0.5 mm

The radius of the helical path of the electron in the uniform magnetic field is

$$r = \frac{mv\perp}{eB} = \frac{mv\sin\theta}{eB} = \frac{(2.4\times10^{-23}\text{ kg m/s})\times\sin 30°}{(16\times10^{-19}\text{ C})\times 0.15\text{ T}}$$

$$= 5\times10^{-4}\text{ m} = 0.5\times10^{-3}\text{ m} = 0.5\text{ mm}$$

Q 4. The magnetic field in a certain region of space is given by $\vec{B} = 8.35\times10^{-2}\,\hat{i}$ T. A proton shot into the field with velocity $\vec{v} = (2\times10^5\,\hat{i} + 4\times10^5\,\hat{j})$ m/s. The proton follows a helical path in the field. The distance moved by proton in the x-direction during the period of one revolution in the yz-plane will be (Mass proton = 1.67×10^{-27} kg):

a. 0.053 m b. 0.136 m c. 0.157 m d. 0.236 m

Ans. (c) 0.157 m

Here, $\vec{B} = 8.35\times10^{-2}\,\hat{i}$ T

$\vec{v} = 2\times10^5\,\hat{i} + 4\times10^5\,\hat{j}$ m/s, $m = 1.67\times10^{-27}$ kg

Pitch of the helix (*i.e.*, the linear distance moved along the magnetic field in one rotation) is given by

Pitch of the helix $= \frac{2\pi m v_x}{qB}$

$$= \frac{2\times3.14\times1.67\times10^{-27}\times2\times10^5}{1.6\times10^{-19}\times8.35\times10^{-2}} = 0.157\text{ m}$$

Q 5. The frequency of revolution of the particle is:

a. $\frac{m}{qB}$ b. $\frac{qB}{2\pi m}$ c. $\frac{2\pi R}{v\cos\theta}$ d. $\frac{2\pi R}{v\sin\theta}$

Ans. (b) $\frac{qB}{2\pi m}$

Period of revolution

$$T = \frac{2\pi R}{v\sin\theta} \Rightarrow T = \frac{2\pi\left(\frac{mv\sin\theta}{qB}\right)}{v\sin\theta} \Rightarrow T = \frac{2\pi m}{qB}$$

$\therefore$ Frequency, $v = \frac{1}{T} = \frac{qB}{2\pi m}$

Case Study 5

A magnetic field can be produced by moving, charges or electric currents. The basic equation governing the magnetic field due to a current distribution is the Biot-Savart law.

Finding the magnetic field resulting from a current distribution involves the vector product, and is inherently a calculus problem when the distance from the current to the field point is continuously changing.

According to this law, the magnetic field at a point due to a current element of length $d\vec{l}$ carrying current I, at a distance r from the element is $dB = \frac{\mu_0}{4\pi}\frac{I(d\vec{l} \times \vec{r})}{r^3}$.

Biot-Savart law has certain similarities as well as difference with Coloumb's law for electrostatic field *e.g.*, there is an angle dependence in Biot-Savart law which is not present in electrostatic case.

Read the given passage carefully and give the answer of the following questions.

Q 1. The direction of magnetic field $d\vec{B}$ due to a current element $Id\vec{l}$ at a point of distance $\vec{r}$ from it, when a current I passes through a long conductor is in the direction:

a. of position vector $\vec{r}$ of the point

b. of current element $d\vec{l}$

c. perpendicular to both $d\vec{l}$ and $\vec{r}$

d. perpendicular to $d\vec{l}$ only

Ans. (c) perpendicular to both $d\vec{l}$ and $\vec{r}$

According to Biot-Savart's law, the magnetic induction due to a current element is given by

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{id\vec{l} \times \vec{r}}{r^3}$$

This is perpendicular to both $d\vec{l}$ and $\vec{r}$.

Q 2. The magnetic field due to a current in a straight wire segment of length L at a point on its perpendicular bisector at a distance $r (r >> L)$:

a. decreasea as $\frac{1}{r}$.

b. decreases as $\frac{1}{r^2}$.

c. decreases as $\frac{1}{r^3}$.

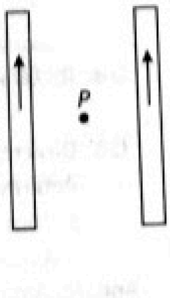
d. approaches a finite limit as $r \to \infty$

Ans. (b) decreases as $\frac{1}{r^2}$.

From Biot-savart's law,

$$dB = \frac{\mu_0}{4\pi}\frac{Idl}{r^2} \text{ i.e. } dB \propto \frac{1}{r^2}$$

Q 3. Two long straight wires are set parallel to each other. Each carries a current i in the same direction and the separation between them is $2r$. The intensity of the magnetic field midway between them is:



a. $\mu_0 i/r$

b. $4\mu_0 i/r$

c. zero

d. $\mu_0 i/4r$

Ans. (c) zero

$$B = \frac{\mu_0}{2\pi}\cdot\frac{i}{r} - \frac{\mu_0}{2\pi}\cdot\frac{i}{r} = 0$$

Q 4. A long straight wire carries a current along the z-axis for any two points in the x-y plane. Which of the following is always false?

a. The magnetic fields are equal

b. The directions of the magnetic fields are the same

c. The magnitudes of the magnetic fields are equal

d. The field at one point is opposite to that at the other point

Ans. (a) The magnetic fields are equal.

Q 5. Biot-Savart law can be expressed alternatively as:

a. Coulomb's Law

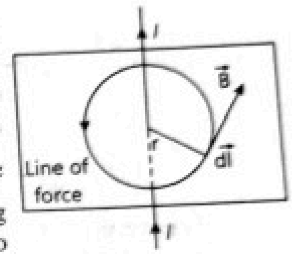
b. Ampere's circuital law

c. Ohm's Law

d. Gauss's Law

Ans. (b) Ampere's circuital law.

Case Study 6



Ampere's law gives a method to calculate the magnetic field due to given current distribution. According to it, the circulation $\oint \vec{B}\cdot d\vec{l}$ of the resultant magnetic field along a closed plane curve is equal to μ_0 times the total current crossing the area bounded by the closed curve provided the electric field inside the loop remains constant. Ampere's law is more useful under certain symmetrical conditions. Consider one such case of a long straight wire with circular cross-section (radius R) carrying current I uniformly distributed across this cross-section.

Read the given passage carefully and give the answer of the following questions.

Q 1. The magnetic field at a radial distance r from the centre of the wire in the region $r > R$, is:

a. $\frac{\mu_0 I}{2\pi r}$

b. $\frac{\mu_0 I}{2\pi R}$

c. $\frac{\mu_0 IR^2}{2\pi r}$

d. $\frac{\mu_0 Ir^2}{2\pi R}$

Ans. (a) $\frac{\mu_0 I}{2\pi r}$

Magnetic field due to a long current carrying wire at r

$$B = \frac{\mu_0}{2\pi}\frac{I}{r}$$

Q 2. The magnetic field at a distance r in the region $r < R$ is:

a. $\frac{\mu_0 I}{2r}$

b. $\frac{\mu_0 Ir^2}{2\pi R^2}$

c. $\frac{\mu_0 I}{2\pi r}$

d. $\frac{\mu_0 Ir}{2\pi R^2}$

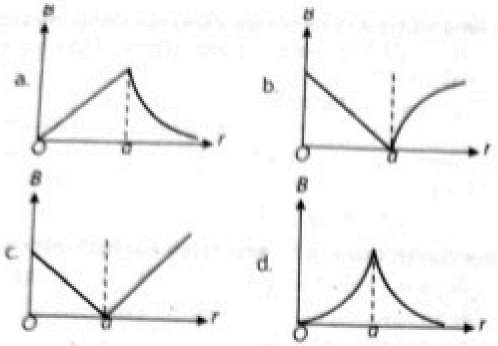
Ans. (d) $\frac{\mu_0 Ir}{2\pi R^2}$

Let I' be the current in region $r < R$

Then, $I' = \frac{I}{\pi R^2}\pi(r^2)$ or $I' = \frac{Ir^2}{R^2}$

So, magnetic field, $B = \frac{\mu_0 I'}{2\pi r} = \frac{\mu_0 Ir^2}{2\pi R^2 r} = \frac{\mu_0 Ir}{2\pi R^2}$

Q 3. A long straight wire of a circular cross section (radius a) carries a steady current I and the current I is uniformly distributed across this cross-section. Which of the following plots represents the variation of magnitude of magnetic field B with distance r from the centre of the wire?

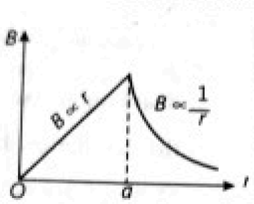


Ans. (a) Magnetic field due to a long straight wire of radius a carrying current I at a point distant r from the centre of the wire is given as follows :

$$B = \frac{\mu_0 Ir}{2\pi a^2} \text{ for } r < a$$

$$B = \frac{\mu_0 I}{2\pi a} \text{ for } r = a$$

$$B = \frac{\mu_0 I}{2\pi r} \text{ for } r > a$$



The variation of magnetic field B with distance r from the centre of wire is shown in the figure.

Q 4. A long straight wire of radius R carries a steady current I. The current is uniformly distributed across its cross-section. The ratio of magnetic field at $R/2$ and $2R$ is:

a. $\frac{1}{2}$ b. 2 c. $\frac{1}{4}$ d. 1

Ans. (d) 1

Let the magnetic fields due to a long straight wire of radius R carrying a steady current I at a distance r from the centre of the wire are

$$B_1 = \frac{\mu_0 Ir}{2\pi R^2} \text{ (For } r < R)$$

and $$B_2 = \frac{\mu_0 I}{2\pi R} \text{ (For } r > R)$$

So, the magnetic field at $r = \frac{R}{2}$ is $B_1 = \frac{\mu_0 I}{2\pi R^2}\left(\frac{R}{2}\right) = \frac{\mu_0 I}{4\pi R}$

and at $r = 2R$ is $B_2 = \frac{\mu_0 I}{2\pi(2R)} = \frac{\mu_0 I}{4\pi R}$

∴ Their corresponding ratio is

$$\frac{B_1}{B_2} = \frac{(\mu_0 I/4\pi R)}{(\mu_0 I/4\pi R)} = 1$$

Q 5. A direct current I flows along the length of an infinitely long straight thin walled pipe, then the magnetic field is:

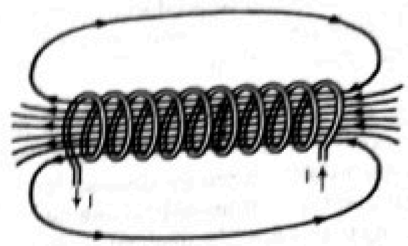
a. uniform throughout the pipe but not zero
b. zero only along the axis of the pipe
c. zero at any point inside the pipe
d. maximum at the centre and minimum at the edges.

Ans. (c) zero at any point inside the pipe.

Case Study 7

As shown in figure a solenoid where the wire is coiled around a cylinder, each wire loop in this coil acts as if it was a separate circular wire carrying the same current I, the current in the coiled wire and the dense enough array of such loops may be approximated by a cylindrical current sheet with the current density.

$$J = I \times (N/L) = I \times L \text{ (loops/solenoid length)}$$



For simplicity, let's assume a long solenoid (length >> diameter) which we approximate as infinitely long. For a long solenoid (compared to its diameter), the magnetic field inside the solenoid is approximately uniform and approximately parallel to the axis, except near the ends of the solenoid. Outside the solenoid, the magnetic field looks like the field of a physical dipole, with the north pole at one end of the solenoid and the south pole at the other end and is approximately negligible.

Read the given passage carefully and give the answer of the following questions.

Q 1. Which of the following material can be used to make loops around the cylinder?

a. Plastic b. Glass c. Quartz d. Copper

Ans. (d) Copper.

Copper (being good conductor) can be used to form solenoid.

Q 2. The magnetic field inside the solenoid is:

a. non-uniform and parallel to the axis
b. uniform and parallel to the axis
c. non-uniform and perpendicular to the axis
d. uniform and perpendicular to the axis

Ans. (b) uniform and parallel to the axis.

The magnetic field of solenoid resembles bar magnet.

Q 3. A proton is moving from left to right direction and outside the solenoid, then what is the direction of force on the proton?

a. Upwards b. Downwards
c. Proton will not deflect d. Inwards

Ans. (c) Proton will not deflect.

Q 4. How the magnetic field inside the solenoid depends upon the number of turns?

a. Inversely proportional
b. Directly proportional
c. Proportional to the number of turns
d. None of the above

Ans. (b) Directly proportional.

$$B \propto N$$

Q 5. Direction of magnetic field in a solenoid can be determined by:

a. Ohm's Law b. Fleming's left-hand rule
c. Ampere's right-hand rule d. Biot-Savart's Law

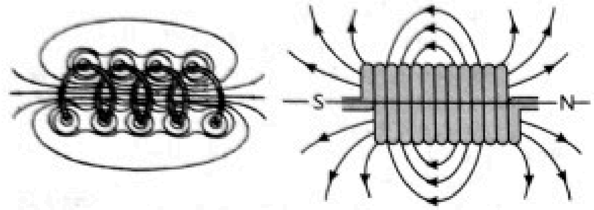
Ans. (c) Ampere's right-hand rule.

It gives relation between current and magnetic field.

Case Study 8

A solenoid is a long coil of wire tightly wound in the helical form. Solenoid consists of closely stacked rings electrically insulated from each other wrapped around a non-conducting cylinder.

Figure below shows the magnetic field lines of a solenoid carrying a steady current I. We see that if the turns are closely spaced, the resulting magnetic field inside the solenoid becomes fairly uniform, provided that the length of the solenoid is much greater than its diameter. For an "ideal" solenoid, which is infinitely long with turns thighly packed, the magnetic field inside the solenoid is uniform and parallel to the axis, and vanishes outside the solenoid.



Read the given passage carefully and give the answer of the following questions.

Q 1. A long solenoid has 800 turns per metre length of solenoid. A current of 1.6 A flows through it. The magnetic induction at the end of the solenoid on its axis is:

a. 16×10^{-4} T b. 8×10^{-4} T
c. 32×10^{-4} T d. 4×10^{-4} T

Ans. (a) 16×10^{-4} T

As $B=\frac{\mu_0 nI}{2}=\frac{(4\pi\times10^{-7})\times800\times1.6}{2}=8\times10^{-4}$ T

Q 2. Choose the correct statement in the following:

a. The magnetic field inside the solenoid is less than that of outside
b. The magnetic field inside an ideal solenoid is not at all uniform
c. The magnetic field at the centre, inside an ideal solenoid is atmost twice that at the ends
d. The magnetic field at the centre, inside an ideal solenoid is almost half of that at the ends

Ans. (c) The magnetic field at the centre, inside an ideal solenoid is atmost twice that at the ends

Magnetic field at one end of a solenoid carrying current is $B=\frac{\mu_0 nI}{2}$

Magnetic field inside the solenoid is uniform and is given by $B_c=\mu_0 nI$

Q 3. The magnetic field (B) inside a long solenoid having n turns per unit length and carrying current I when iron core is kept in it is (μ_0 = permeability of vacuum, χ = magnetic susceptibility):

a. $\mu_0 nI(1-\chi)$ b. $\mu_0 nI\chi$ c. $\mu_0 nI^2(1+\chi)$ d. $\mu_0 nI(1+\chi)$

Ans. (d) $\mu_0 nI(1+\chi)$

Magnetic field inside a long solenoid with an iron core inside it is $B=\mu nI$

But $\mu=\mu_0(1+\chi)\therefore B=\mu_0(1+\chi)nI$

Q 4. A solenoid of length l and having n turns carries a current I is in anticlockwise direction. The magnetic field is:

a. $\mu_0 nI$ b. $\mu_0\frac{nI}{l^2}$
c. along the axis of solenoid
d. perpendicular to the axis of coil

Ans. (c) along the axis of solenoid

A solenoid of length l and having n turns carries a current I in anticlockwise direction. The magnetic field as $\frac{\mu_0 nI}{l}$. Its direction will be along the axis of solenoid.

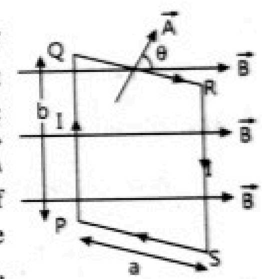
Q 5. The magnitude of the magnetic field inside a long solenoid is increased by:

a. decreasing its radius
b. decreasing the current through it
c. increasing its area of cross-section
d. introducing a medium of higher permeability

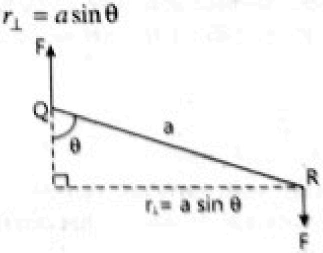
Ans. (d) introducing a medium of higher permeability.

Case Study 9

When a rectangular loop $PQRS$ of sides 'a' and 'b' carrying current I is placed in uniform magnetic field $\vec{B}$, such that area vector $\vec{A}$ makes an angle θ with direction of magnetic field, then forces on the arms QR and SP of loop are equal, opposite and collinear, thereby perfectly cancel each other, whereas forces on the arms PQ and RS of loop are equal and opposite but not collinear, so they give rise to torque on the loop.



Force on side PQ or RS of loop is $F=IbB\sin90°=IbB$ and perpendicular distance between two non-collinear forces is $r_\perp=a\sin\theta$



So, torque on the loop, $\tau=IAB\sin\theta$

In vector form, torque $\tau=\vec{M}\times\vec{B}$

where $\vec{M}=NI\vec{A}$ is called magnetic dipole moment of current loop and is directed in direction of area vector $\vec{A}$ *i.e.*, normal to the plane of loop.

Read the given passage carefully and give the answer of the following questions.

Q 1. A circular loop of area 1 cm ^{2}, carrying a current of 10 A is placed in a magnetic field of 0.1 T perpendicular to the plane of the loop. The torque on the loop due to the magnetic field is:

a. zero b. 10^{-4} N m c. 10^{-2} N m d. 1 N m

Ans. (a) zero

Torque on a current carrying loop in magnetic field, $\tau = IBA\sin\theta$

Here, $I = 10$ A, $B = 0.1$ T, $A = 1\text{ cm}^2 = 10^{-4}\text{ m}^2, \theta = 0°$

$\therefore \tau = 10 \times 0.1 \times 10^{-4}\sin 0° = 0°$

Q 2. Relation between magnetic moment and angular velocity is:

a. $M \propto \omega$ b. $M \propto \omega^2$ c. $M \propto \sqrt{\omega}$ d. None of these

Ans. (a) $M \propto \omega$

Magnetic moment, $M = IA = I(\pi r^2) = \frac{q}{T} \times \pi r^2$

As $\omega = \frac{2\pi}{T} \therefore M = \frac{q\omega r^2}{2}$ or $M \propto \omega$

Q 3. A current loop in a magnetic field:

a. can be a equilibrium in two orientations, both the equilibrium states are unstable

b. can be in equilibrium in two orientations, one stable while the other is unstable

c. experiences a torque whether the field is uniform or non uniform in all orientations

d. can be in equilibrium in one orientation

Ans. (b) can be in equilibrium in two orientations, one stable while the other is unstable

When a current loop is placed in a magnetic field it experiences a torque. It is given by

$$\vec{\tau} = \vec{M} \times \vec{B}$$

where $\vec{M}$ is the magnetic moment of the loop and $\vec{B}$ is the magnetic field.

or $\tau = MB\sin\theta$ where θ is angle between M and B

When $\vec{M}$ and $\vec{B}$ are parallel (*i.e.*, $\theta = 0°$) the equilibrium is stable and when they are antiparallel (*i.e.*, $\theta = \pi$) the equilibrium is unstable.

Q 4. The magnetic moment of a current *I* carrying circular coil of radius *r* and number of turns *N* varies as:

a. $\frac{1}{r^2}$ b. $\frac{1}{r}$ c. r d. r^2

Ans. (d) r^2

Magnetic moment, $M = NIA = NI\pi r^2$ *i.e.*, $M \propto r^2$.

Q 5. A rectangular coil carrying current is placed in a non-uniform magnetic field. On that coil the total:

a. force is non-zero b. force is zero

c. torque is zero d. None of these

Ans. (a) force is non-zero.

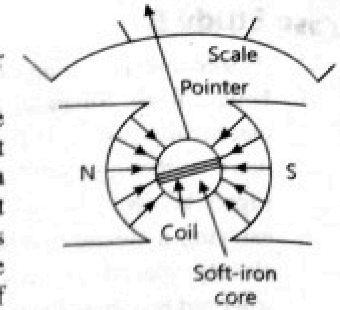
Case Study 10

Moving coil galvanometer operates on Permanent Magnet Moving Coil (PMMC) mechanism and was designed by the scientist D'arsonval.

Moving coil galvanometers are of two types:

(i) Suspended coil

(ii) Pivoted coil type or tangent galvanometer.



Its working is based on the fact that when a current carrying coil is placed in a magnetic field, it experiences a torque. This torque tends to rotate the coil about its axis of suspension in such a way that the magnetic flux passing through the coil is maximum.

Read the given passage carefully and give the answer of the following questions.

Q 1. A moving coil galvanometer is an instrument which:

a. is used to measure emf

b. is used to measure potential difference

c. is used to measure resistance

d. is a deflection instrument which gives a deflection when a current flows through its coil

Ans. (d) is a deflection instrument which gives a deflection when a current flows through its coil

A moving coil galvanometer is a sensitive instrument which is used to measure a deflection when a current flows through its coil.

Q 2. To make the field radial in a moving coil galvanometer.

a. number of turns of coil is kept small

b. magnet is taken in the form of horse-shoe

c. poles are of very strong magnets

d. poles are cylindrically cut

Ans. (d) poles are cylindrically cut

Uniform field is made radial by cutting pole pieces cylindrically.

Q 3. The deflection in a moving coil galvanometer is:

a. directly proportional to torsional constant of spring

b. directly proportional to the number of turns in the coil

c. inversely proportional to the area of the coil

d. inversely proportional to the current in the coil

Ans. (b) directly proportional to the number of turns in the coil

The deflection in a moving coil galvanometer, $\phi = \frac{NAB}{k} \cdot I$

or $\phi \propto N$, where N is number of turns in a coil, B is magnetic field and A is area of cross-section.

Q 4. In a moving coil galvanometer, having a coil of *N*-turns of area *A* and carrying current *I* is placed in a radial field of strength *B*.

a. NA^2B^2I b. $NABI^2$ c. N^2ABI d. $NABI$

Ans. (d) $NABI$

The deflecting torque acting on the coil.

$$\tau_{deflection} = NIAB$$

Q 5. To increase the current sensitivity of a moving coil galvanometer, we should decrease:

a. strength of magnet b. torsional constant of spring

c. number of turns in coil d. area of coil

Ans. (b) torsional constant of spring

Current sensitivity of galvanometer

$$\frac{\phi}{I} = S_I = \frac{NBA}{k}$$

Hence, to increase (current sensitivity) S_p (torsional constant of spring) k must be decreased.

CHAPTER 5

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Magnetism and Matter

Fastrack REVISION

- **Magnetism:** The phenomenon of attraction of small bits of iron, steel, cobalt, nickel etc. towards the ore (magnetite) is called magnetism.
- **Some Basics of Magnetism**
  (i) The Earth behaves as a magnet.
  (ii) Every magnet attracts small piece of magnetic substance like iron, steel, cobalt and nickel towards it.
  (iii) When a magnet is suspended freely with the help of a thread, it comes to rest along the north-south direction.
  (iv) The poles always exist in pairs.
  (v) Like poles repel each other and unlike poles attract each other.
  (vi) The force of attraction or repulsion between two magnetic poles of strength m_1 and m_2 separated by a distance r is directly proportional to the product of pole strengths and inversely proportional to the square of the distance between their centres.

$$F = \frac{\mu_0 m_1 m_2}{4\pi r^2}$$

- **Magnetic Field Lines**
  (i) The magnetic field lines of a magnet form closed continuous loops (from south pole to north pole).
  (ii) Outside the body of the magnet, the direction of magnetic field lines is from north pole to south pole.
  (iii) At any given point, tangent to the magnetic field lines represents the direction of net magnetic field at that point.
  (iv) The magnitude of magnetic field at any point is represented by the number of magnetic field lines passing around that point.
  (v) No two magnetic field lines can intersect each other.
- **Magnetic Dipole Moment:** It is the product of strength of either pole (m) and the magnetic length ($2l$) of the magnet.

$$\vec{M} = m \times 2l$$

S.I. unit of M is J/tesla or Am^2.

- **Potential Energy of a Magnetic Dipole in a Magnetic Field:** Potential energy of a magnetic dipole *i.e.,* barmagnet in a magnetic field is given by $U = -MB\cos\theta$
$= -\vec{M}\cdot\vec{B}$

where, θ is the angle between $\vec{M}$ and $\vec{B}$.

- **Oscillation of a Freely suspended Magnet:** The oscillations of a freely suspended magnet in a uniform magnetic field are in SHM.

The time period of oscillation, $T = 2\pi\sqrt{\frac{I}{MB}}$

- **The Electrostatic Anlogy**

Electrostatics	Magnetism
$\vec{E}$	$\vec{B}$
$\vec{p}$	$\vec{M}$
$\frac{1}{4\pi\varepsilon_0}$	$\frac{\mu_0}{4\pi}$

- **Magnetism and Guass' Law:** According to Gauss' law for magnetism, the net magnetic flux (ϕ_B) through any closed surface is also zero.

$$\phi_B = \sum_{\text{all}} \Delta\phi_B = 0$$

$$\phi_B = \oint \vec{B}\cdot d\vec{S} = 0$$

- **The Earth's Magnetism:** Earth's magnetic field is of the order 10^{-5} tesla.
  - **Causes of Earth's Magnetism**
    (i) Due to giant bar magnet placed along axis of rotation of Earth.
    (ii) Due to electrical currents produced by motion of metallic fluids (iron and nickel) in outer region of Earth.
- **Magnetic Declination and Dip**
  (i) The small angle between magnetic axis and geographic axis at a place is defined as the magnetic declination at the place. It is represented by θ.
  (ii) Magnetic dip or magnetic inclination at a place is defined as the angle which the direction of total strength of Earth's magnetic field makes with a horizontal line in magnetic meridian. It is represented by δ.
- **Horizontal Component (B_H):** It is the component of total intensity of Earth's magnetic field in the horizontal direction.

$$B_H = B_E\cos\delta$$

$$B_V = B_E\sin\delta$$

$$\tan\delta = \frac{B_V}{B_H}$$

where B_E = total magnetic field of Earth,
B_V = vertical component of the Earth's magnetic field

- **Intensity of Magnetisation:** It is defined as the magnetic moment per unit volume of the material.

$$\vec{M} = \frac{m}{V}$$

- **Magnetic Permeability (μ):** Magnetic permeability of a material is defined as the ratio of the number of magnetic field lines per unit area in that material to the number of magnetic field lines per unit area that would be present, if the medium is replaced by vacuum.

$$\mu = \mu_0\mu_r$$

- **Magnetic Field Strength/Magnetic Induction/Flux Density:** It is the force experienced by a unit positive charge moving with unit velocity in a direction perpendicular to the magnetic field.
- **Magnetising Field Intensity ($\vec{H}$):** It is defined as the number of ampere turns flowing round unit length of toroidal to produce the magnetic induction.

$$\vec{H} = \mu n I$$

- **Magnetic Susceptibility (χ_m):** It is defined as the ratio of the intensity of magnetisation (M) to the magnetising force (H).

$$\chi_m = \frac{M}{H}$$

- **Relation between Magnetic Permeability and Magnetic Susceptibility**

$$\mu_r = 1 + \chi_m$$

Objective TYPE QUESTIONS

Multiple Choice Questions

Q 1. Which of the following is correct about magnetic monopole?

a. Magnetic monopole exist.
b. Magnetic monopole does not exist.
c. Magnetic monopole have constant value of monopole momentum.
d. The monopole momentum increases due to increase at its distance from the field.

Ans. (b) Magnetic monopole does not exist.

When a bar magnet is broken into two halves, we get two similar bar magnet with weaker properties. So, magnetic monopoles do not exist.

Q 2. Which of the following statements is true?

a. A freely suspended magnet comes to rest in north-south direction.
b. Opposite poles of magnets attract each other.
c. The Earth behaves as a giant magnet.
d. All of the above

Ans. (d) All of the above

Q 3. A stationary magnet does not interact with:

a. iron rod
b. moving charge
c. magnet
d. stationary charge

Ans. (d) stationary charge

Q 4. Magnetic moment for a solenoid and corresponding bar magnet is:

a. equal for both
b. more for solenoid
c. more for bar magnet
d. None of these

Ans. (a) equal for both

Since a bar magnet and a corresponding solenoid produce similar magnetic fields. Hence the magnetic moment of a bar magnet is equal to the magnetic moment of an equivalent solenoid that produces the same magnetic field.

T!P

Magnetic moment of a current loop is defined as the product of current (I) and the area (A) enclosed by the current loop i.e., $M = IA$.

Q 5. Which of the following is not correct about the magnetic field lines?

a. The magnetic field lines of a magnet form continuous closed loops.
b. The tangent to the field line at a given point represents the direction of the net magnetic field B at that point.
c. The larger number of field lines crossing per unit area, the stronger is the magnitude of the magnetic field B.
d. The magnetic field lines may intersect to each other in certain conditions.

Ans. (d) The magnetic field lines may intersect to each other in certain conditions.

The magnetic field lines do not intersect.

Q 6. S.I. unit of magnetic pole strength is:

a. ampere/metre
b. ampere-metre
c. volt/metre
d. ampere/metre^2

Ans. (b) ampere-metre.

Q 7. A wire is placed between the poles of two fixed bar magnets as shown in the figure. A small current in the wire is into the plane of the paper. The direction of the magnetic force on the wire is:

a. ↑
b. ↓
c. →
d. ←

Ans. (d) ←

According of Fleming's left-hand rule, the direction of the magnetic force on the wire is ←.

Q 8. A solenoid of cross-sectional area $2\times10^{-4}\,m^2$ and 900 turns has 0.6 Am^2 magnetic moment. Then the current flowing through it is:

a. 2.24 A
b. 2.34 mA
c. 3.33 A
d. 3.33 mA

Ans. (c) 3.33 A

Here, $N = 900$ turns,

$A = 2\times10^{-4} m^2, M_S = 0.6\ Am^2$

The magnetic moment of solenoid, $M_S = NIA$

The current flowing through the solenoid is

$$I = \frac{M_S}{NA} = \frac{0.6}{900\times2\times10^{-4}} = 3.33\ A$$

Q 9. A closely wound solenoid of 750 turns and area of cross-section of $5\times10^{-4}\,m^2$ carries a current of 3.0A. Its associated magnetic moment is:

a. 4.12 J T^{-1} b. 3.12 J T^{-1} c. 2.12 J T^{-1} d. 1.13 J T^{-1}

Ans. (d) 1.13 J T^{-1}.

Here, $N = 750$ turns, $A = 5\times10^{-4}\ m^2$, $I = 3\ A$

Then, magnetic moment,

$M = NIA = 750\times3\times5\times10^{-4} = 11250\times10^{-4}$

$= 1.125\ JT^{-1} = 1.13\ JT^{-1}$ along the axis of solenoid.

Q 10. A closely wound solenoid of 1000 turns and area of cross-section $1.4\times10^{-4}\,m^2$ carrying a current of 3A is suspended through its centre allowing it to turn in a horizontal plane. The magnetic moment associated with this solenoid is:

a. 0.22 J T^{-1} b. 0.32 J T^{-1} c. 0.42 J T^{-1} d. 0.52 J T^{-1}

Ans. (c) 0.42 J T^{-1}.

Here, $N = 1000$, $A = 1.4\times10^{-4}\ m^2$, $I = 3\ A$

$M = NIA = 1000\times3\times1.4\times10^{-4} = 0.42\ J\,T^{-1}$

Q 11. The magnetic dipole moment of a current carrying coil does not depend upon:

a. number of turns of the coil.
b. cross-sectional area of the coil.
c. current flowing in the coil.
d. material of the turns of the coil.

Ans. (d) material of the turns of the coil.

Magnetic dipole moment does not depend upon material of the turns of the coil.

Q 12. A circular coil of 300 turns and diameter 14 cm carries a current of 15 A. The magnitude of magnetic moment associated with the loop is:

a. $51.7\ JT^{-1}$ b. $69.2\ JT^{-1}$ c. $38.6\ JT^{-1}$ d. $19.5\ JT^{-1}$

Ans. (b) $69.2\ JT^{-1}$.

Here, $N = 100, I = 15\ A, r = 7\ cm = 7 \times 10^{-2}\ m$

$\therefore\ M = NIA = NI \times \pi r^2$

$= 300 \times 15 \times 3.14 \times (7 \times 10^{-2})^2 = 69.2\ JT^{-1}$

Q 13. A closely wound solenoid of 3000 turns and area of cross-section $2 \times 10^{-4}\ m^2$, carrying a current of 6 A is suspended through its centre allowing it to turn in a horizontal plane. The magnetic moment associated with this solenoid is:

a. $1.2\ JT^{-1}$ b. $2.4\ JT^{-1}$ c. $3.0\ JT^{-1}$ d. $3.6\ JT^{-1}$

Ans. (d) $3.6\ JT^{-1}$.

Here, $N = 3000, A = 2 \times 10^{-4}\ m^2, I = 6\ A$

$\therefore\ M = NIA = 3000 \times 6 \times 2 \times 10^{-4} = 3.6\ JT^{-1}$

Q 14. A circular coil of 25 turns and radius of 12 cm is placed in a uniform magnetic field of 0.5 T normal to the plane of coil. If the current in the coil is 5A, then total torque experienced by the coil is:

a. 1.5 Nm b. 2.5 Nm c. 3.5 Nm d. zero

Ans. (d) zero

Here, $N = 15$ turns, $r = 12$ cm, $B = 0.5$ T

Since the coil is placed in uniform magnetic field normal to the plane of the coil.

Hence the angle between magnetic moment and magnetic field direction is zero (*i.e.*, $\theta = 0°$)

$\therefore\ \tau = MB\sin\theta = MB\sin 0° \Rightarrow \tau = 0$

Q 15. A toroid of *n* turns, mean radius *R* and cross-sectional radius *a* carries current *I*. It is placed on a horizontal table taken as *x-y* plane. Its magnetic moment $\vec{M}$: *(NCERT EXEMPLAR)*

a. is non-zero and points in the z-direction by symmetry.

b. points along the axis of the toroid ($\vec{M} = M\hat{\phi}$)

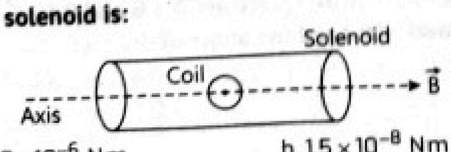
c. is zero, otherwise there would be a field falling as $\frac{1}{r^3}$ at large distances outside the toroid.

d. is pointing radially outwards.

Ans. (c) is zero, otherwise there would be a field falling as $\frac{1}{r^3}$ at large distances outside the toroid.

In a toroid magnetic field is only confined inside the body of toroid in the form of concentric magnetic lines of force and outside the toroid magnetic field is zero.

Q 16. The torque required to hold a small circular coil of 10 turns, area 1 mm² and carrying a current of $\left(\frac{21}{44}\right)$A in the middle of a long solenoid of 10^3 turns/m carrying a current of 2.5 A, with its axis perpendicular to the axis of the solenoid is:



a. 1.5×10^{-6} Nm b. 1.5×10^{-8} Nm
c. 1.5×10^{6} Nm d. 1.5×10^{8} Nm

Ans. (b) 1.5×10^{-8} N m

Here, for small circular coil,

Number of turns, $N = 10$, Area, $A = 1 mm^2 = 1 \times 10^{-6}\ m^2$

Current, $I_1 = \frac{21}{44}$ A

For a long solenoid,

Number of turns per metre, $n = 10^3$/m

Current, $I_2 = 2.5$ A

Magnetic field due to a long solenoid on its axis is

$$B = \mu_0 n I_2 \quad ...(1)$$

Magnetic moment of a circular coil is

$$M = NAI_1 \quad ...(2)$$

Torque, $\vec{\tau} = \vec{M} \times \vec{B}$

$\tau = MB\sin\theta = MB$ [$\because \theta = 90°$ (Given)]

$\tau = (NAI_1)(\mu_0 n I_2)$ [Using eqs. (1) and (2)]

$\tau = 10 \times 1 \times 10^{-6} \times \frac{21}{44} \times 4 \times \frac{22}{7} \times 10^{-7} \times 10^3 \times 2.5$

$= 1.5 \times 10^{-8}$ Nm

Q 17. If a solenoid is having magnetic moment of $0.65\ JT^{-1}$ is free to turn about the vertical direction and has a uniform horizontal magnetic field of 0.25 T applied. What is the magnitude of the torque on the solenoid when its axis makes an angle of 30° with the direction of applied field?

a. 0.075 Nm b. 0.080 Nm
c. 0.081 Nm d. 0.091 Nm

Ans. (c) 0.081 Nm.

Here, $M = 0.65\ JT^{-1}, B = 0.25\ T, \theta = 30°$.

$\therefore\ \tau = MB\sin\theta = 0.65 \times 0.25 \times \sin 30°$

$= 0.65 \times 0.25 \times \frac{1}{2} = 0.08125\ Nm = 0.081\ Nm$

Q 18. A circular coil is 100 turns, radius 10 cm carries a current of 5A. It is suspended vertically in a uniform horizontal magnetic field of 0.5 T and the field lines make an angle of 60° with the plane of the coil. The magnitude of the torque that must be applied on it to prevent it from turning is:

a. 2.93 Nm b. 3.43 Nm
c. 3.93 Nm d. 4.93 Nm

Ans. (c) 3.93 Nm

Here, $N = 100, r = 10\ cm = 0.10\ m, I = 5\ A, B = 0.5\ T$.

$\theta = 90° - 60° = 30°$

Area of the coil, $A = \pi r^2 = 3.14 \times (0.1)^2$

$\tau = NIBA\sin\theta$

$= 100 \times 5 \times 0.5 \times 3.14 \times (0.1)^2 \times \sin 30°$

$= 3.931\ Nm$

Q 19. A dipole of magnetic moment $\vec{M} = 30\hat{j}\ Am^2$ is placed along the Y-axis in a uniform magnetic field $\vec{B} = (2\hat{i} + 5\hat{j})T$. The torque acting on it is:

a. $-40\hat{k}$ Nm b. $-50\hat{k}$ Nm
c. $-60\hat{k}$ Nm d. $-70\hat{k}$ Nm

Ans. (c) $-60\hat{k}$ Nm

Here, $\vec{M} = 30\hat{j}\ Am^2$ and $\vec{B} = (2\hat{i} + 5\hat{j})$ T.

Since $\vec{\tau} = \vec{M} \times \vec{B}$

$= 30\,\hat{i} \times (2\,\hat{i} + 5\,\hat{j}) = 60\,\hat{i} \times \hat{i} + 150\,\hat{j} \times \hat{j} = 60(-\hat{k}) + 150 \times 0$

$= -60\,\hat{k}$ Nm $\quad (\because \hat{j} \times \hat{i} = -\hat{k}$ and $\hat{j} \times \hat{j} = 0)$

Q 20. A uniform horizontal magnetic field of 7.5×10^{-2} T is set up at an angle of 30° with the axis of an solenoid and the magnetic moment associated with it is $1.28\ JT^{-1}$. Then the torque on it is:

a. 4.8×10^{-2} Nm
b. 1.6×10^{-2} Nm
c. 1.2×10^{-2} Nm
d. 4.8×10^{-4} Nm

Ans. (a) 4.8×10^{-2} Nm.

Torque, $\tau = MB\sin\theta$

Here, $M = 1.28\ JT^{-1}$, $B = 7.5 \times 10^{-2}$ T, $\theta = 30°$

$\therefore \tau = 1.28 \times 7.5 \times 10^{-2} \sin 30°$

$= 1.28 \times 7.5 \times 10^{-2} \times \frac{1}{2}$

$= 0.64 \times 7.5 \times 10^{-2} = 4.8 \times 10^{-2}$ Nm

Q 21. A magnetic dipole is under the influence of two magnetic fields. The angle between the field directions is 60° and one of the fields has a magnitude of 1.2×10^{-2} T. If the dipole comes to stable equilibrium at an angle of 30° with this field, then the magnitude of the field is:

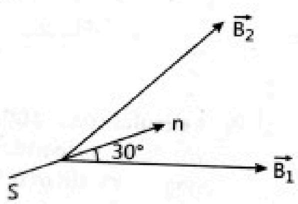
a. 1.2×10^{-4} T
b. 2.4×10^{-4} T
c. 1.2×10^{-2} T
d. 2.4×10^{-2} T

Ans. (c) 1.2×10^{-2} T

Here, $\theta = 60°$, $B_1 = 1.2 \times 10^{-2}$ T

$\theta_1 = 30°$ and $\theta_2 = 60° - 30° = 30°$

In stable equilibrium, torques due to two fields must be balanced *i.e.* $\tau_1 = \tau_2$



$\Rightarrow MB_1 \sin\theta_1 = MB_2 \sin\theta_2$

or $B_2 = B_1 \frac{\sin\theta_1}{\sin\theta_2}$

$= B_2 \frac{\sin 30°}{\sin 30°} = B_1$

$= 1.2 \times 10^{-2}$ T

Q 22. Which of the following is not showing the essential difference between electrostatic shielding by a conducting shell and magnetostatic shielding?

a. Electrostatic field lines can end on charges and conductors have free charges.
b. Magnetic field lines can end but conductors cannot end them.
c. Lines of magnetic field cannot end on any material and perfect shielding is not possible.
d. Shells of high permeability materials can be used to divert lines of magnetic field from the interior region.

Ans. (b) Magnetic field lines can end but conductors cannot end them.

Options (a), (c) and (d) all are correct about electrostatic shielding and magnetostatic shielding.

Q 23. The net magnetic flux through any closed surface, kept in a magnetic field is:

a. zero
b. $\frac{\mu_0}{4\pi}$
c. $4\pi\mu_0$
d. $\frac{4\mu_0}{\pi}$

Ans. (a) zero

The net magnetic flux through a closed surface will be zero, *i.e.* $\oint \vec{B} \cdot d\vec{s} = 0$, because there are no magnetic monopoles.

Q 24. The Earth behaves as a magnet with magnetic field pointing approximately from the geographic:

a. North to South
b. South to North
c. East to West
d. West to East

Ans. (b) South to North

Q 25. The strength of the Earth's magnetic field is:

a. constant everywhere.
b. zero everywhere.
c. having very high value.
d. vary from place to place on the Earth's surface.

Ans. (d) vary from place to place on the Earth's surface.

The strength of the Earth's magnetic field is not constant. It varies from one place to other place on the surface of Earth. Its value being of the order of 10^{-5} T.

Q 26. Which of the following is responsible for the Earth's magnetic field?

a. Convective currents in Earth's core.
b. Diversive current in Earth's core.
c. Rotational motion of Earth.
d. Translational motion of Earth.

Ans. (a) Convective currents in Earth's core.

The Earth's core is hot and molten. Hence, convective current in Earth's core is responsible for it's magnetic field.

Q 27. Which of the following independent quantities is not used to specify the Earth's magnetic field?

a. Magnetic declination (θ).
b. Magnetic dip (δ).
c. Horizontal component of Earth's magnetic field (B_H).
d. Vertical component of Earth's magnetic field (B_V).

Ans. (d) Vertical component of Earth's field (B_V).

Vertical component of Earth's magnetic field (B_V) is not used to specify the Earth's magnetic field.

Q 28. If you made a map of magnetic field lines at Melbourne in Australia, then the magnetic field lines seem to be:

a. go into the ground.
b. come out of the ground.
c. maintain a spiral path on the surface of Earth.
d. move on helical path above the surface of ground.

Ans. (b) come out of the ground.

As Melbourne is situated in southern hemisphere where north pole of Earth's magnetic field lies therefore magnetic lines of force seem to come out of the ground.

Q 29. The area of *B-H* loop for soft iron, as compared to that for steel is:

a. more
b. less
c. equal
d. zero

Ans. (b) less.

Q 30. The horizontal and vertical components of Earth's magnetic field at a place are 0.3 G and 0.52 G. The Earth's magnetic field and the angle of dip are:

a. 0.3 G and $\delta = 30°$
b. 0.4 G and $\delta = 40°$
c. 0.5 G and $\delta = 50°$
d. 0.6 G and $\delta = 60°$

Ans. (d) 0.6 G and $\delta = 60°$

Here, $B_H = 0.3$ G, $B_V = 0.52$ G

The Earth's magnetic field,

$$B = \sqrt{B_H^2 + B_V^2} = \sqrt{(0.3)^2 + (0.52)^2} = 0.6\ G$$

and angle of dip, $\tan\delta = \frac{B_V}{B_H} = \frac{0.52}{0.3} = 1.734$

$$\delta = \tan^{-1}(1.734) = 60°$$

Q 31. Let the magnetic field on Earth be modelled by that of a point magnetic dipole at the centre of Earth. The angle of dip at a point on the geographical equator is:

a. always zero.
b. positive, negative or zero.
c. unbounded.
d. always negative.

Ans. (b) positive, negative or zero.

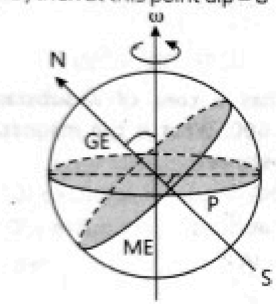
The angle of dip at a point on the geographical equator is positive, negative or zero depending upon the situation.

Q 32. Consider the plane *S* formed by the dipole axis and the axis of Earth. If *P* be the point of intersection of the geographical and magnetic equators then the declination and dip angle at point *P* are:

a. 0°, 11.3°
b. 11.3°, 0°
c. 11.3°, 11.3°
d. 0°, 0°

Ans. (b) 11.3°, 0°

Refer to the adjacent figure given below. The point *P* is at the intersection of geographical equator (*GE*) and magnetic equator (*ME*) then at this point dip = 0° and declination = 11.3°.



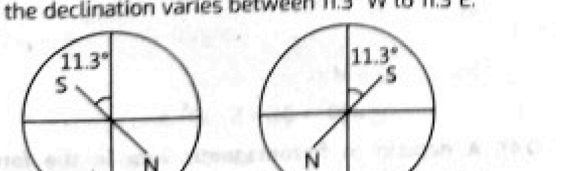
Common ⚠ Error

Students often take wrong angle of dip at equator.

Q 33. The magnetic field of the Earth can be modelled by that of a point dipole placed at the centre of the Earth. The dipole axis makes an angle of 11.3° with the axis of the Earth. At Mumbai, declination is nearly zero. Then, *(NCERT EXEMPLAR)*

a. the declination varies between 11.3° W to 11.3°E.
b. the least declination is 0°.
c. the plane defined by dipole axis and the Earth axis passes through Greenwich.
d. declination averaged over the Earth must be always negative.

Ans. (a) the declination varies between 11.3° W to 11.3°E.



Since the axis of the magnetic dipole placed at the centre of Earth makes an angle of 11.3° with the axis of Earth, the two possibilities arise as shown in above figure. Hence, the declination varies between 11.3° W to 11.3° E.

Q 34. The dip angle at a location in southern India is about 18°. Then the dip angle in Britain will be:

a. greater than 18°
b. lesser than 18°
c. equal to 18°
d. zero

Ans. (a) greater than 18°

As Britain is located close to north pole, hence dip angle in Britain is greater and its approximate value is $\delta = 70°$.

Q 35. The angle of dip at a certain place where the horizontal and vertical components of the Earth's magnetic field are equal is:

a. 30°
b. 75°
c. 60°
d. 45°

Ans. (d) 45°

$$\tan\delta = \frac{B_V}{B_H} = \frac{B_H}{B_H} = 1 \qquad [\because B_H = B_V \text{ (Given)}]$$

$$\therefore \quad \delta = 45°$$

Q 36. The vertical component of Earth's magnetic field at a place is $\sqrt{3}$ times the horizontal component, the value of angle of dip at this place is:

a. 30°
b. 45°
c. 60°
d. 90°

Ans. (c) 60°

As, $B_V = \sqrt{3}\, B_H$

Also, $\tan\delta = \frac{B_V}{B_H} = \frac{\sqrt{3}B_H}{B_H} = \sqrt{3}$ or $\delta = \tan^{-1}(\sqrt{3}) = 60°$

$\therefore$ Angle of dip, $\delta = 60°$.

Q 37. At a certain location in Africa, compass points 12° west of geographic north. The north tip of magnetic needle of a dip circle placed in the plane of magnetic meridian points 60° above the horizontal. The horizontal component of Earth's magnetic field is measured to be 0.16 G. The magnitude of Earth's magnetic field at the location is:

a. 0.32 G
b. 0.42 G
c. 4.2 G
d. 3.2 G

Ans. (a) 0.32 G

Here, $H_E = 0.16\ G = 0.16 \times 10^{-4}\ T$, dip angle $\delta = 60°$

Then, magnitude of Earth's magnetic field,

$$B_E = \frac{H_E}{\cos\delta} = \frac{0.16 \times 10^{-4}}{\cos 60°}\ T$$

$$\Rightarrow \quad B_E = \frac{0.16 \times 10^{-4}}{1/2} = 0.32 \times 10^{-4}\ T = 0.32\ G$$

Q 38. Assume the dipole model for Earth's magnetic field *B* which is given by the vertical component of magnetic field, $B_V = \frac{\mu_0}{4\pi}\frac{2m\cos\theta}{r^3}$ and the horizontal component of magnetic field $B_H = \frac{\mu_0}{4\pi}\frac{m\sin\theta}{r^3}$, where θ = 90° - latitude as measured from magnetic equator, then the loci of point for which dip angle is ±45°.

a. $\tan^{-1}(3)$
b. $\tan^{-1}(2)$
c. $\tan^{-1}(0.5)$
d. $\tan^{-1}(1)$

Ans. (b) $\tan^{-1}(2)$

Here, $B_V = \frac{\mu_0}{4\pi}\frac{2m\cos\theta}{r^3}$

$B_H = \frac{\mu_0}{4\pi}\frac{m\sin\theta}{r^3}$ and $\delta = 45°$

$\because \quad \tan\delta = \frac{B_V}{B_H}$

Hence, $\tan 45° = \frac{2\cos\theta}{\sin\theta} = 2\cot\theta$

$\therefore \quad 1 = \frac{2}{\tan\theta} \Rightarrow \tan\theta = 2$

or $\quad \theta = \tan^{-1}(2)$ is the loci of points.

Q 39. At a given place on Earth's surface the horizontal component of Earth's magnetic field is 2×10^{-5} T and resultant magnetic field is 4×10^{-5} T. The angle of dip at this place is:

a. 30° b. 60° c. 90° d. 45°

Ans. (b) 60°.

Since $B_H = B\cos\delta$

Here, $B = 4\times10^{-5}$ T, $B_H = 2\times10^{-5}$ T

$\therefore \quad \cos\delta = \frac{B_H}{B} = \frac{2\times10^{-5}}{4\times10^{-5}} = \frac{1}{2} = \cos 60° \Rightarrow \delta = 60°$

Q 40. The Earth's magnetic field departs from its dipole shape substantially at large distance (greater than about 5000 km). The responsible factor for this distortion is:

a. motion of ions in Earth's ionosphere.
b. motion of ions in Earth's atmosphere.
c. motion of ions in Earth's lithosphere.
d. motion of ions in the space.

Ans. (a) motion of ions in Earth's ionosphere.

Due to motion of ions in Earth's ionosphere the Earth's magnetic field gets modified.

Q 41. In the magnetic meridian of a certain place the horizontal component of Earth's magnetic field is 0.25 G and dip angle is 60°. The magnetic field of the Earth at this location is:

a. 0.50 G b. 0.52 G c. 0.54 G d. 0.56 G

Ans. (a) 0.50 G

Here, $H_E = 0.25$ G and $\cos\delta = \frac{H_E}{B_E}$

$\therefore$ The magnetic field of Earth at the given location is

$$B_E = \frac{H_E}{\cos 60°} = \frac{0.25}{1/2} = 0.50 \text{ G}$$

Q 42. The equatorial magnetic field of Earth is 0.4 G. Then its dipole moment on equator is:

a. 1.05×10^{23} Am² b. 2.05×10^{23} Am²
c. 1.05×10^{21} Am² d. 2.05×10^{21} Am²

Ans. (a) 1.05×10^{23} Am².

Here, $B_E = 0.4$ G $= 0.4\times10^{-4}$ T; $r = 6.4\times10^6$ m

As $B_E = \frac{\mu_0}{4\pi}\frac{M}{r^3}$

$$\therefore \quad M = \frac{B_E r^3}{\mu_0/4\pi} = \frac{0.4\times10^{-4}\times(6.4\times10^6)^3}{10^{-7}} = 1.05\times10^{23} \text{ Am}^2.$$

Q 43. A compass needle whose magnetic moment is 60 Am² pointing geographical north at a certain place where the horizontal component of Earth's magnetic field is 40×10^{-6} Wbm^{-2} experiences a torque of 1.2×10^{-3} Nm. The declination of the place is:

a. 20° b. 45° c. 60° d. 30°

Ans. (d) 30°.

In stable equilibrium, a compass needle points along magnetic north and experiences no torque.

When it is turned through declination α, it points along geographic north and experiences torque.

$\tau = MB\sin\alpha$

$$\therefore \quad \sin\alpha = \frac{\tau}{MB} = \frac{12\times10^{-3}}{60\times40\times10^{-6}} = \frac{1}{2} \text{ or } \alpha = 30°$$

Q 44. A magnetising field of 1500 Am^{-1} produces flux of 2.4×10^{-5} weber in a iron bar of the cross-sectional area of 0.5 cm². The permeability of the iron bar is:

a. 245 b. 250 c. 252 d. 255

Ans. (d) 255

Here, $H = 1500$ Am^{-1}, $\phi = 2.4\times10^{-5}$ weber

$A = 0.5$ cm² $= 0.5\times10^{-4}$ m²

$$\therefore \quad B = \frac{\phi}{A} = \frac{2.4\times10^{-5}}{0.5\times10^{-4}} = 4.8\times10^{-1} \text{ T}$$

and $\quad \mu = \frac{B}{H} = \frac{4.8\times10^{-1}}{1500} = 3.2\times10^{-4}$

So relative permeability

$$\mu_r = \frac{\mu}{\mu_0} = \frac{3.2\times10^{-4}}{4\pi\times10^{-7}}$$

$$= 0.255\times10^3 = 255$$

Q 45. A solenoid has a core of a substance with relative permeability 600. What is the magnetic permeability of the given substance?

a. $20\pi\times10^{-5}$ NA^{-2} b. $21\pi\times10^{-5}$ NA^{-2}
c. $22\pi\times10^{-5}$ NA^{-2} d. $24\pi\times10^{-5}$ NA^{-2}

Ans. (d) $24\pi\times10^{-5}$ NA^{-2}

As $\quad \mu = \mu_r\mu_0$

Here, $\mu_r = 600$ and $\mu_0 = 4\pi\times10^{-7}$ NA^{-2}

$\therefore$ Magnetic permeability,

$$\mu = 600\times4\pi\times10^{-7}$$

$$= 24\pi\times10^{-5} \text{ NA}^{-2}$$

Q 46. A permanent magnet in the shape of a thin cylinder of length 50 cm has intensity of magnetisation 10^6 Am^{-1}. The magnetisation current is:

a. 5×10^5 A b. 6×10^5 A
c. 5×10^4 A d. 6×10^4 A

Ans. (a) 5×10^5 A

Here, $l = 50$ cm $= 0.5$ m, $M = 10^6$ Am^{-1}

As $\quad M = \frac{\text{magnetisation current } (I_M)}{l \text{ (length)}}$

Then, $\quad I_M = M\times l$

$$= 10^6\times0.5 = 5\times10^5 \text{ A}$$

Q 47. A domain in ferromagnetic iron in the form of cube is having 5×10^{10} atoms. If the side length of this domain is 1.5 μm and each atom has a dipole moment of 8×10^{-24} Am², then magnetisation of domain is:

a. 1.18×10^5 Am^{-1} b. 1.18×10^4 Am^{-1}
c. 2.35×10^4 Am^{-1} d. 1.18×10^5 Am^{-1}

Ans. (d) 1.18×10^5 Am^{-1}.

The volume of the cubic domain is

$$V = (1.5 \times 10^{-6} \text{ m})^3$$
$$= 3.38 \times 10^{-18} \text{ m}^3 = 3.38 \times 10^{-12} \text{ cm}^3$$

Number of atoms in domain $(N) = 5 \times 10^{10}$ atoms

Since each iron atom has a dipole moment (M)

$$= 8 \times 10^{-24} \text{ Am}^2$$

M_{max} = total number of dipole moment for all atoms

$$= N \times M = 5 \times 10^{10} \times 8 \times 10^{-24}$$
$$= 40 \times 10^{-14} = 4 \times 10^{-13} \text{ Am}^2$$

Now the consequent magnetisation

$$M'_{max} = \frac{M_{max}}{\text{Domain volume}}$$
$$= \frac{4 \times 10^{-13} \text{ Am}^2}{3.38 \times 10^{-18} \text{ m}^2} = 1.18 \times 10^5 \text{ Am}^{-1}$$

Q 48. A magnetising field of 2×10^3 Am^{-1} produces a magnetic flux density of 8π T in an iron rod. The relative permeability of the rod will be:

a. 10^2 b. 1 c. 10^4 d. 10^3

Ans. (c) 10^4

Here, $H = 2 \times 10^3$ Am^{-1},

$B = 8\pi$ T, $\mu_0 = 4\pi \times 10^{-7}$

Since $\mu_r = \frac{\mu}{\mu_0} = \frac{\mu H}{\mu_0 H} = \frac{B}{\mu_0 H} = \frac{8\pi}{4\pi \times 10^{-7} \times 2 \times 10^3} = 10^4$

Q 49. A permanent magnet in the shape of a thin cylinder of length 10 cm has magnetisation $(M) = 10^6$ Am^{-1}. It's magnetisation current I_M is:

a. 10^5 A b. 10^6 A

c. 10^7 A d. 10^8 A

Ans. (a) 10^5 A

As $Bl = \mu_0 Ml = \mu_0 (I + I_M)$

Here, $I = 0$

Then $\mu_0 Ml = \mu_0 (I_M)$

$\Rightarrow$ $I_M = Ml = 10^6 \times 0.1 = 10^5$ A

Q 50. A ring of mean radius 15 cm has 3500 turns of wire wound on a ferromagnetic core of relative permeability 800. The magnetic field in the core for a magnetising current of 1.2 A is:

a. 2.48 T b. 3.48 T

c. 4.48 T d. 5.48 T

Ans. (c) 4.48 T

Here, $r = 15 \text{ cm} = 15 \times 10^{-2}$ m

$N = 3500$ turns, $I = 1.2$ A, $\mu_r = 800$

Then number of turns/length (n)

$$= \frac{N}{2\pi r} = \frac{3500}{2\pi \times 15 \times 10^{-2}} = 3715.5$$

$$B = \mu_0 \mu_r nI$$
$$B = 4\pi \times 10^{-7} \times 800 \times 3715.5 \times 1.2 = 4.48 \text{ T}$$

Q 51. A solenoid has core of a material with relative permeability of 500. The windings of the solenoid are insulated from the core and carry a current of 2 A. If the number of turns is 1000 per meter, then magnetisation is:

a. 7.78×10^5 Am^{-1} b. 8.88×10^5 Am^{-1}

c. 9.98×10^5 Am^{-1} d. 10.2×10^5 Am^{-1}

Ans. (c) 9.98×10^5 Am^{-1}

As $B = \mu_0 (M + H)$

Magnetisation, $M = \frac{(B - \mu_0 H)}{\mu_0}$

then $M = \frac{\mu_0 \mu_r H - \mu_0 H}{\mu_0} = (\mu_r - 1)H$ $(\because B = \mu_0 \mu_r H)$

Here, $\mu_r = 500$

and $H = nI = 1000 \times 2 = 200$ Am^{-1}

$\therefore$ $M = (500 - 1)H = 499 \times 2000$

or $M = 9.98 \times 10^5$ Am^{-1}

Q 52. A solenoid has core of a material with relative permeability 500 and its windings carry a current of 1.2 A. The number of turns of the solenoid is 500 per metre. The magnetisation of the material is nearly:

a. 2.5×10^3 Am^{-1} b. 3×10^5 Am^{-1}

c. 2.0×10^3 Am^{-1} d. 2.0×10^5 Am^{-1}

Ans. (b) 3×10^5 Am^{-1}

Here, $n = 500$ turns/m

$I = 1.2$ A, $\mu_r = 500$

Magnetic intensity,

$$H = nI = 500 \text{ m}^{-1} \times 1.2 \text{ A} = 600 \text{ Am}^{-1}$$

As $\mu_r = 1 + \chi$

where χ is the magnetic susceptibility of the material

or $\chi = (\mu_r - 1)$

Magnetisation, $M = \chi H$

$$= (\mu_r - 1)H = (500 - 1) \times 600 \text{ Am}^{-1}$$
$$= 499 \times 600 \text{ Am}^{-1}$$
$$= 2.994 \times 10^5 \text{ Am}^{-1}$$
$$\approx 3 \times 10^5 \text{ Am}^{-1}$$

Q 53. The relation connecting magnetic susceptibility χ_m and relative permeability μ_r is:

a. $\chi_m = \mu_r + 1$ b. $\chi_m = \mu_r - 1$

c. $\chi_m = \frac{1}{\mu_r}$ d. $\chi_m = 3(1 + \mu_r)$

Ans. (b) $\chi_m = \mu_r - 1$

Relationship between magnetic susceptibility χ_m and relative permeability μ_r is $\mu_r = 1 + \chi_m$ or $\chi_m = \mu_r - 1$

Q 54. The relative permeability of iron is 6200. Its magnetic susceptibility is:

a. 6099 b. 6201 c. 6199 d. 6200×10^7

Ans. (c) 6199

Relative permeability of iron, $\mu_r = 6200$

Magnetic susceptibility $\chi_m = \mu_r - 1 = 6199$

Assertion and Reason Type Questions

Directions (Q.Nos. 55 to 76): In the following questions, astatement of Assertion (A) is followed by a statement of Reason (R). Mark the correct choice as:

a. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A)
b. Both Assertion (A) and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A)
c. Assertion (A) is true but Reason (R) is false
d. Assertion (A) is false and Reason (R) is also false

Q 55. Assertion (A): When a bar magnet is freely suspended, it points in the north-south direction.

Reason (R): The Earth behaves as a magnet with the magnetic field pointing approximately from the geographic south to north.

Ans. (a)

The magnet align itself in north-south direction, when it is freely suspended because Earth behaves as a magnet.

Q 56. Assertion (A): Magnetic force between two short magnets, when they are co-axial follows inverse saquare law of distance.

Reason (R): The magnetic forces between two poles do not follow inverse square law of distance.

Ans. (d)

It does not follow inverse square law of distance. The assertion and reason both are false.

Q 57. Assertion (A): Gauss's law of magnetism is different from that for electrostatics.

Reason (R): Isolated magnetic poles are not known to exist.

Ans. (a)

Gauss's law of magnetism is different from that for electrostatics because electric charges do not necessarily exist in pairs but magnetic monopoles do not exist.

Q 58. Assertion (A): Earth's magnetic field does not affect the working of a moving coil glavanometer.

Reason (R): The Earth's magnetic field as quite weak as compared to magnetic field produces in the moving coil galvanometer.

Ans. (a)

The field magnet used in a moving coil galvanometer is very strong. The Earth's magnetic field is quite weak as compared to the magnetic field produced by the field magnet. Practically the coil rotates under the effect of the strong magnetic field due to the field magnet and the weak magnetic field due to the Earth does not affect the working of the moving coil galvanometer.

Q 59. Assertion (A): The magnetic field lines of the Earth resemble that of a magnetic dipole located at the centre of the Earth.

Reason (R): The axis of the dipole coincide with the axis of rotation of the Earth.

Ans. (c)

The magnetic field lines of the Earth resemble that of a hypothetical magnetic dipole located at the centre of the Earth.The axis of the dipole does not coincide with the axis of rotation of the Earth but is presently tilted by approximately 11.3° with respect to the later.

Q 60. Assertion (A): In water, value of magnetic field decreases.

Reason (R): Water is a diamagnetic substance.

Ans. (a)

Water is a diamagnetic substance. The relative permeabilityof water is less than 1.

Q 61. Assertion (A): When diamagnetic material is placed in a non-uniform magnetic field, it tends to move from stronger to the weaker part of the magnetic field.

Reason (R): Diamagnetic materials possess strong magnetism.

Ans. (c)

Electrons in an atom orbiting around nucleus possess orbital angular momentum. These orbiting electrons are equivalent to current-carrying loop and thus possess orbital magnetic moment. Diamagnetic substances are the ones in which resultant magnetic moment in an atom is zero. When magnetic field is applied, those electrons having orbital magnetic moment in the same direction slow down and those in the opposite direction speed up. Thus, the substance develops a net magnetic moment in direction opposite to that of the applied field.

Q 62. Assertion (A): The ability of a material to permit the passage of magnetic lines of force through it is called magnetic permeability.

Reason (R): For a perfect diamagnetic substance, permeability is always one.

Ans. (c)

For a perfectly diamagnetic substance,

$$B = \mu_0(H + I) = 0 \quad \therefore \quad I = -H.$$

Therefore, $\chi_m = \frac{I}{H} = -1$

Therefore relative permeability

$$\mu_r = 1 + \chi_m = 1 - 1 = 0$$

$$\therefore \quad \mu = \mu_0 \mu_r = \text{zero}$$

i.e. for a perfect diamagnetic material permeability is zero.

Q 63. Assertion (A): Magnetic moment of an atom is due to both, the orbital motion and spin motion of every electron.

Reason (R): A charged particle produces a magnetic field.

Ans. (c)

In an atom, electrons revolve around the nucleus and as such the circular orbits of electrons may be considered as the small current loops. In addition to orbital motion, an electron has got spin motion also. So the total magnetic moment of electron is the vector sum of its magnetic moments due to orbital and spin motion.

Q 64. Assertion (A): The Earth's magnetic field is due to iron present in its core.

Reason (R): At a low temperature magnet losses its magnetic property or magnetism.

Ans. (d)

The temperature inside the Earth is so high that it is impossible for iron core to behave as a magnet and act as a source of magnetic field. The magnetic field of Earth is considered to be due to circulating electric current in the iron (in molten state) and other conducting materials inside the Earth.

Q 65. Assertion (A): The ends of a magnet suspended freely point out always along north south.

Reason (R): Earth behaves as a huge magnet.

Ans. (a)

Earth's magnetic field can be represented as the field of a huge bar magnet. If the magnet is freely suspended its north-pole points towards geographic north pole (really a south magnet pole of Earth).

Q 66. Assertion (A): A compass needle when placed on the magnetic north pole of the Earth rotates in vertical direction.

Reason (R): The Earth has only horizontal component of its magnetic field at the north poles.

Ans. (d)

The Earth has only vertical component of its magnetic field at the magnetic poles. Since compass needle is only free to rotate in horizontal plane. At north pole the vertical component of Earth's field will exert torque on the magnetic needle so as to align it along its direction. As the compass needle can not rotate in vertical plane. It will rest horizontally, when placed on the magnetic north pole of the Earth.

Q 67. Assertion (A): At neutral point, a compass neddle point out in any arbitrary direction.

Reason (R): Magnetic field of Earth is balanced by field due to magnets at the neutral points.

Ans. (a)

A neutral point in the magnetic field of a bar magnet is that point, where the field due to magnet is completely neutralised by the horizontal component of Earth's magnetic field. The net horizontal field is zero at such a point. If a compass needle is placed at such a point, it can stay in any position.

Q 68. Assertion (A): Magnetic moment is measured in joule/tesla or amp m^2.

Reason (R): Joule/tesla is equivalent to amp m^2.

Ans. (a) Magnetic moment $= \frac{\text{joule}}{\text{tesla}} = \frac{W}{B} = \frac{W}{F/qv}$

$$= \frac{Wqv}{F} = \frac{[ML^2T^{-2}][AT][LT^{-1}]}{[MLT^{-2}]}$$

$$= [AL^2] = \text{amp m}^2$$

Q 69. Assertion (A): A clinic lines on the magnetic map represents lines of equal dip.

Reason (R): When the horizontal and vertical components of the Earth's magnetic field are equal, the angle of dip is 60°.

Ans. (d)

The angle of dip is the angle between the axis of the dip needle in the magnetic meridian and the horizontal direction.

$$\tan\theta = \frac{\text{Vertical component of the Earth's magnetic field}}{\text{Horizontal component of the Earth's magnetic field}}$$

$$= \frac{B_V}{B_H}, \quad \text{when } B_V = B_H, \ \tan\theta = 1 \Rightarrow \theta = 45°$$

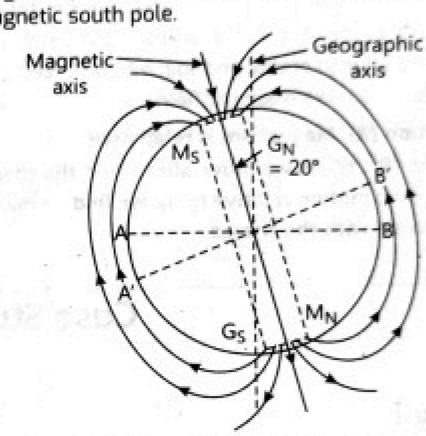
Lines joining points of zero dip are called Aclinic lines. Lines joining points of equal dip are called isoclinic lines.

Q 70. Assertion (A): The true geographic north direction is found by using a compass needle.

Reason (R): The magnetic meridian of the Earth is along the axis of rotation of the Earth.

Ans. (d)

From the compass we are able to know the direction of the magnetic poles. The north of compass points towards the magnetic south pole.



If we know the magnetic declination at that particular place (which is angle between geographic meridian and magnetic meridian) we can easily find out the true geographic north-south direction.

Imaginary lines drawn along the Earth's surface in the direction of the horizontal component of the magnetic field of the Earth at all points passing through the north and south magnetic poles. This is similar to the longitudes of the Earth, which pass through the geographic north and south poles.

Q 71. Assertion (A): There is only one neutral point an a horizontal board when a magnet is held vertically on the board.

Reason (R): At the neutral point the net magnetic field due to the magnetic field of the Earth is zero.

Ans. (b)

There will be only one neutral point on the horizontal board. This is because field of Earth magnetic field is from south to north; and the field of pole on the board is radially outwards. At any point towards south of magnetic pole, field of pole will cancel out to give a neutral point.

Q 72. Assertion (A): The poles of magnet cannot be separated by breaking into two pieces.

Reason (R): The magnetic moment will be reduced to half when a magnet is broken into two equal pieces.

Ans. (b)

As we know every atom of a magnet acts as a dipole. So, poles cannot be separated. When magnet is broken into two equal pieces, magnetic moment of each part will be half of the original magnet.

T!P

Dipoles of an atom of a magnet always exists in pair.

Q 73. Assertion (A): Magnetic moment of an atom is due to both, the orbital motion and spin motion of every electron.

Reason (R): A charged particle produces a magnetic field.

Ans. (c)

In an atom, electrons revolve around the nucleus and as such the circular orbits of electrons may be considered as the small current loops. In addition to orbital motion, an electron has got spin motion also. So, the total magnetic moment of electron is the vector addition of its magnetic moments due to orbital and spin motion. Charge particles at rest do not produce electric field.

Q 74. Assertion (A): Magnetism is relativistic.

Reason (R): When we move along with the charge so that there is no motion relative to us, we find no magnetic field associated with the charge.

Ans. (a)

A magnetic field is produced by the motion of electric charge. Since motion is relative, the magnetic field is also relative.

Q 75. Assertion (A): When radius of circular loop carrying current is doubled, its magnetic moment becomes four times.

Reason (R): Magnetic moment depends on area of the loop.

Ans. (b)

Magnetic dipole moment of the current loop

= Ampere turns × Area of the coil

Initially magnetic moment $\vec{M} = I\pi r^2$, new magnetic moment

$$\vec{M} = I\pi(2r)^2 = 4I(\pi r^2) = 4\vec{M}$$

So magnetic moment becomes four times when radius is doubled.

Q 76. Assertion (A): The Earth's magnetic field does not affect the working of a moving coil galvanometer.

Reason (R): Earth's magnetic field is very weak.

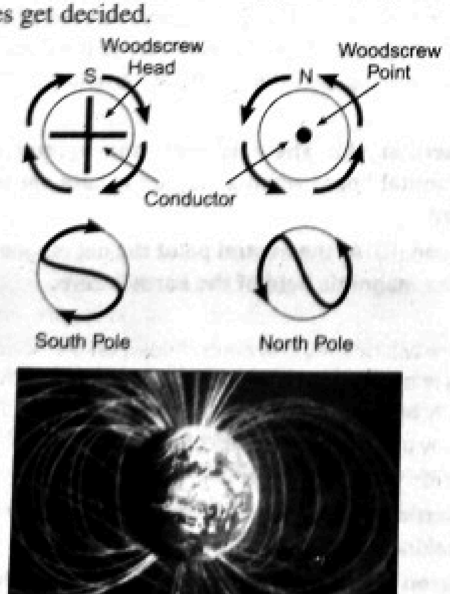
Ans. (a)

In a moving coil galvanometer, the coil is suspended in a very strong uniform magnetic field created by two magnetic pole pieces. The Earth's magnetic field is quite weak as compared to that field, therefore, it does not effect the working of moving coil galvanometer.

Case Study Based QUESTIONS

Case Study 1

Current loop behaves like a magnetic dipole and has a magnetic field. They behave just like a magnet. Interesting part is, it depends upon the direction of current in loop which decides whether magnetic field line is in outward or inward direction. With the help of this outward and inward direction of magnetic field, north and south poles get decided.



Behaviour of current loop as a Magnetic Dipole

Anticlockwise direction of current creates north pole (outward direction magnetic field) and clockwise direction of current creates a south pole (inward direction magnetic field). Magnetic dipole moment $\vec{M}$ with the circular current loop carrying a current I and of area A. The magnitude of m is given by

$$|\vec{M}| = I \times A$$

Current in the circular coil produces magnetic field and Amperes found out that magnetic field created due to circular coil is similar to the magnetic field due to a bar magnet. Wood screw head sign shows that direction of screw is inward because we are not able to see pointed part of screw and so direction is inward. This inward direction of screw denotes the direction of the magnetic field.

Read the given passage carefully and give answer of the following questions:

Q 1. A thin circular wire carrying a current I, has a magnetic moment M. The shape of the wire is changed to a square and it carries the same current. It will have a magnetic moment:

a. $\frac{4}{\pi^2}M$ b. M c. $\frac{4}{\pi}M$ d. $\frac{\pi}{4}M$

Ans. (d) $\frac{\pi}{4}M$

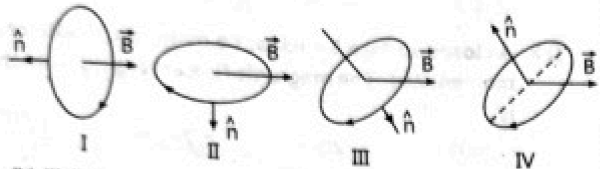
$$2\pi r = 4l$$

$$\Rightarrow \quad l = \frac{\pi r}{2} \qquad [\because M = l]$$

$$\Rightarrow \quad \frac{M'}{M} = \frac{l \cdot \frac{\pi^2 r^2}{4}}{l \cdot \pi r^2} = \frac{\pi}{4}$$

$$\Rightarrow \quad M' = \frac{\pi}{4}M$$

Q 2. A current carrying loop is placed in a uniform magnetic field in four different orientations as shown in figure. Arrange them in the decreasing order of potential energy.



a. IV, III, II, I
b. I, IV, II, III
c. IV, II, III, I
d. I, II, III, IV

Ans. (b) I, IV, II, III

$$U = -MB\cos\theta$$

$$U_1 = -MB\cos 180° = +MB$$

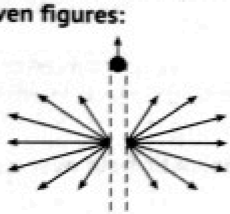
$$U_2 = -MB\cos 90° = 0$$

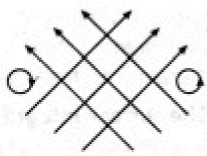
$$U_3 = -MB\cos(\text{Acute angle}) = -ve$$

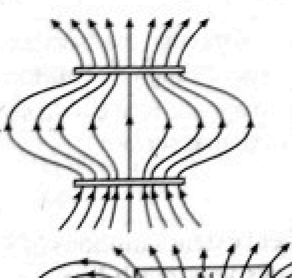
$$U_4 = -MB\cos(\text{Obtuse angle}) = +ve$$

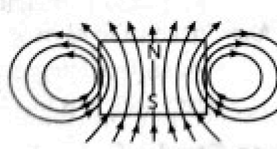
Hence, I > IV > II > III.

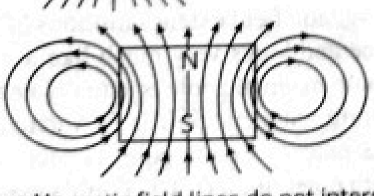
Q 3. Point out the correct direction of magnetic field in the given figures:

a.


b.


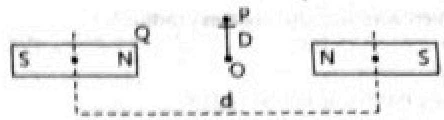
c.


d.


Ans. (d)


Since Magnetic field lines do not intersect each other and originates from N pole. So, (d) is correct.

Q 4. Two identical bar magnets are fixed with their centres at a distance d apart. A stationary charge Q is placed at P in between the gap of the two magnets at a distance D from the centre O as shown in the figures. The force on the charge Q is:



a. zero
b. directed along OP
c. directed along PO
d. directed perpendicular to the plane of paper

Ans. (a) zero

Since the charge is at rest, zero force acts on it.

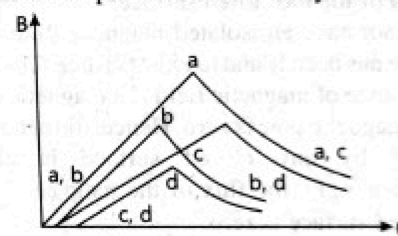
Q 5. In a bar magnet, magnetic lines of force:

a. are produced only at north pole like rays of light from a bulb.
b. starts from north pole and ends at the south pole.
c. emerge in circular paths from the middle of the bar.
d. run continuously through the bar and outside.

Ans. (b) starts from north pole and ends at the south pole.

Case Study 2

The field of a hollow wire with constant current is homogenous. Curves in the graph shown give, as functions of radius distance r, the magnitude B of the magnetic field inside and outside four long wires a, b, c and d carrying currents that are uniformly distributed across the cross-sections of the wires. Overlapping portions of the plots are indicated by double labels.



Read the given passage carefully and give answer of the following questions:

Q 1. Which wire has the greatest magnitude of the magnetic field on the surface?

a. a
b. b
c. c
d. d

Ans. (a) a

It can be seen that slop of curve for wire a is greater than wire c.

Q 2. The current density in a wire a is:

a. greater than in wire c
b. less than in wire c
c. equal to that in wire c
d. not comparable to that of in wire c due to lack of information

Ans. (b) less than in wire c

Inside the wire

$$B(r) = \frac{\mu_0}{2\pi}\frac{I}{R^2}r \Rightarrow \frac{dB}{dr} = \frac{\mu_0}{2\pi}\frac{I}{R^2}r$$

i.e., $\quad \text{Slope} \propto \frac{I}{\pi R^2} \propto \text{Current density}$

Q 3. Which wire has the greatest radius?

a. *a* b. *b* c. *c* d. *d*

Ans. (c) *c*

Wire *c* has the greatest radius.

Q 4. A direct current *I* flows along the length of an infinitely long straight thin walled pipe, then the magnetic field is:

a. uniform throughout the pipe but not zero.
b. zero only along the axis of the pipe.
c. zero at any point inside the pipe.
d. maximum at the centre and minimum at the edges.

Ans. (c) zero at any point inside the pipe.

Q 5. In a coaxial, straight cable, the central conductor and the outer conductor carry equal currents in opposite direction. The magnetic field is zero:

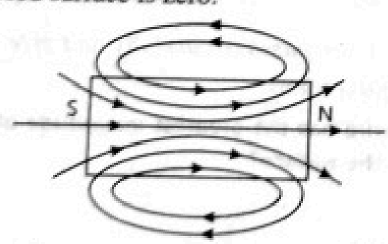
a. outside the cable.
b. inside the inner conductor.
c. inside the outer conductor.
d. in between the two conductor.

Ans. (a) outside the cable.

Case Study 3

By analogy to Gauss's law of electrostatics, we can write Gauss's law of magnetism as $\oint \vec{B} \cdot d\vec{S} = \mu_0 \, m_{inside}$ where $\oint \vec{B} \cdot d\vec{S}$ is the magnetic flux and m_{inside} is the net pole strength inside the closed surface.

We do not have an isolated magnetic pole in nature. At least one has been found to exist till date. The smallest unit of the source of magnetic field is a magnetic dipole where the net magnetic pole is zero. Hence, the net magnetic pole enclosed by any closed surface is always zero. Correspondingly, the flux of the magnetic field through any closed surface is zero.



Read the given passage carefully and give answer of the following questions:

Q 1. Consider the two idealised systems

(i) A parallel plate capacitor with large plates and small separation and

(ii) a long solenoid of length $L >> R$, radius of cross-section.

In (i) $\vec{E}$ is ideally treated as a constant between plates and zero outside. In (ii) magnetic field is constant inside the solenoid and zero outside. These idealised assumptions, however, contradict fundamental laws as below:

a. case (i) contradicts Gauss's law for electrostatic fields.
b. case (ii) contradicts Gauss's law for magnetic fields.
c. case (i) agrees with $\oint \vec{E} \cdot d\vec{l} = 0$.
d. case (ii) contradicts $\oint \vec{E} \cdot d\vec{l} = I_{en}$.

Ans. (b) case (ii) contradicts Gauss's law for magnetic fields.

According to Gauss's law in magnetism $\oint \vec{B} \cdot d\vec{S} = 0$, which implies that number of magnetic field lines entering the Gaussian surface is equal to the number of magnetic field lines leaving it. Therefore, case (ii) is not possible.

Q 2. The net magnetic flux through any closed surface, kept in a magnetic field is:

a. zero b. $\frac{\mu_0}{4\pi}$ c. $4\pi\mu_0$ d. $\frac{4\mu_0}{\pi}$

Ans. (a) zero

The net magnetic flux through a closed surface will be zero, *i.e.* $\oint \vec{B} \cdot d\vec{S} = 0$, because there are no magnetic monopoles.

Q 3. A closed surface *S* encloses a magnetic dipole of magnetic moment $2ml$. The magnetic flux emerging from the surface is:

a. $\mu_0 m$ b. zero c. $2\mu_0 m$ d. $\frac{2m}{\mu_0}$

Ans. (b) zero

Q 4. Which of the following is not a consequence of Gauss's law?

a. The magnetic poles always exist as unlike pairs of equal strength.
b. If several magnetic lines of force enter in a closed surface, then an equal number of lines of force must leave that surface.
c. There are abundant sources or sinks of the magnetic field inside a closed surface.
d. Isolated magnetic poles do not exist.

Ans. (c) There are abundant sources or sinks of the magnetic field inside a closed surface.

Gauss' law indicates that there are no sources or sinks of the magnetic field inside a closed surface. In other words, there are no free magnetic charges.

Q 5. The surface integral of a magnetic field over a surface:

a. is proportional to mass enclosed.
b. is proportional to charge enclosed.
c. is zero.
d. equal to its magnetic flux through that surface.

Ans. (d) equal to its magnetic flux through that surface.

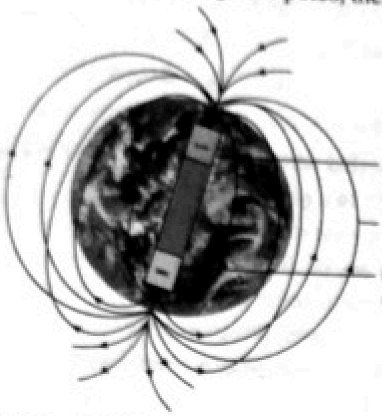
The surface integral of a magnetic field over a surface gives magnetic flux through that surface.

Case Study 4

The Earth's magnetic field extends millions of kilometres into outer space and looks very much like a bar magnet. The Earth's south magnetic pole is actually near the north pole and the north magnetic pole is in Antarctica. This is why a compass magnet's north pole actually points north (north and south poles attract). The Earth's magnetic field extends far and wide but is very weak in terms of field strength.

Magnetic Declination: It is defined as the angle between the true north and the magnetic north. On the horizontal plane, the true north is never at a constant position and keeps varying depending upon the position on the Earth's surface and time.

Magnetic Inclination: The magnetic inclination is also known as the angle of dip. It is the angle made the plane on the Earth's surface. At the magnetic equator, the angle of dip is 0° and at the magnetic poles, the angle of dip is 90°.



Horizontal Component of the Earth's Magnetic Field: There are two components to explain the intensity of the Earth's magnetic field: Horizontal component (B_H) and vertical component (B_V).

$$\tan\delta = B_V / B_H$$

Read the above passage carefully and give the answer of the following questions:

Q 1. The vertical component of the Earth's magnetic field is at a place is $\sqrt{3}$ times the horizontal component. What is the value of angle of dip at this place?

a. 60° b. 45° c. 90° d. 30°

Ans. (a) 60°.

$$B_V = \sqrt{3}\, B_H$$

Q 2. A bar magnet is placed with its north pole pointing Earth's north. The points of zero magnetic field will be in which direction from the centre of the magnet?

a. North and south
b. East and west
c. North-east and south-west
d. North-west and south-east

Ans. (b) East and west.

Q 3. Which of the following statements is true about magnetic lines of force?

a. Magnetic lines of force are always closed.
b. Magnetic lines of force always intersect Earth other.
c. Magnetic lines of force tend to crowd far away from the poles of the magnet.
d. Magnetic lines of force do not pass through the vacuum.

Ans. (a) Magnetic lines of force are always closed.

Q 4. A long magnet is cut into two parts such that the ratio of their lengths is 2 : 1. What is the ratio poles strength of both the section?

a. 1 : 2 b. 2 : 1 c. 4 : 1 d. Equal

Ans. (d) Equal

Poles strength remain same always.

Q 5. If a man in Antarctica, then the angle of dip for the man is:

a. 60° b. 45° c. 90° d. 30°

Ans. (c) 90°.

Angle of dip at pole is 90°.

Cast Study 5

Earth's magnetic field is dynamo effect. The circulating electric current in the Earth's core is the origin of the magnetic field. The fluid motion in Earth's outer core moves liquid iron and generates an electric current. The rotation of Earth on its axis causes these electric current to form a magnetic field which extends around a planet. The magnetic field magnitude measured at the surface of the Earth is about a half Gauss.

The magnetic field is extremely important to sustaining life on Earth.Without it, we would be exposed to high amounts of radiation from the Sun and our atmosphere would be free to leak into space.This is likely what happened to the atmosphere on Mars. As Mars doesn't have flowing liquid metal in its core, it doesn't produce the same dynamo effect. This left the plant with a very weak magnetic field, allowing for its atmosphere to be stripped away by solar winds, leaving it uninhabitable. Based upon the study of lava flows throughout the world, it has been proposed that the Earth's magnetic field reverses at an average interval of approximately 3,00,000 years. However, the last such event occurred some 7,80,000 years ago.

Read the above passage carefully and give the answer of the following questions:

Q 1. Which of the following is responsible for Earth's magnetic field?

a. Circulating electric current in Earth's core
b. Rotation of Earth
c. Attraction due to other celestial bodies
d. Solar flares

Ans. (a) Circulating electric current in Earth's core

The circulating electric current in the Earth's core is the origin of the magnetic field.

Q 2. Electric current in the Earth's core is generated due to:

a. Movement of charged particle in the atmosphere.
b. Flowing of liquid metal in the outer core.
c. Electric discharges during thunderstorm.
d. Its revolution around the Sun.

Ans. (b) Flowing of liquid metal in the outer core.

The fluid motion in Earth's outer core moves liquid iron and generates an electric current.

Q 3. Which planet has no own magnetic field?

a. Jupiter b. Neptune
c. Mars d. Mercury

Ans. (c) Mars

As mars doesn't have flowing liquid metal in its core, it doesn't produce the same dynamo effect. So it has very weak or almost no magnetic field.

Q 4. Magnetic field strength at the Earth's surface is:

a. 5 Gauss b. 0.5 Gauss
c. 500 Gauss d. Cannot be measured

Ans. (b) 0.5 Gauss

The magnetic field strength at the Earth's surface is about a half Gauss.

Q 5. Which of the following statement is true?

a. Earth's magnetic field is due to electric current induced in the ionosphere.

b. The average magnetic field strength in the Earth's outer core is equal to the magnetic field at the surface

c. Earth's magnetic field reverses at an average interval of approximately 3,00,000 years.

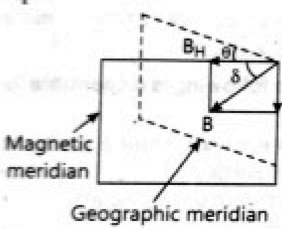
d. Angle of dip is same at every point of the surface of Earth.

Ans. (c) Earth's magnetic field reverses at an average interval of approximately 3,00,000 years.

Based upon the study of lava flows throughout the world, it has been proposed that the Earth's magnetic field reverse at an average interval of approximately 3,00,000 years.

Case Study 6

The Earth's magnetic field at a point on its surface is usually characterised by three quantities: (a) declination (b) inclination or dip and (c) horizontal component of the field. These are known as the elements of the Earth's magnetic field. At a place, angle between geographic meridian and magnetic meridian is defined as magnetic declination, whereas angle made by the Earth's magnetic field with the horizontal in magnetic meridian is known as magnetic dip.



Read the above passage carefully and give the answer of the following questions:

Q 1. In a certain place, the horizontal component of magnetic field is $\frac{1}{\sqrt{3}}$ times the vertical component. The angle of dip at this place is:

a. zero b. $\pi/3$ c. $\pi/2$ d. $\pi/6$

Ans. (b) $\pi/3$

$$\tan\theta = \frac{B_V}{B_H} \text{ and } B_H = \frac{B_V}{\sqrt{3}}$$

$$\therefore \quad \tan\theta = \sqrt{3} \quad i.e.\ \theta = \frac{\pi}{3}$$

Q 2. The angle between the true geographic north and the north shown by a compass needle is called as:

a. inclination b. magnetic declination

c. angle of meridian d. magnetic pole

Ans. (b) magnetic declination

The angle between the true geographic north and the north shown by a compass needle is called as magnetic declination or simply declination.

Q 3. The angles of dip at the poles and the equator respectively are:

a. 30°, 60° b. 0°, 90° c. 45°, 90° d. 90°, 0°

Ans. (d) 90°, 0°

Since angle of dip at a place is defined as the angle δ, which is the direction of total intensity of Earth's magnetic field B makes with a horizontal line in magnetic meridian.

At poles $B = B_V$ and $B_V = B\sin\delta$

$\therefore$ $\sin\delta = 1$ $\Rightarrow$ $\delta = 90°$

At equator $B = B_H$ and $B_H = B\cos\delta$

$\therefore$ $\cos\delta = 1$ $\Rightarrow$ $\delta = 0$

Q 4. A compass needle which is allowed to move in a horizontal plane is taken to a geomagnetic pole. It:

a. will become rigid showing no movement.

b. will stay in any position.

c. will stay in north-south direction only.

d. will stay in east-west direction only.

Ans. (a) will become rigid showing no movement.

A compass needle which is allowed to move in a horizontal plane is taken to a geomagnetic pole. It will stay in any position as the horizontal component of Earth's magnetic field becomes zero at the geomagnetic pole.

Q 5. Select the correct statement from the following:

a. The magnetic dip is zero at the centre of the Earth.

b. Magnetic dip decreases as we move away from the equator towards the magnetic pole.

c. Magnetic dip increases as we move away from the equator towards the magnetic pole.

d. Magnetic dip does not vary from place to place.

Ans. (c) Magnetic dip increases as we move away from the equator towards the magnetic pole.

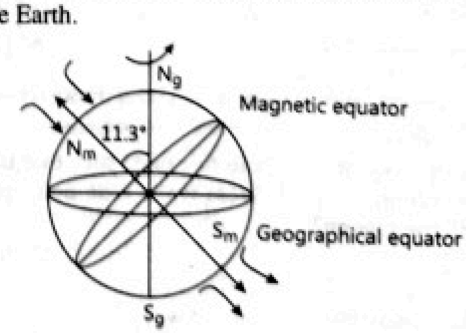
At equator, $\delta = 0°$

At poles, $\delta = 90°$

$\therefore$ δ increases as we move from equator towards poles.

Case Study 7

The magnetic field lines of the Earth resemble that of a hypothetical magnetic dipole located at the centre of the Earth. The axis of the dipole is presently tilted by approximately 11.3° with respect to the axis of rotation of the Earth.



The pole near the geographic north pole of the Earth is called the north magnetic pole and the pole near the geographic south pole is called south magnetic pole.

Read the given passage carefully and give the answer of the following questions:

Q 1. The strength of the Earth's magnetic field varies from place to place on the Earth's surface, its value being of the order of:

a. 10^5 T b. 10^{-6} T c. 10^{-5} T d. 10^8 T

Ans. (c) 10^{-5} T

Q 2. A bar magnet is placed North-South with its North-pole due North. The points of zero magnetic field will be in which direction from centre of magnet?

a. North-South
b. East-West
c. North-East and South-West
d. None of the above

Ans. (b) East-West

Q 3. The value of angle of dip is zero at the magnetic equator because on it:

a. B_V and B_H are equal.
b. the values of B_V and B_H are zero.
c. the value of B_V is zero.
d. the value of B_H is zero.

Ans. (c) the value of B_V is zero.

At equator vertical component of magnetic fields is zero.

Q 4. The angle of dip at a certain place, where the horizontal and vertical components of the Earth's magnetic field are equal, is:

a. 30° b. 90° c. 60° d. 45°

Ans. (d) 45°

Given $B_V = B_H$

$\therefore \quad \tan\delta = \dfrac{B_V}{B_H} = 1$ or $\delta = 45°$

Q 5. At a place, angle of dip is 30°. If horizontal component of Earth's magnetic field is B_H, then the total intensity of magnetic field will be:

a. $\dfrac{B_H}{2}$ b. $\dfrac{2B_H}{\sqrt{3}}$ c. $B_H\sqrt{\dfrac{3}{2}}$ d. $2B_H$

Ans. (b) $\dfrac{2B_H}{\sqrt{3}}$

Case Study 8

When the atomic dipoles are aligned partially or fully, there is a net magnetic moment in the direction of the field in any small volume of the material. The actual magnetic field inside material placed in magnetic field is the sum of the applied magnetic field and the magnetic field due to magnetisation. This field is called magnetic intensity (H).

$$H = \frac{B}{\mu_0} - M$$

where M is the magnetisation of the material, μ_0 is the permittivity of vacuum and B is the total magnetic field. The measure that tells us how a magnetic material responds to an external field is given by a dimensionless quantity is appropriately called the magnetic susceptibility: for a certain class of magnetic materials, intensity of magnetisation is directly proportional to the magnetic intensity.

Read the given passage carefully and give the answer of the following questions:

Q. 1. Magnetisation of a sample is:

a. volume of sample per unit magnetic moment.
b. net magnetic moment per unit volume.
c. ratio of magnetic moment and pole strength.
d. ratio of pole strength to magnetic moment.

Ans. (b) net magnetic moment per unit volume.

Q 2. Identify the wrongly matched quantity and unit pair.

a. Pole strength	-Am
b. Magnetic susceptibility	-dimensionless number
c. Intensity of magnetisation	-Am^{-1}
d. Magnetic permeability	-Henry m

Ans. (d) Magnetic permeability -Henry m

Magnetic permeability -Henry m^{-1}

Q 3. A bar magnet has length 3 cm, cross-sectional area 2 cm^2 and magnetic moment 3 Am^2. The intensity of magnetisation of bar magnet is:

a. 2×10^5 A/m b. 3×10^5 A/m
c. 4×10^5 A/m d. 5×10^5 A/m

Ans. (d) 5×10^5 A/m

Given, $l = 3$ cm, $A = 2\,cm^2$, $M = 3\,Am^2$

Intensity of magnetisation $= \dfrac{M}{lA} = \dfrac{3}{3\times10^{-2}\times2\times10^{-4}}$

$= \dfrac{1}{2\times10^{-6}} = 0.5\times10^6 = 5\times10^5$ A/m

Q 4. A solenoid has core of a material with relative permeability 500 and its windings carry a current of 1 A. The number of turns of the solenoid is 500 per metre. The magnetisation of the material is nearly:

a. $2.5\times10^3\ Am^{-1}$ b. $2.5\times10^5\ Am^{-3}$
c. $2.0\times10^3\ Am^{-1}$ d. $2.0\times10^5\ Am^{-1}$

Ans. (b) $2.5\times10^5\ Am^{-3}$

Here, $n = 500$ turns/m

$I = 1A,\ \mu_r = 500$

Magnetic intensity,

$H = nI = 500\,m^{-1}\times1\,A = 500\,Am^{-1}$

As $\mu_r = 1 + \chi_m$

or $\chi_m = (\mu_r - 1)$

Magnetisation, $M = \chi_m H$

$= (\mu_r - 1)H = (500-1)\times500\ Am^{-1}$

$= 2.495\times10^5\ Am^{-1}$

$\approx 2.5\times10^5\ Am^{-1}$

Q 5. The relative permeability of iron is 6000. Its magnetic susceptibility is:

a. 5999 b. 6001
c. 6000×10^{-7} d. 6000×10^7

Ans. (a) 5999

Relative permeability of iron, $\mu_r = 6000$

Magnetic susceptibility, $\chi_m = \mu_r - 1 = 5999$.

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CHAPTER 6

Electromagnetic Induction

Fastrack REVISION

- **Electromagnetic Induction:** When magnetic flux changes through a coil, an e.m.f. is induced which is called E.M.I.
- **Magnetic Flux:** Magnetic lines of force passing through a surface area is called magnetic flux. It is a scalar quantity.

$$\phi = BA\cos\theta$$

S.I. unit of ϕ is weber of Tm^2

$$1\ Wb = 10^8\ Maxwell$$

- **Faraday's Law of Induction:**

(i) When a magnetic flux associated with closed circuit changes, an e.m.f. is induced which lasts as ling as flux changes.

(ii) The rate of change of magnetic flux is directly proportional to induced current.

$$\varepsilon = -\frac{d\phi}{dt} \text{ or } \varepsilon = \frac{\phi_2 - \phi_1}{t}$$

- Negative sing shows that the emf induced opposes the cause by which it is produced.

If N is the number of turns of the coil then,

$$\varepsilon = -\frac{Nd\phi}{dt}$$

- **The Experiments of Faraday and Henry:**

Experiment 1: Current induced by a magnet.

Experiment 2: Current induced by current.

Experiment 3: Current induced by changing current.

- **Lenz's law:** The production of e.m.f. induced through a coil opposes the change in magnetic flux responsible for its production.
- **Montional E.M.F. of a coil in Uniform Magnetic Field:**

$$\varepsilon = -Blv$$

- **Eddy Currents:** The current induced on a metallic block by changing a magnetic field is called eddy current.

$$I = \frac{\varepsilon}{R} \quad \text{or} \quad I = \frac{-d\phi / dt}{R}$$

- **Applications of Eddy Currents:**

(i) The eddy current is used in induction furnace to prepare alloys by melting the constituent metals.

(ii) It is used in designing dead beat galvanometer.

- **Self Inductance:**

$$L = \frac{-\varepsilon}{dI / dt}$$

where, L = coefficient of self-induction or self-inductance

S.I. unit of L is henry.

- **Inductance of a Long Solenoid,**

$$L = \frac{\mu_0 N^2 A}{l} = \mu_0 n^2 Al$$

- **Mutual Inductance:** The phenomenon of inducing e.m.f. by changing the magnetic flux in nearby coil,

$$\phi_S \propto I_p \quad \text{or} \quad \phi_S = MI_p$$

where, M = coefficient of mutual inductance

S.I. unit of M is henry.

- **Mutual Inductance of Two Long Co-axial Solenoids:**

$$M = \frac{\mu_0 N_1 N_2 A}{l}$$

- **Energy Stored in an Inductor:**

$$W = \frac{1}{2} LI_0^2$$

Objective TYPE QUESTIONS

Multiple Choice Questions

Q 1. Which of the following options is true?

a. Moving electric charges produce magnetic fields.

b. The phenomenon of generating current of e.m.f. by changing magnetic fields is called electromagnetic induction.

c. Generators, transformers etc. works on the principle of electromagnetic induction.

d. All of these.

Ans. (d) All of these.

Q 2. Electromagnetic induction is the:

a. charging of a body with a positive charge

b. production of current by relative motion between magnet and a coil

c. rotation of the coil of an electric motor

d. generation of magnetic field due to current carrying solenoid.

Ans. (b) production of current by relative motion between magnet and a coil

Q 3. In Faraday's experiment, current is not produced when:

a. the coil is moved and bar magnet is kept stationary

b. the bar magnet is moved and the coil is kept stationary

c. both coil and bar magnet are kept stationary

d. both a. and b.

Ans. (c) both coil and bar magnet are kept stationary.

Q 4. In Faraday's experiment on electromagnetic induction, more deflection will be shown by galvanometer, when:

a. magnet is in uniform motion towards the coil

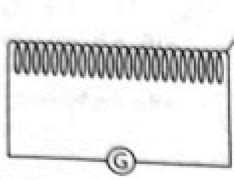
b. magnet is in uniform motion away from the coil

c. magnet is in accelerated motion towards the coil

d. magnet is at rest near the coil

Ans. (c) magnet is in accelerated motion towards the coil.

Q 5. The diagram shows a coil of wire connected to a galvano meter A student has a magnet and an unmagnetised iron rod. How can an e.m.f. be induced across the coil?



a. Holding the magnet inside the coil
b. Holding the iron rod inside the coil
c. Pushing the magnet into the coil
d. Pushing the iron rod into the coil.

Ans. (c) Pushing the magnet into the coil

Q 6. The magnetic flux linked with a vector area $\vec{A}$ in a uniform magnetic field $\vec{B}$ is:

a. $\vec{B} \times \vec{A}$ b. $\vec{B} \cdot \vec{A}$
c. both a. and b. d. None of these

Ans. (b) $\vec{B} \cdot \vec{A}$

Q 7. The flux linked with a closed coil held in a magnetic field is zero, when:

a. the plane of coil is parallel to the magnetic field
b. the plane of coil is perpendicular to the magnetic field
c. the plane of coil is at an angle of 60° with the magnetic field
d. the plane of coil is at an angle of 120° with the magnetic field

Ans. (a) the plane of coil is parallel to the magnetic field

Magnetic flux, $\phi = BA\cos\theta$

$\phi = 0$ when $\theta = 0°$, *i.e.*, plane of coil is parallel to the magnetic field.

Q 8. S.I. unit of magnetic flux is:

a. ampere-meter b. ampere m^2
c. weber d. weber/m^2

Ans. (c) weber

Q 9. The dimensions of magnetic flux are:

a. $[ML^2T^{-1}A^{-2}]$ b. $[ML^2T^{-2}A^{-1}]$
c. $[MLT^{-2}A^{-2}]$ d. $[ML^2T^{-2}A^{-2}]$

Ans. (b) $[ML^2T^{-2}A^{-1}]$

Q 10. A circular loop of area 0.05 m^2 is kept parallel to a uniform magnetic field of 2 T. What is the flux linked with the loop?

a. 0.1 b. 0.05 c. 1 d. zero

Ans. (d) zero

T!P

Circular loop is kept parallel to uniform magnetic field, i.e., angle between $\vec{B}$ and $\vec{A}$ is 90°.

Q 11. A rectangular loop of area 20 cm × 30 cm is placed in a magnetic field of 0.3 T, with its plane normal to the field. The flux linked with the coil is:

a. 0.009 Wb b. 0.018 Wb
c. zero d. 0.06 Wb

Sol. (b) 0.018 Wb

Loop area $= l \times b = 20 \times 30 = 600\ cm^2 = 0.06\ m^2$

$B = 0.3\,T$ and $\theta = 0°$ (plane is normal to field)

$\therefore\ \phi = BA\cos\theta = 0.06 \times 0.3 \times \cos 0° = 0.018 \times 1 = 0.018$ Wb

Q 12. If area vector $\vec{A} = 3i + 2j + 5k\ m^2$, flux density $\vec{B} = 5i + 10j + 6k\ (Wb/m^2)$. The magnetic flux linked with the soil is:

a. 31 Wb b. 65 Wb c. 100 Wb d. 90 Wb

Ans. (b) 65 Wb

$\phi = \vec{B} \cdot \vec{A} = (5i + 10j + 6k) \cdot (3i + 2j + 5k) = 15 + 20 + 30 = 65$ Wb

Q 13. A circular disc of radius 0.2 m is placed in a uniform magnetic field of induction $\frac{1}{\pi}\left(\frac{Wb}{m^2}\right)$ in such a way that its axis makes an angle of 60° with B. The magnetic flux linked with the disc is:

a. 0.02 Wb b. 0.06 Wb c. 0.08 Wb d. 0.01 Wb

Ans. (a) 0.02 Wb

Here, $\theta = 60°$, $B = \frac{1}{\pi}\ Wbm^{-2}$, $A = \pi(0.2)^2$

$\therefore\ \phi = BA\cos\theta \Rightarrow \phi = \frac{1}{\pi} \times \pi(0.2)^2 \times \cos 60° = (0.2)^2 \times \frac{1}{2} = 0.02$ Wb

Q 14. A square of side *L* meters lies in the *x-y* plane in a region, where the magnetic field is given by $\vec{B} = B_0(2i + 3j + 4k)$ T. where B_0 is constant. The magnitude of flux passing through the square is: **(NCERT EXEMPLAR)**

a. $2B_0L^2$ Wb b. $2B_0L^2$ Wb c. $4B_0L^2$ Wb d. $\sqrt{29}B_0L^2$ Wb

Ans. (c) $4B_0L^2$ W

Here, $\vec{B} = B_0(2i + 3j + 4k)$ T

Area of the square $= L^2k\ m^2$

$\therefore$ Flux passing through the square.

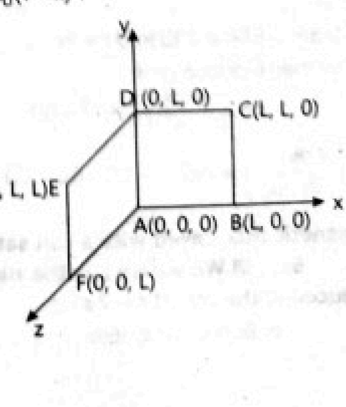
$\phi = \vec{B} \cdot \vec{A} = B_0(2i + 3j + 4k) \cdot L^2k = 4B_0L^2$ Wb

Q 15. A loop, made of straight edges has six corners at *A*(0, 0, 0), *B*(*L*, 0, 0) *C*(*L*, *L*, 0), *D*(0, *L*, 0), *E*(0, *L*, *L*) and *F*(0, 0, *L*). A magnetic field $\vec{B} = B_0(i + k)$ T is present in the region. The flux passing through the loop *ABCDEFA* (in that order) is: **(NCERT EXEMPLAR)**

a. B_0L^2 Wb b. $2B_0L^2$ Wb c. $\sqrt{2}B_0L^2$ Wb d. $4B_0L^2$ Wb

Ans. (b) $2B_0L^2$ Wb

Here, $\vec{B} = B_0(i + k)$ T



Area vector of $ABCD = L^2\hat{k}$

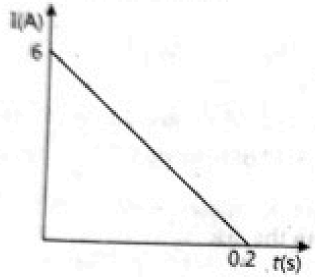
Area vector $DEFA = L^2\hat{i}$

Total area vector, $\vec{A} = L^2(\hat{i} + \hat{k})$

Total magnetic flux, $\phi = \vec{B}\cdot\vec{A}$

$$= B_0(\hat{i} + \hat{k})\cdot L^2(\hat{i} + \hat{k}) = B_0L^2(1+1) = 2B_0L^2 \text{ Wb}$$

Q 16. A graph between induced current and time is shown below, for a coil of resistance 5Ω, when it is kept in a changing magnetic flux. The magnitude of change in flux through the coil (in weber) is:



a. 6 Wb b. 3 Wb c. 4 Wb d. 2 Wb

Ans. (b) 3 Wb

The change in flux is given by,

$$dq = \frac{d\phi}{dt}$$

$$\Rightarrow \quad d\phi = dq \times dt$$

$$= (\text{area of } I - t \text{ graph}) \times R$$

$$= \left(\frac{1}{2} \times 0.2 \times 6\right) \times 5 = 0.6 \times 5 = 3 \text{ Wb}$$

Q 17. Due to relative motion of a magnet with respect to a coil, an emf is induced in the coil, identify the principle involved:

a. Ampere's circuital law b. Faraday's law

c. Gauss law d. Biot-Savart law

Ans. (b) Faraday's law

Q 18. Induced emf in the coil depend upon:

a. conductivity of coil

b. amount flux

c. rate of change of linked flux

d. resistance coil

Ans. (c) rate of change of linked flux

Q 19. The magnetic flux linked with a coil at any instant is given by $\phi = (5t^3 - 50t + 200)$ Wb. The magnitude of emf induced in the coil at $t = 2s$ is:

a. 40 V b. 140 V c. 10 V d. 300 V

Ans. (c) 10 V

Here, $\phi = 5t^3 - 50t + 200$ and $t = 2s$

We know that, induced emf

$$\varepsilon = \left|\frac{-d\phi}{dt}\right| = 15t^2 - 50$$

$$\left|\frac{-d\phi}{dt}\right|_{t=2} = 15(2)^2 - 50 = 60 - 50 = 10\text{V}$$

Q 20. The magnetic flux linked with a coil satisfies the relation $\phi = (4t^2 + 6t + 9)$ Wb where t is the time in second. The emf induced in the coil at $t = 2$ s is:

a. 22 V b. 18 V c. 16 V d. 40 V

Ans. (a) 22 V

Given, $\phi = 4t^2 + 6t + 9$ and $t = 2s$

We know that, $|\varepsilon| = \left|\frac{d\phi}{dt}\right|$

Here, $\left|\frac{d\phi}{dt}\right| = |8t + 6|$

$$\Rightarrow \quad \left(\frac{d\phi}{dt}\right)_{t=2} = 8 \times 2 + 6$$

Induced emf in the coil = 22 V

Q 21. A conducting coil is held stationary in a non-uniform magnetic field. The emf induced in the coil is:

a. maximum b. minimum

c. zero d. Blv

Ans. (c) zero

Here, coil is stationary so there is no change in magnetic flux, so no emf will be induced.

Q 22. A small piece of metal wire is dragged across the gap between the poles of a magnet in 0.4 s. If change in magnetic flux in the wire is 8×10^{-4} Wb, then e.m.f. induced in the wire is:

a. 8×10^{-3} V b. 6×10^{-3} V

c. 4×10^{-3} V d. 2×10^{-3} V

Ans. (d) 2×10^{-3} V

$$\varepsilon = \frac{d\phi}{dt} = \frac{8 \times 10^{-4}}{0.4} = 2 \times 10^{-3}\text{ V}$$

Q 23. A coil having an area A_0 is placed in a magnetic field which changes from B_0 to $4B_0$ in a time interval t. the e.m.f. induced in the coil will be:

a. $\frac{3A_0B_0}{t}$ b. $\frac{4A_0B_0}{t}$ c. $\frac{3B_0}{A_0t}$ d. $\frac{4B_0}{A_0t}$

Ans. (a) $\frac{3A_0B_0}{t}$

Emf induced, $\varepsilon = \frac{d\phi}{dt}$

$$= \frac{d}{dt}(BA) = A_0\frac{dB}{dt}$$

$$= A_0\left(\frac{4B_0 - B_0}{t}\right) = \frac{3A_0B_0}{t}$$

Q 24. A coil of area 0.4 m^2 has 100 turns. A magnetic field of 0.04 Wb m^{-2} is acting normal to the coil surface. If this magnetic field is reduced to zero in 0.01 s, then the induced emf in the coil is:

a. 160 V b. 250 V c. 270 V d. 320 V

Ans. (a) 160 V

Here, $A = 0.4 \text{ m}^2, N = 100, dB = 0.04 \text{ Wb m}^{-2}, dt = 0.01\text{s}$

As $\varepsilon = \frac{d\phi}{dt} = NA\frac{dB}{dt} = 100 \times 0.4 \times \frac{0.04}{0.01} = 160\text{V}$

Q 25. Whenever there is a change in the magnetic flux linked with a closed circuit, an emf and a current are induced in the circuit. This statement is referred to as:

a. Lenz's law

b. Faraday's second law of electromagnetic induction

c. Faraday's first law of electromagnetic induction

d. Laplace's law

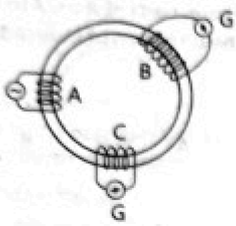
Ans. (c) Faraday's first law of electromagnetic induction

Q 26. Unit of induced emf is:

a. ampere b. volt c. joule d. electron volt

Ans. (b) volt

Q 27. A, B and C are the three coils of conductor having different number of turns, wound around a soft iron ring as shown in the figure. Ends of coils B and C are connected to the galvanometers. The observation that can be made when ends of coil A are connected to an A.C. source is:



a. Same electric current is induced in B and C

b. No electric current is induced in B and C

c. Induced electric current is more in B than in C

d. Induced electric current is less in B than in C

Ans. (c) Induced electric current is more in B than in C

When the end of coil A is connected to an A.C. source the induced electric current will be more in B than in C as the number of turns in the coil is more in B than in C.

Q 28. A rectangular coil of 100 turns and size 0.1 m × 0.05 m is placed perpendicular to a magnetic field of 0.1 T. If the field drops to 0.05 T in 0.05 second, the magnitude of the e.m.f. induced in the coil is:

a. 2 V b. 3 V

c. 0.5 V d. 6 V

Ans. (c) 0.5 V

Here, area of coil $A = 0.1\,m \times 0.05\,m = 5 \times 10^{-3}\,m^2$

Number of turns, $N = 100$

Initial flux linked with the coil

$\phi_1 = BA\cos\theta = 0.1 \times 5 \times 10^{-3}\cos 0^\circ = 5 \times 10^{-4}$ Wb

Final flux linked with the coil

$\phi_2 = 0.05 \times 5 \times 10^{-3}\cos 0^\circ = 25 \times 10^{-5}\,Wb = 2.5 \times 10^{-4}$ Wb

The magnitude of induced emf in the coil is

$$\varepsilon = \frac{N|\Delta\phi|}{\Delta t} = \frac{N|\phi_2 - \phi_1|}{t} = \frac{100|2.5 \times 10^{-4} - 5 \times 10^{-4}|}{0.05}$$

$$= \frac{100 \times 2.5 \times 10^{-4}}{0.05}\,V = 0.5\,V$$

Q 29. The magnetic flux through a coil perpendicular to its plane and directed into paper is varying according to the relation $\phi = (2t^2 + 4t + 6)$ mWb. The emf induced in the loop at $t = 4$ s is:

a. 0.12 V b. 2.4 V

c. 0.02 V d. 1.2 V

Ans. (c) 0.02 V

Give, $\phi = (2t^2 + 4t + 6)$ mWb

As $\varepsilon = \frac{d\phi}{dt} = \frac{d}{dt}(2t^2 + 4t + 6) \times 10^{-3} = (4t + 4) \times 10^{-3}$ V

At $t = 4$ s, $\varepsilon = (4 \times 4 + 4) \times 10^{-3}\,V = 20 \times 10^{-3}\,V = 0.02$ V

Q 30. A long solenoid with 10 turns per cm has a small loop of area 3 cm² placed inside, normal to the axis of the solenoid. If the current carried by the solenoid changes steadily from 2 A to 4 A in 0.2 s, what is the induced voltage in the loop, while the current in changing?

a. 4.2×10^{-8} V b. 2.8×10^{-8} V

c. 7.3×10^{-6} V d. 3.8×10^{-6} V

Ans. (d) 3.8×10^{-6} V

Here, $\frac{N}{l} = 10$ turns per cm = 1000 turns per metre

$$A = 3\,cm^2 = 3 \times 10^{-4}\,m^2 \text{ or } \frac{dI}{dt} = \frac{4-2}{0.2} = 10\,A\,s^{-1}$$

$$\text{Also } \varepsilon = \frac{d\phi}{dt} = \frac{d}{dt}(BA) = A\frac{d}{dt}\left(\mu_0 \frac{N}{l} I\right) = A\mu_0\left(\frac{N}{l}\right)\frac{dI}{dt}$$

$$= 3 \times 10^{-4} \times 4\pi \times 10^{-7} \times 1000 \times 10 = 3.8 \times 10^{-6}\,V$$

Q 31. The phase different between the flux linked with a coil rotating in a uniform magnetic field and induced emf produced in it is:

a. $\frac{\pi}{4}$ b. $\frac{\pi}{2}$ c. $\frac{-\pi}{6}$ d. π

Ans. (b) $\frac{\pi}{2}$

We know that flux linked with the coil

$$\phi = BA\cos\theta$$

$$\text{Induced emf, } \varepsilon = -\frac{d\phi}{dt} = -\frac{d(BA\cos\theta)}{dt} = BA\sin\theta$$

$$= BA\cos\left(\frac{\pi}{2} + \theta\right)$$

$$\therefore \text{ Phase difference} = \frac{\pi}{2} + \theta - \theta = \frac{\pi}{2}$$

Q 32. If the instantaneous magnetic flux and induced emf produced in a coil is ϕ and ε respectively, then according to Faraday's law of electromagnetic induction:

a. ε must be zero if $\phi = 0$ and changing

b. $\varepsilon \neq 0$ and $\phi = 0$

c. $\varepsilon = 0$ then ϕ must be zero

d. $\varepsilon \neq 0$ if ϕ is changing

Ans. (d) $\varepsilon \neq 0$ if ϕ is changing

We know that, $\varepsilon = -\frac{d\phi}{dt} \Rightarrow \varepsilon = 0$ only if $\frac{d\phi}{dt} = 0$

if $\varepsilon = 0$, then ϕ = constant

$\therefore$ $\varepsilon \neq 0$, then ϕ is changing

Q 33. A square loop side 12 cm and resistance 0.60 Ω is placed vertically in the east-west plane. A uniform magnetic field of 0.10 T is set up across the plane in north-east direction. The magnetic field is decreased to zero in 0.6 s at a steady rate. The magnitude of current during this time interval is:

a. 1.42×10^{-3} A b. 2.67×10^{-3} A

c. 3.41×10^{-3} A d. 4.21×10^{-3} A

Ans. (b) 2.67×10^{-3} A

Here, Area $A = l^2 = (12\,cm)^2 = 1.4 \times 10^{-2}\,m^2$

$R = 0.60\,\Omega$, $B_1 = 0.10\,T$, $\theta = 45^\circ$, $B_2 = 0$, $dt = 0.6$ s

Initial flux, $\phi_1 = B_1 A\cos\theta$

$= 0.10 \times 1.4 \times 10^{-2} \times \cos 45^\circ = 9.9 \times 10^{-4}$ Wb

Final flux, $\phi_2 = 0$

Induced emf, $\varepsilon = \frac{|d\phi|}{dt} = \frac{|\phi_2 - \phi_1|}{dt} = \frac{|9.8 \times 10^{-4}|}{0.6\ s}$

$= 1.65 \times 10^{-3}$ V

Current, $I = \frac{\varepsilon}{R} = \frac{1.65 \times 10^{-3}}{0.6} = 2.75 \times 10^{-3}$ A

Q 34. According to Lenz's law of electromagnetic induction:

a. the induced emf is not in the direction opposing the change in magnetic flux

b. the relative motion between the coil and magnet produces change in magnetic flux

c. only the magnet should be moved towards coil

d. only the coil should be moved towards magnet

Ans. (b) the relative motion between the coil and magnet produces change in magnetic flux

Q 35. Lenz's law is consequence of the law of conservation of:

a. momentum b. mass

c. charge d. energy

Sol. (d) energy

Q 36. A bar magnet is dropped between a current carrying coil. What would be its acceleration?

a. g downwards

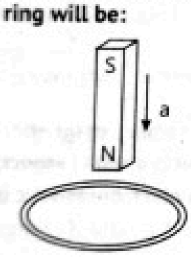
b. Greater than g downwards

c. Less than g downwards

d. Bar will be stationary

Ans. (c) Less than g downwards

Q 37. A metallic ring is attached with the wall of a room. When the north pole of a magnet is brought near it, the induced current in the ring will be:



a. first clockwise than anticlockwise

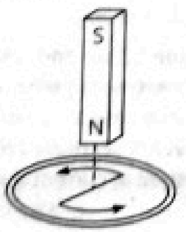
b. in clockwise direction

c. in anticlockwise direction

d. first anticlockwise then clockwise

Ans. (c) in anticlockwise direction

As it is seen from the side of the magnet, induced current will be anticlockwise.



Q 38. Which of the following is found using Lenz's law?

a. induced emf

b. induced current

c. direction of induced emf

d. direction of alternating current

Ans. (c) direction of induced emf

Q 39. There is a uniform magnetic field directed perpendicular and into the plane of the paper. An irregular shaped conducting loop is slowly changing into a circular loop in the plane of the paper. Then:

a. current is induced in the loop in the anti-clockwise direction

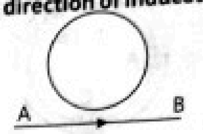
b. current is induced in the loop in the clockwise direction

c. ac is induced in the loop.

d. no current is induced in the loop.

Ans. (a) current is induced in the loop in the anti-clockwise direction

Q 40. In the given figure, current from A to B in the straight wire is decreasing. The direction of induced current in the loop is:

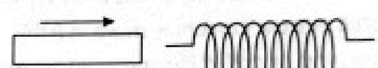


a. clockwise b. anticlockwise

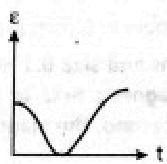
c. changing d. nothing can be said

Ans. (b) anticlockwise

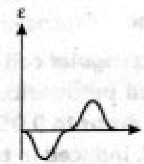
Q 41. The variation of induced emf (ε) with time (t) in a coil if a short bar magnet is moved along its axis with a constant velocity is best represented as:



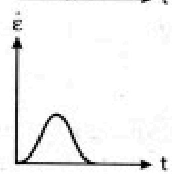
a.



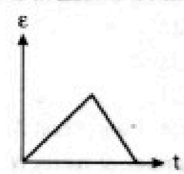
b.



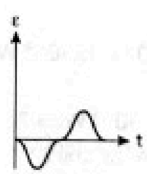
c.



d.



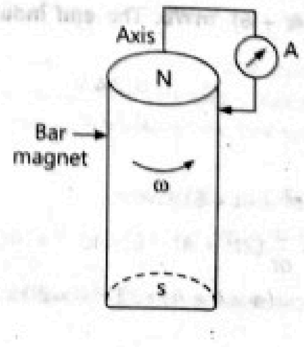
Ans. (b)



The polarity of emf will be opposite in the two cases while the magnet enters the coil and while the magnet leaves the coil. Only in option (b) polarity is changing.

Q 42. A cylindrical bar magnet is rotated about its axis as shown in figure. A wire is connected from the axis and is made to touch the cylindrical surface through a contact. Then:

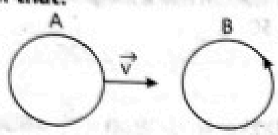
(NCERT EXEMPLAR)



a. a direct current flows in through the ammeter *A*.
b. no current flows through the ammeter *A*.
c. an alternating sinusoidal current flows through the ammeter *A* with a time period, $T = \frac{2\pi}{\omega}$.
d. a time varying non-sinusoidal current flows through the ammeter *A*.

Ans. (b) no current flows through the ammeter *A*.
As there is no change in magnetic flux associated with the circuit, no current is induced in the circuit. The ammeter *A* shows no deflection.

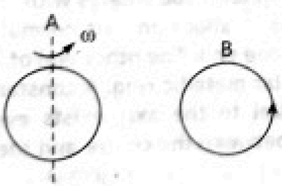
Q 43. There are two coils *A* and *B* as shown in the figure. A current starts flowing in *B* as shown, when *A* is moved towards *B* and stops when *A* stops moving. The current in *A* is counter clockwise, *B* is kept stationary when *A* moves. We can infer that: *(NCERT EXEMPLAR)*



a. there is a constant current in the clockwise direction of *A*.
b. there is a varying current in *A*.
c. there is no current in *A*.
d. there is a constant current in the counter-clockwise direction in *A*.

Ans. (d) there is a constant current in the counter-clockwise direction in *A*.
Coil *A* must be carrying a constant current in counter clockwise direction. Because of that, when *A* moves towards *B*, current induced in *B* is counter-clockwise direction as per Lenz's law. The current in *B* would stops when *A* steps moving.

Q 44. Same as problem 43 except the coil *A* is made to rotate about a vertical axis. No current flows in *B* if *A* is at rest. The current in coil *A*, when the current in *B* (at $t = 0$) is counter-clockwise and the coil *A* is as shown at this instant, $t = 0$, is: *(NCERT EXEMPLAR)*



a. constant current clockwise
b. varying current clockwise
c. varying current counter-clockwise
d. constant current counter-clockwise

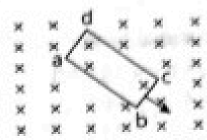
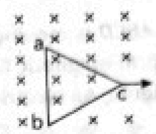
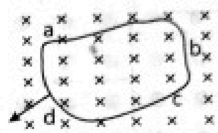
Ans. (a) constant current clockwise

Q 45. Two different loops are concentric and lie in the same plane. The current in the outer loop is clockwise and increasing with time.
The induced current in the inner loop, is:

a. clockwise
b. zero
c. counter-clockwise
d. in a direction that depends on the ratio of the loop radii

Ans. (c) counter-clockwise
According to Lenz's law, induced current will be in such a direction so that it opposes the change due to which it is produced. So induced current in the inner loop will be in counter-clockwise direction.

Q 46. Match the Column I with Column II and mark the correct option from the codes given below:

	Column I (Planar loops of different shapes)	Column II (Direction of induced current)
(A)		(p) *b a c b*
(B)		(q) *c d a b c*
(C)		(r) *b c d a b*

	A	B	C		A	B	C
a.	p	q	r	b.	r	q	p
c.	p	r	q	d.	r	p	q

Ans. (d) r p q

Q 47. A conducting rod of length '*l*' is falling with a constant velocity *v* perpendicular to a uniform magnetic field *B*. A potential difference between its two ends wil be:

a. $2Blv$
b. Blv
c. $\frac{1}{2}Blv$
d. $B^2l^2v^2$

Ans. (b) Blv

Q 48. A straight line conductor of length 0.4 m is moved with a speed of 7 m/s perpendicular to a magnetic field of intensity 0.9 Wb/m^2. The induced e.m.f across the conductor is:

a. 5.04 V
b. 1.26 V
c. 2.52 V
d. 25.2 V

Ans. (c) 2.52 V
Magnetic field $B = 0.9$
Length = 0.4 m
speed = 7 m/s
Induced emf = Blv
$= 0.9 \times 0.4 \times 7 = 2.52$ V

Q 49. A wire of length 50 cm moves with a velocity of 300 m/min, perpendicular to a magnetic field. If the emf induced in the wire is 2 V, then the magnitude of the field (in tesla) is:

a. 2
b. 5
c. 0.4
d. 0.8

Ans. (d) 0.8
Given $l = 50$ cm $= 0.5$ m
$\Rightarrow v = 300 \text{ m min}^{-1}$
$= \frac{300}{60} = 5 \text{ ms}^{-1}$ and $\varepsilon = 2$ V

Magnetic field, $B = \frac{\varepsilon}{lv} = \frac{2}{0.5 \times 5} = 0.8$ T

Q 50. An aeroplane having a wing span of 35 m flies due north with the speed of 90 m/s. If the magnetic field $B = 4 \times 10^{-5}$ T then, the potential difference developed between the tip of the wings is:

a. 1.26 V b. 1.03 V c. 12.6 V d. 0.126 V

Ans. (d) 0.126 V

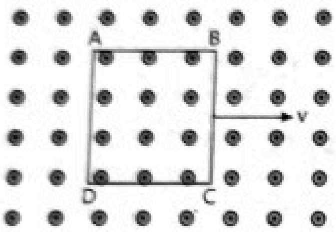
Potential difference developed = Blv

$= 4 \times 10^{-5} \times 35 \times 90$

$= 12600 \times 10^{-5}$

$= 0.126$ V

Q 51. A metallic square loop ABCD is moving in its own plane with velocity v in a uniform magnetic field perpendicular to its plane as shown in figure. An electric field is induced



a. in AD, but not in BC

b. in BC, but not in AD

c. neither in AD nor in BC

d. in both AD and BC

Ans. (c) neither in AD nor in BC

The electric field/emf is induced neither in sides AD and nor in BC unless the metallic square loop is entering or leaving the magnetic field and the flux linked with it is changing.

Q 52. A conductor is moving with the velocity v in the magnetic field and let I be the induced current. If the velocity of conductor becomes double, the induced current will be:

a. 0.5 I b. 1.5 I c. 2 I d. 2.5 I

Ans. (c) 2 I

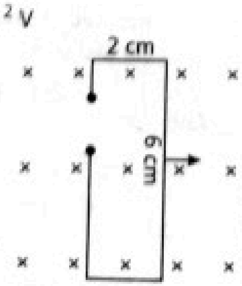
When the velocity of conductor becomes double, area intercepted per second become twice. Therefore induced current becomes twice.

Q 53. A rectangular loop of side 6 cm and 2 cm with a small cut is moving out of a region of uniform magnetic field of magnitude 0.4 T directed normal to the loop. The voltage developed across the cut if velocity of loop is 2 cm s^{-1} in a direction normal to the longer side is:

a. 3.8×10^{-4} V b. 4.8×10^{-4} V

c. 2.2×10^{-2} V d. 3.2×10^{-2} V

Ans. (b) 4.8×10^{-4} V



Here, $l = 6$ cm $= 6 \times 10^{-2}$ m

$B = 0.4$ T,

$v = 2 \times 10^{-2}$ ms^{-1}

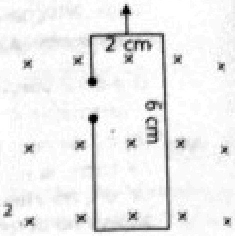
Voltage developed is

$\varepsilon = Blv$

$= 0.4 \times 6 \times 10^{-2} \times 2 \times 10^{-2}$

$= 4.8 \times 10^{-4}$ V

Q 54. In the question number 53, if velocity is normal in the shorter side then the voltage developed is:



a. 2.3×10^{-4} V

b. 2.4×10^{-2} V

c. 4.8×10^{-2} V

d. 1.6×10^{-4} V

Sol. (d) 1.6×10^{-4} V

Here, $l = 2$ cm $= 2 \times 10^{-2}$ m

$\varepsilon = Blv = 0.4 \times 2 \times 10^{-2} \times 2 \times 10^{-2}$

$= 16 \times 10^{-4}$ V

Q 55. A jet plane is travelling west at the speed of 1800 km h^{-1}. The potential difference developed between the ends of the wing having a span of 25 m, if the earth's magnetic field at the location has a magnitude of 5×10^{-4} T and the dip angle is 30° is:

a. 4.125 V b. 3.125 V c. 2.225 V d. 3.8 V

Ans. (b) 3.125 V

Here, $v = 1800 \text{ km h}^{-1} = 1800 \times \frac{5}{18} = 500$ m/s

$l = 25$ m $B_H = 5 \times 10^{-4}$ T, $\delta = 30°$

$\varepsilon = B_v l v$, where B_v = vertical component of earth magnetic field

$= (B_H \sin\delta)\, lv$

$= 5 \times 10^{-4} \times \sin 30° \times 25 \times 500$

$= 31250 \times 10^{-4} = 3.125$ V

Q 56. A copper rod of length l rotates about its end with angular velocity ω in a uniform magnetic field B. The emf developed between the ends of the rod if the field is normal to the plane of rotation is:

a. $B\omega l^2$ b. $\frac{1}{2} B\omega l^2$ c. $2 B\omega l^2$ d. $\frac{1}{4} B\omega l^2$

Ans. (b) $\frac{1}{2} B\omega l^2$

Q 57. A 2 m long metallic rod rotates with an angular frequency of 200 rad s^{-1} about an axis normal to the rod passing through its one end. The other end of the rod is in contact with a circular metallic ring. A constant magnetic field of 0.5 T parallel to the axis exists everywhere. The emf developed between the centre and the ring is:

a. 100 V b. 200 V c. 300 V d. 400 V

Ans. (b) 200 V

The emf developed between the centre and the ring is

$$\varepsilon = \frac{1}{2} Bl^2 \omega = \frac{0.5 \times (2)^2 \times 200}{2} = 200 \text{ V}$$

Q 58. A metal conductor of length 1 m rotates vertically about one of its ends with an angular velocity 5 rad s^{-1}. If the horizontal component of earth's magnetic field is 0.2×10^{-4} T, then the emf developed between the end of the conductor is:

a. 5 μV b. 5 mV c. 50 μV d. 50 mV

Ans. (c) 50 μV

The emf developed between the ends of the conductor is

$$\varepsilon = \frac{1}{2} \omega B l^2 = \frac{1}{2} \times 5 \times 0.2 \times 10^{-4} \times (1)^2$$

$$= 5 \times 10^{-5} \text{ V} = 50 \times 10^{-6} \text{ V} = 50\ \mu\text{V}$$

Q 59. A wheel with 20 metallic spokes each of length 0.5 m long is rotated with a speed of 120 revolution per minute in a plane normal to the horizontal component of earth magnetic field H at a place. If $H = 0.4 \times 10^{-4}$ T at the place, then induced emf between the axle and the rim of the wheel is:

a. 6.28×10^{-5} V   b. 3.14×10^{-5} V
c. 1.256×10^{-5} V   d. 1.57×10^{-5} V

Ans. (a) 6.28×10^{-5} V

Here, $v = \frac{120}{60} = 2$ rps

$$\text{Induced emf} = \left(\frac{1}{2}\right)\omega BR^2 = \frac{1}{2}2\pi vBR^2$$
$$= 3.14 \times 2 \times 0.4 \times 10^{-4} \times (0.5)^2$$
$$= 0.628 \times 10^{-4} = 6.28 \times 10^{-5} \text{ V}$$

Q 60. A circular copper disc 10 cm in diameter rotates 1800 revolution per minute about an axis through its centre and at right angles to disc. A uniform field of 1 Wb m^{-2} is perpendicular to disc. What potential difference is developed between the axis of the disc and the rim?

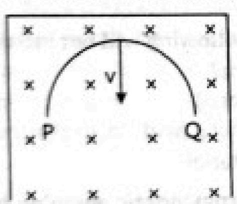
a. 0.023 V   b. 0.23 V   c. 23 V   d. 230 V

Ans. (b) 0.23 V

Here, $l = r = 5$ cm $= 5 \times 10^{-2}$ m

$$\omega = 2\pi\left(\frac{1800}{60}\right) \text{ rad s}^{-1} = 60\pi \text{ rad s}^{-1}$$
$$B = 1 \text{ Wb m}^{-2}$$
$$\varepsilon = \frac{1}{2}Bl^2\omega = \frac{1}{2} \times 1 \times (5 \times 10^{-2})^2 \times 60\pi = 0.23 \text{ V}$$

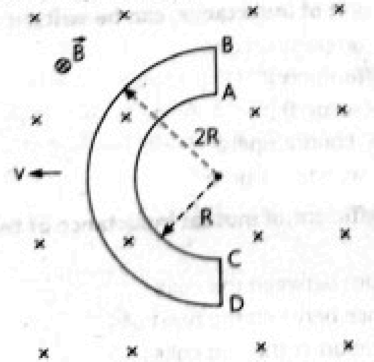
Q 61. A semicircle loop PQ of radius 'R' is moved with velocity 'v' in transverse magnetic field as shown in figure. The value of induced emf at the end of loop is:



a. $2BvR$ b. BvR c. $\frac{1}{2}BvR$ d. $B^2v^2R^2$

Ans. (a) $2BvR$

Q 62. If given arrangement is moving towards left with speed v, then potential difference between B and D and current in the loop are respectively.



a. BvR and non-zero   b. $2BvR$ and zero
c. $4BvR$ and non-zero   d. $4BvR$ and zero

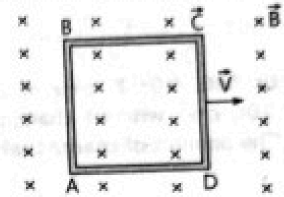
Ans. (d) $4BvR$ and zero

The potential difference between B and d will be

$$V_d - V_b = Bv \times 4R$$
$$V_d - V_b = 4BvR$$

The current in the loop will be zero because we know that net emf in any closed loop is zero.

Q 63. A conductor square loop of side L and resistance R moves in its plane with a uniform velocity v perpendicular to one of its sides. A magnetic induction B constant in time and space, pointing perpendicular and into the plane of the loop exists everywhere. The current induced in the loop is:



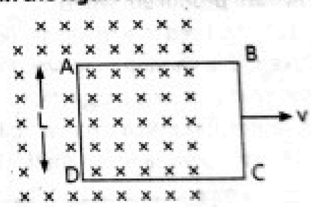
a. $\frac{Blv}{R}$ clockwise   b. $\frac{Blv}{R}$ anticlockwise
c. $\frac{2Blv}{R}$ anticlockwise   d. zero

Ans. (d) zero

No flux change is taking place because magnetic field is uniform everywhere.

As there is no change in flux, induced emf is zero and therefore no current induced.

Q 64. A conducting square loop of side L and resistance R moves out of a uniform magnetic field B with a uniform velocity v as shown in the figure. The induced current in the loop is:



a. zero   b. BRv c. BvL/R d. BvL

Ans. (c) BvL/R

Q 65. A square loop of side l, resistance R is placed in a uniform magnetic field B acting normally to the plane of the loop. If we attempt to pull it out of the field with a constant velocity v, then the power needed is:

a. $BRlv$ b. $\frac{B^2l^2v^2}{R}$ c. $\frac{Bl^2v^2}{R}$ d. $\frac{Bvl}{R}$

Ans. (b) $\frac{B^2l^2v^2}{R}$

$$\text{Power, } P = Fv = ilBv = \left(\frac{Bvl}{R}\right)lBv = \frac{B^2l^2v^2}{R}$$

Q 66. The magnetic flux through a circuit of resistance R changes by an amount $\Delta\phi$ in time Δt, then the total quantity of electric charge Q, which passing during this time through any point of the circuit is given by:

a. $Q = \frac{\Delta\phi}{\Delta t}$ b. $Q = \frac{\Delta\phi}{\Delta t} \times R$
c. $Q = -\frac{\Delta\phi}{\Delta t} + R$ d. $Q = \frac{\Delta\phi}{R}$

Ans. (d) $Q = \frac{\Delta\phi}{R}$

We know that $\varepsilon = \frac{d\phi}{dt}$

But $\varepsilon = IR$ and $I = \frac{dQ}{dt} \Rightarrow \frac{dQ}{dt}R = \frac{d\phi}{dt} \Rightarrow dQ = \frac{d\phi}{R}$ or $\Delta Q = \frac{\Delta\phi}{R}$

Q 67. In a circuit with a coil of resistance 2 ohms, the magnetic flux changes from 2.0 Wb to 10.0 Wb in 0.2 second. The charge that flows in the coil during this time is:

a. 5.0 coulomb b. 4.0 coulomb
c. 1.0 coulomb d. 0.8 coulomb

Ans. (b) 4.0 coulomb

$$\Delta Q = \frac{\Delta\phi}{R} = \frac{(10-2)}{2} = 4C$$

Q 68. In a magnetic field 0.05 T, area of coil changes from 101 cm² to 100 cm² without changing the resistance which is 2Ω. The amount of charge that flows during this period is:

a. 10^{-6} C b. 2×10^{-6} C
c. 8×10^{-6} C d. 2.5×10^{-6} C

Ans. (d) 2.5×10^{-6} C

Magnetic flux $\phi = B.A$

$\therefore$ change in flux $\Delta\phi = B.dA$

$$\Delta\phi = 0.05(101-100)\times10^{-4}$$
$$= 5\times10^{-6}\text{ Wb}$$

$\therefore$ Change in charge $\Delta Q = \frac{\Delta\phi}{r} = \frac{5\times10^{-6}}{2}$

$$= 2.5\times10^{-6}\text{ C}$$

Q 69. Eddy currents are produced, when

a. a circular coil is placed in a magnetic field
b. a metal is kept in a varying magnétic field
c. a metal is kept in a steady magnetic field
d. current is passes through a circular coil

Ans. (b) a metal is kept in a varying magnetic field

KNOWLEDGE BOOSTER

Eddy current are produced when a conductor is moving through a magnetic field or when the magnetic field surrounding a stationary conductor is varying.

Q 70. Which of the following is true in context of Eddy currents?

a. By Lenz's law, an eddy current creates a magnetic field that opposes the magnetic field that created it
b. Eddy currents are loops of electrical current induced within conductors by a changing magnetic field in the conductor due to Faraday's law of induction
c. Eddy currents are a cause of energy loss in AC inductors, transformers, generators etc.
d. All of the above

Ans. (d) All of the above

Q 71. Oscillating metallic pendulum in a uniform magnetic field directed perpendicular to the plane of oscillation:

a. slows down
b. becomes faster
c. remains unaffected
d. oscillates with changing frequency

Ans. (a) slows down (Eddy current)

Q 72. A coil is suspended in a uniform magnetic field. When a current is passed through the coil it starts oscillating. But when an aluminium plate is placed near the coil, it stops. This is due to:

a. development of air current when the plate is placed
b. induction of electrical charge on the plate
c. shielding of magnetic lines of force as aluminium is a paramagnetic material
d. electromagnetic induction in the aluminium plate giving rise to electromagnetic damping

Ans. (d) electromagnetic induction in the aluminium plate giving rise to electromagnetic damping

Q 73. Eddy current can be minimised by using:

a. thick wires b. thin sheets of metal
c. thick sheets d. laminated sheets

Ans. (d) laminated sheets

Q 74. Induction furnace is based on the principle of:

a. self induction b. mutual induction
c. eddy current d. None of these

Sol. (c) eddy current

Q 75. Which of the following does not use the application of eddy current?

a. Electric power meters
b. Induction furnace
c. LED lights
d. Magnetic brakes in trains

Ans. (c) LED lights

Q 76. Eddy currents do not cause:

a. heating b. loss of energy
c. sparking d. damping

Ans. (c) sparking

Q 77. Which of the following will not increase the size and effect of eddy current?

a. thinner material b. low resistivity materials
c. strong magnetic field d. thicker material

Ans. (a) thinner material

Q 78. How can electromagnetic damping be increased?

a. increasing the magnetic density
b. reduce viscosity
c. winding the coil on the aluminum frame
d. increase the temperature of the coil

Ans. (c) winding the coil on the aluminum frame

Q 79. The SI unit of inductance, can be written as:

a. volt - ampere/second
b. joule/(ampere)^2
c. ohm-(second)^2
d. volt-second/ampere

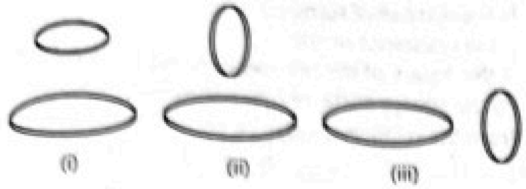
Ans. (d) volt-second/ampere

Q 80. The coefficient of mutual inductance of two coils depends on:

a. medium between the coils
b. distance between the two coils
c. orientation of the two coils
d. All of these

Ans. (d) All of these

Q 81. Two circular coils can be arranged if any of three situations as shown in the figure. Their mutual inductance will be:



a. maximum in situation (i)
b. maximum in situation (ii)
c. maximum in situation (iii)
d. same in all situations

Ans. (a) maximum in situation (i)

Q 82. Two coils *A* and *B* are separated by a certain distance. If a current of 4 *A* flows through *A*, a magnetic flux of 10^{-3} Wb passes through *B* (no current through *B*).
If no current passes through *A* and a current of 2 *A* passes through *B*, then the flux *A* is:

a. 5×10^{-3} Wb   b. 4×10^{-4} Wb
c. 5×10^{-4} Wb   d. 2×10^{-4} Wb

Ans. (c) 5×10^{-4} Wb

Magnetic flux linked with coil *B*, $\phi_B = MI_A$

$$\therefore \quad M = \frac{\phi_B}{I_A} = \frac{10^{-3}}{4} \text{ henry}$$

Magnetic flux linked with coil *A*

$$\phi_A = MI_B = \frac{10^{-3}}{4} \times 2 = 5 \times 10^{-4} \text{ Wb}$$

Q 83. A short solenoid of radius *a*, number of turns per unit length n_1 and length *L* is kept coaxially inside a very long solenoid of radius *b*, number of turns per unit length n_2. What is the mutual inductances of the system?

a. $\mu_0 \pi b^2 n_1 n_2 L$ b. $\mu_0 \pi a^2 n_1 n_2 L^2$
c. $\mu_0 \pi a^2 n_1 n_2 L$ d. $\mu_0 \pi b^2 n_1 n_2 L^2$

Ans. (c) $\mu_0 \pi a^2 n_1 n_2 L$

Q 84. If numbers of turns in primary and secondary coils is increased to two times each, the mutual inductances:

a. becomes 4 times   b. becomes 2 times
c. becomes $\frac{1}{4}$ times   d. remain unchanged

Ans. (a) becomes 4 times

$$m \propto n_1 n_2$$

$\therefore$ *m* becomes 4 times

Q 85. A 2 m long solenoid with diameter 2 cm and 2000 turns has a secondary coil of 1000 turns would closely near its midpoint. The mutual inductance between the two coils is:

a. 2.4×10^{-4} H   b. 3.9×10^{-4} H
c. 1.28×10^{-3} H   d. 3.14×10^{-3} H

Ans. (b) 3.9×10^{-4} H

Here, $l = 2$ m, diameter = 2 cm

$\therefore$ Radius, $r = \frac{2}{2} = 1 \text{cm} = 1 \times 10^{-2}$ m

$$N_1 = 2000, N_2 = 1000$$

$$\text{Area} = \pi r^2 = \pi \times (1 \times 10^{-2})^2 = 3.14 \times 10^{-4} \text{m}^2$$

Mutual inductance, $M = \frac{\mu_0 N_1 N_2 A}{l}$

$$= \frac{4\pi \times 10^{-7} \times 2000 \times 1000 \times 3.14 \times 10^{-4}}{2}$$

$$= 3.9 \times 10^{-4} \text{ H}$$

Q 86. Two coils '*A*' and '*B*' having turns 300 and 600 respectively are placed near each other. On passing a current of 3A in '*A*', the flux linked with '*A*' is 1.2×10^{-4} Wb and with '*B*' it is 9×10^{-5} Wb. The mutual induction of the system is:

a. 2.4×10^{-4} H   b. 0.4×10^{-5} H
c. 8×10^{-5} H   d. 2×10^{-5} H

Ans. (c) 8×10^{-5} H

flux linked,

$$\phi_1 = \mu_0 N_1^2 I \left(\frac{A}{L}\right) \quad \text{...(1)}$$

Mutual inductance, $M = \mu_0 N_1 N_2 \left(\frac{A}{L}\right)$ ...(2)

[Assuming both coil have same *A* and *L*]

On dividing eq. (2) from eq. (1)

$$\frac{M}{\phi_1} = \frac{N_2}{N_1 I}$$

$$\Rightarrow \quad M = \frac{N_2 \phi}{N_1 I} = \frac{600}{300} \times \frac{1.2 \times 10^{-4}}{3}$$

$$= 8 \times 10^{-5} \text{ H}$$

Q 87. Two coils *X* and *Y* are placed in a circuit such that a current changes by 3*A* in coil *X* and magnetic flux change of 1.2 Wb occurs in *Y*. The value of mutual inductance of the coils is:

a. 0.2 H   b. 0.4 H   c. 3.6 H   d. 0.6 H

Ans. (b) 0.4 H

Here, $d\phi = 1.2$ and $dI = 3$

We know that, $\phi = MI$

$$\therefore \quad d\phi = MdI$$

$$\Rightarrow \quad M = \frac{d\phi}{dI} = \frac{1.2}{3} = 0.4 \text{ H}$$

Q 88. In mutual induction:
A : When current in one coil increases, induced current in neighbouring coil flows in the opposite direction.
B : When current in one coil decreases, induced current in neighbouring coil flows in the opposite direction.

a. A is true B is false   b. A and B are false
c. A and B are true   d. A is false B is true

Ans. (a) A is true B is false

Q 89. For a current carrying inductor, emf associated is 20 mV. Now, current through it changes from 6A to 2A in 2s. The coefficient of mutual inductance is:

a. 1 mH   b. 20 mH   c. 2 mH   d. 10 mH

Ans. (d) 10 mH

Here, $\varepsilon = 20 \text{ mV} = 20 \times 10^{-3}$ V

We know that, $|\varepsilon| = M\frac{dI}{dt}$

$$\Rightarrow \quad 20 \times 10^{-3} = M\left(\frac{6-2}{2}\right)$$

$$20 \times 10^{-3} = M(2)$$

$$\Rightarrow \quad M = 10 \times 10^{-3} \text{ H} = 10 \text{ mH}$$

Q 90. Two conducting circular loops of radii R_1 and R_2 are placed in the same plane with their centres coinciding. If $R_1 > R_2$, the mutual inductance M between them will be directly proportional to:

a. $\frac{R_1}{R_2}$ b. $\frac{R_2}{R_1}$ c. $\frac{R_1^2}{R_2}$ d. $\frac{R_2^2}{R_1}$

Ans. (d) $\frac{R_2^2}{R_1}$

Let a current I_1 flows through the outer circular coil of radius R_1.

The magnetic field at the centre of the coil is $B_1 = \frac{\mu_0 I_1}{2R_1}$

As the inner coil of radius R_2 placed co-axially has small radius ($R_2 < R_1$), therefore B_1 may be taken constant over its cross-sectional area.

Hence, flux associated with the inner coil is

$$\phi_1 = B_1 \pi R_2^2 = \frac{\mu_0 I_1}{2R_1} \pi R_2^2$$

As $$M = \frac{\phi_2}{I_1} = \frac{\mu_0 \pi R_2^2}{2R_1}; \quad \therefore M \propto \frac{R_2^2}{R_1}$$

Q 91. Which of the following units denotes the dimension $\frac{ML^2}{Q^2}$, where Q denotes the electric charge?

a. weber/m^2 b. Henry(H)

c. H/m^2 d. weber

Ans. (b) Henry(H)

Dimension of Henry = $[ML^2T^{-2}A^{-2}]$

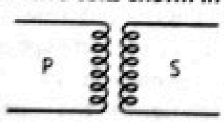
Dimension of charge = $[AT]$ ...(1)

$\therefore$ Dimension of Henry = $[ML^2(AT)^{-2}]$

$= [ML^2Q^{-2}]$ [from (1)]

$= \left[\frac{ML^2}{Q^2}\right]$

Q 92. The value of coefficient of mutual induction for the arrangement of two coils shown in the figure will be:



a. Zero b. maximum c. positive d. negative

Ans. (a) Zero

T!P

The mutual inductance between two coils depend upon the manner, in which , two coils are placed relative to each other.

In the given figure, the magnetic flux linked with a coil due to current in another coil, seems to be zero, therefore coefficient of mutual inductance will be zero.

Q 93. The physical quantity which is measured in the unit of Wb A^{-1} is:

a. self inductance b. mutual inductance

c. magnetic flux d. Both a. and b.

Ans. (d) Both a. and b.

Q 94. The self inductance of a coil is proportional to:

a. its length

b. the number of turns

c. the resistance of soil

d. the square of the number of turns

Ans. (d) the square of the number of turns

From the relation, $L = \mu_0 n^2 lA$

$\Rightarrow$ $$L = \mu_0 \frac{N^2}{l} A \qquad \left(\because n = \frac{N}{l}\right)$$

$\Rightarrow$ $$L \propto N^2$$

Q 95. The self inductance is independent of:

a. number of turns b. medium

c. length d. current

Ans. (d) current

Q 96. If N is the number of turns in a coil, then the value of self-inductance varies as:

a. N b. N^2 c. N^{-2} d. N^3

Ans. (b) N^2

Q 97. If coil is open, then L and R become:

a. ∞, 0 b. 0, ∞ c. ∞, ∞ d. 0, 0

Ans. (b) 0, ∞

Q 98. When the number of turns of the coil is increased twice and the length is reduced by 4, what will be the self inductance of the coil?

a. increased by 4 b. decreased by 4

c. remain the same d. increased by 2

Ans. (c) remain the same

We know that, $L = \mu_0 n^2 Al$

$n' = 2n$ and $l' = \frac{l}{4}$

$\therefore$ $$L' = \mu_0 (2n)^2 A\left(\frac{l}{4}\right)$$

$$= \mu_0 4n^2 A\left(\frac{l}{4}\right) = \mu_0 n^2 Al = L$$

Q 99. The self inductance L of a solenoid of length l and area of cross-section A, with a fixed number of turns N increases as: *(NCERT EXEMPLAR)*

a. l and A increases

b. l decreases and A increases

c. l increases and A decreases

d. Both l and A decreases

Ans. (b) l decreases and A increases

Q 100. The number of turns and length of the solenoid are both doubled, keeping area of cross-section of the solenoid same. Then self-inductance of the coil will be:

a. halved

b. doubled

c. 1/4 times the original value

d. unaffected

Ans. (b) doubled

We know that, $L = \frac{\mu_0 N^2 A}{l}$

Now, $N' = 2N$ and $l' = 2l$

$\therefore$ $$L' = \frac{\mu_0 (2N)^2 A}{2l} = \mu_0 \frac{4N^2 A}{2l}$$

$$= \frac{2\mu_0 N^2 A}{l} = 2L$$

Q 101. The self inductance of a long solenoid cannot be increased by:

a. increasing its area of cross section
b. decreasing its length
c. increasing the current through it
d. increasing the number of turns in it

Ans. (c) increasing the current through it

Q 102. When the rate of change of current is unity, the induced emf is equal to:

a. thickness of coil
b. number of turns in coil
c. coefficient of self inductance
d. total flux linked with coil

Ans. (c) coefficient of self inductance

As, $\varepsilon = L\dfrac{dI}{dt}$

When $\dfrac{dI}{dt} = 1, \varepsilon = L$

Q 103. When the current changes from +2 A to − 2 A in 0.05 s, an emf of 8V as induced in a coil. The coefficient of self-induction of the coil is:

a. 0.2 H b. 0.4 H c. 0.8 H d. 0.1 H

Ans. (d) 0.1 H

Induced emf, $e = -L\dfrac{di}{dt} = -L\dfrac{(-2-2)}{0.05}$

$8 = L\dfrac{(4)}{0.05} \Rightarrow L = \dfrac{8\times 0.05}{4} = 0.1\text{H}$

Q 104. Two solenoids of equal number of turns have their lengths and the radii in the same radio 1 : 2. The ratio of their self inductances will be:

a. 1 : 2 b. 2 : 1 c. 1 : 1 d. 1 : 4

Ans. (a) 1 : 2

Q 105. What would be the coefficient of self-inductance of a coil of 100 turns, if 5A current flows through it? (Given that, magnetic flux = 5×10^3 Maxwell)

a. 0.5×10^{-3} H b. 2×10^{-3} H
c. Zero d. 10^{-3} H

Ans. (d) 10^{-3} H

Coefficient of self inductance, $L = \dfrac{N\phi}{I}$

$= \dfrac{100\times 5\times 10^3\times 10^{-8}}{5}$ [1 Wb = 10^{+8} Maxwell]

$= 10^{-3}$ H

Q 106. The self inductance of an inductor coil having 100 turns is 20 mH. The magnetic flux through the cross-section of the coil corresponding to a current of 4 mA is:

a. 2×10^{-5} Wb b. 4×10^{-7} Wb
c. 8×10^{-7} Wb d. 8×10^{-5} Wb

Ans. (c) 8×10^{-7} Wb

Total magnetic flux,

$N\phi = LI = 20\times 10^{-3}\times 4\times 10^{-3}$

$= 8\times 10^{-5}$ Wb

Magnetic flux through the cross-section of the coil,

$\phi = \dfrac{8\times 10^{-5}}{N} = \dfrac{8\times 10^{-5}}{100} = 8\times 10^{-7}$ Wb

Q 107. In an inductor of self inductance L = 2 mH, current changes with time according to relation, $I = t^2e^{-t}$. At what time emf is zero.

a. 4s b. 3s c. 2s d. 1s

Ans. (c) 2s

$L = 2\text{ mH} = 2\times 10^{-3}$ H

$I = t^2e^{-t}$

$\Rightarrow \dfrac{dI}{dt} = t^2e^{-t}(-1) + e^{-t}(2t) = te^{-t}(-t+2)$

emf $\varepsilon = L\dfrac{dI}{dt} = 2\times 10^{-3}\times te^{-t}(-t+2)$

Now, emf = 0, when $(-t+2) = 0$ or $t = 2$ s.

Q 108. The equivalent quantity of mass in electricity is:

a. current b. self inductance
c. potential d. charge

Ans. (b) self inductance

Self inductance of an inductor is referred as interia of electricity.

Q 109. If the self inductance of 500 turns coils is 125 mH, then the self inductance of the similar coil of 800 turns is:

a. 48.8 mH b. 200 mH c. 290 mH d. 320 mH

Ans. (d) 320 mH

As $\dfrac{L_1}{L_2} = \dfrac{N_1^2}{N_2^2}$

Here, self inductance of 500 turns coil = 125 mH

∴ L for the coil of 800 turns $= \dfrac{125}{(500)^2}\times(800)^2 = 320$ mH

Q 110. A 10V better connected to 5Ω resistance coil having inductance 10 H through a switch drives a constant current in the circuit. The switch is suddenly opened and the time taken to open it is 2 ms. The average emf induced across the coil is:

a. 4×10^4 V b. 2×10^4 V c. 2×10^2 V d. 1×10^4 V

Ans. (d) 1×10^4 V

Here, current $I = \dfrac{V}{R} = \dfrac{10}{5} = 2$ A

Final current, when the switch is opened becomes zero.

∴ $\dfrac{dI}{dt} = \dfrac{0-2}{2\times 10^{-3}} = -1\times 10^3\text{ A s}^{-1}$

As $\varepsilon = -L\dfrac{dI}{dt} = -10(-1\times 10^3) = 10^4$ V

Q 111. A solenoid 30 cm long is made by winding 2000 loops of wire on an iron rod whose cross-section is 1.5 cm². If the relative permeability of iron is 6000. What is the self-inductance of the solenoid?

a. 25 H b. 5 H c. 15 H d. 35 H

Ans. (c) 15 H

Here, $\mu_r = 6000$, $l = 30$ cm = 0.3 m, $N = 2000$,

$A = 1.5\text{ cm}^2 = 1.5\times 10^{-4}\text{ m}^2$

$L = \dfrac{\mu_r\mu_0 N^2 A}{l} = \dfrac{6000\times 4\pi\times 10^{-7}\times(2000)^2\times 1.5\times 10^{-4}}{0.3}$

$= 15$ H

Q 112. The energy stored in an inductor of self inductance L henry carrying a current of I ampere is:

a. $\frac{1}{2}L^2I$ b. $\frac{1}{2}LI^2$

c. LI^2 d. L^2I

Ans. (b) $\frac{1}{2}LI^2$

Q 113. A 200 mH coil carries a current of 2 A. Energy stored in its magnetic field is:

a. 0.5 J b. 0.4 J

c. 1 J d. 0.1 J

Ans. (b) 0.4 J

Here, $L = 200\text{ mH} = 200 \times 10^{-3}\text{ H}, I = 2\text{ A}$

As $U = \frac{1}{2}LI^2 = \frac{1}{2} \times (200 \times 10^{-3}) \times 2^2 = 0.4\text{ J}$

Q 114. By a change of current from 5 A to 10 A in 0.1 s the self induced emf is 10 V. The change in the energy of the magnetic field of a coil will be:

a. 5 J b. 6 J c. 7.5 J d. 9 J

Ans. (c) 7.5 J

$|\varepsilon| = L\frac{\Delta I}{\Delta t}$

$L = \frac{|\varepsilon|\Delta t}{\Delta I} + \frac{10 \times 0.1}{(10-5)} = 0.2\text{ H}$

The magnetic field energies for currents I_1 and I_2 are

$$U_1 = \frac{1}{2}LI_1^2 \text{ and } U_2 = \frac{1}{2}LI_2^2$$

Change in energy, $\Delta U = U_2 - U_1$

$$= \frac{1}{2}LI_2^2 - \frac{1}{2}LI_1^2 = \frac{L}{2}(I_2^2 - I_1^2)$$

$$= \frac{0.2}{2}(10^2 - 5^2) = 7.5\text{ J}$$

Q 115. Two coils of self-inductance 4 mH and 9 mH are placed so close together that the effective flux in one coil is completely linked with the other. The natural inductance between these coils are:

a. 16 mH b. 10 mH c. 26 mH d. 6 mH

Ans. (d) 6 mH

Mutual inductance between coils is

$$M = K\sqrt{L_1 \times L_2}$$

$$= 1\sqrt{4 \times 10^{-3} \times 9 \times 10^{-3}} \quad (\because K = 1)$$

$$= 6 \times 10^{-3}\text{H} = 6\text{ mH}$$

Assertion and Reason Type Questions

Directions (Q.Nos. 116 to 141): In the following questions, astatement of Assertion (A) is followed by a statement of Reason (R). Mark the correct choice as:

a. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A)

b. Both Assertion (A) and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A)

c. Assertion (A) is true but Reason (R) is false

d. Assertion (A) is false and Reason (R) is also false

Q 116. Assertion (A): Changing magnetic flux can produced induced emf.,

Reason (R): Faraday established induced emf experimentally.

Ans. (b) emf induces, when there is change in magnetic flux. The magnitude of induced emf depends upon the rate at which the magnetic flux changes. When magnetic flux is steady or constant no emf is induced. Faraday did experiment in which there is relative motion between the coil and magnet, the flux linked with the coil changes and emf induces.

Q 117. Assertion (A): The presence of large magnetic flux through a coil maintains a current in the coil if the circuit is continuous.

Reason (R): Magnetic flux is essential to maintain an induced current in the coil.

Ans. (d) Varying magnets flux is essential to maintain an included current in the coil.

Q 118. Assertion (A): Only a change in magnetic flux will maintain an induced current the coil.

Reason (R): The presence of large magnetic flux through a coil maintains a current in the coil if the circuit is continuous.

Ans. (c) Presence of magnetic flux cannot produce current.

Q 119. Assertion (A): The induced emf in a conducting loop of wire will be non zero when it rotates in a uniform magnetic field.

Reason (R): The emf is induced due to change in magnetic flux.

Ans. (a) As the coil rotates, the magnetic flux linked with the coil (being $\vec{B} \cdot \vec{A}$) will change and emf will be induced in the loop.

Q 120. Assertion (A): Induced emf depends on number of turns and area of the coil.

Reason (R): Induced emf increases with increases in number of turns of coil.

Ans. (b) According to Faraday's law, the induced emf (ε) is given by $\varepsilon = \frac{-d(N\phi)}{dt} = -\frac{d(NBA)}{dt} = -NA\frac{dB}{dt}$. Thus the induced emf depends on the rate of change of magnetic flux, number of turns of coil and area of the coil. If any of these factor increases (or decreases) then induced e.m.f. also increases (or decreases).

Q 121. Assertion (A): Faraday's laws are consequences of conservation of energy.

Reason (R): In a purely resistive ac circuit, the current lags behind the emf in phase.

Ans. (c) According to Faraday's laws, the conversion of mechanical energy into electrical energy is in accordance with the law of conservation of energy. It is also clearly known that in pure resistance, the emf is in phase with the current.

Q 122. Assertion (A): An induced emf is generated when magnet is withdrawn from the solenoid.

Reason (R): The relative motion between magnet and solenoid induces emf.

Ans. (a) According to Faraday's law of electromagnetic induction induced emf will be generated in the solenoid because of the relative motion between magnet and solenoid.

Q 123. **Assertion (A): An aircraft flies along the meridian, the potential develops at the ends of its wings.**

Reason (R): Whenever there is change in the magnetic flux emf induces.

Ans. (a) As the aircraft flies, magnetic flux changes through its wings due to the vertical component of the earth's magnetic field. Due to this, induced emf is produced across the wings of the aircraft.

Q 124. **Assertion (A): Sensitive electrical instruments should not be placed in the vicinity of an electromagnet.**

Reason (R): Magnetic flux is essential to maintain and induced current in the coil.

Ans. (a) Sensitive electrical instruments in the vicinity of electromagnet can be damaged due to the induced electromotive forces and the resulting currents when the electromagnet is turned on or off.

Q 125. **Assertion (A): A spark occur between the poles of a switch when the switch is opened.**

Reason (R): Current flowing in the conductor produces magnetic field.

Sol. (b) According to Lenz's law, induced emf are in a direction such as to attempt to maintain the original magnetic flux when a change occurs. When the switch is opened, the sudden drop in the magnetic field in the circuit induces an emf in a direction that attempts to keep the original current flowing. This can cause a spark as the current bridges the air gap between the poles of the switch. (The spark is more likely in circuits with large inductance).

Q 126. **Assertion (A): A copper sheet placed in a magnetic field. If we pull it out of the field or push it into the field, we experience of opposing force.**

Reason (R): According to Lenz's law, eddy current produced in sheet opposes the motion of the sheet.

Ans. (a) When we pull a copper plate out of the magnetic field or push it into the magnetic field, magnetic flux linked with the plate changes. As a result of this eddy currents are produced in the plate which oppose its motion (according to Lenz's law).

Q 127. **Assertion (A): It is more difficult to push a magnet into a coil with more loops.**

Reason (R): emf induced in the current loop resists the motion of the magnet.

Ans. (a) According to Lenz's law, the emf induced in a current loop is such that it resists the motion of the magnet. As emf in each turns opposes the motion of the magnet, when the number of turns is increased the force opposing the motion also increases. Thus pushing a magnet into a coil with more number of loops is more difficult.

Q 128. **Assertion (A): The direction of induced emf is always such that it opposes change that causes it.**

Reason (R): Conservation of energy applies to know the direction of induced emf.

Ans. (a)

Q 129. **Assertion (A): Acceleration of a magnet falling through a copper ring decreases.**

Reason (R): The induced current produced in a circuit always flow in such direction that it opposes the change or the cause that produced.

Ans. (a) When the magnet falls, the magnetic flux through the copper ring increases and induced emf is produced in the ring. The induced emf so produced, opposes the motion of falling magnet. Therefore, the acceleration of the falling magnet will be less than that due to gravity.

Q 130. **Assertion (A): Eddy currents heat up the core and dissipate electrical energy in the form of heat.**

Reason (R): Eddy currents are always undesirable.

Ans. (c) Eddy currents are not always undesirable. They are used in certain applications like electromagnetic damping, induction furnace, magnetic breaking in trains etc.

Q 131. **Assertion (A): When two coils are wound on each other, the mutual induction between the coils is maximum.**

Reason (R): Mutual induction does not depend on the orientation of the coils.

Ans. (c) The manner in which the two coils are oriented, determines the coefficient of coupling between them.

$$M = K^2 . L_1L_2$$

When the two coils are wound on each other, the coefficient of coupling is maximum and hence mutual inductance between the coil is maximum.

Q 132. **Assertion (A): In the phenomenon of mutual induction, self induction of each of the coils persists.**

Reason (R): Self induction arises when strength of current in same coil changes. In mutual induction, current is changing in both the individual coils.

Ans. (b) Mutual inductance is the phenomenon according to which an opposing emf produce flux in a coil as a result of change in current of magnetic flux linked with a neighbouring coil. But when two coils are inductively coupled, in addition to induced emf produced due to mutual induction, also induced emf is produced in each of the two coil due to self-induction.

Q 133. **Assertion (A): In the phenomenon of mutual induction, self induction of each of the coil persists.**

Reason (R): Self induction arises when strength of current in one coil change. In mutual induction, current is changing in both the individual coils.

Ans. (a) Mutual inductance is the phenomenon according to which an opposing emf produces flux in a coil as a result of change in current or magnetic flux linked with a neighbouring coil. But when two coils are inductively coupled, in addition to induced emf produced due to mutual induction, also induced emf is produced in each of the two coils due to self induction.

Q 134. **Assertion (A): When number of turns in a coil doubled, coefficient of self inductance of the coil becomes four times.**

Reason (R): Coefficient of self inductance is proportional to the square of number of turns.

Ans. (a) The coefficient of self inductance of the coil is given by

$$L = \frac{\mu_0 N^2 A}{l}$$

where N is number of turns, l is length of the coil and A is area of coil, so $L \propto N^2$.

Q 135. **Assertion (A): Self-inductance is called the inertia of electricity.**

Reason (R): Self-inductance is the phenomenon, according to which an opposing induced emf is produced in a coil as a result of change in current of magnetic flux linked in the coil.

Ans. (b) Self-inductance of a coil is its property virtue of which the coil opposes any change in the current flowing through it.

Q 136. Assertion (A): Mutual inductance of a pair of coils depend on their separation as well as their relative orientation.

Reason (R): Mutual inductance depend upon the length of the coil only.

Ans. (c) The mutual inductance in case of a medium of relative permeability μ_r present is

$M = \mu_r \mu_0 n_1 n_2 \pi r_1^2 l$

Q 137. Assertion (A): When two coils are wound on each other, the mutual induction between the coils is maximum.

Reason (R): Mutual induction is independent of the orientation of the coils.

Ans. (c) Mutual induction depends on the separation as well as relative orientation of the coil.

When two coils are wound on each other all the flux of the primary is linked with the secondary. Hence, the mutual induction between the coils is maximum.

Q 138. Assertion (A): The self-inductance of a long solenoid is proportional to the area of cross-section and length of the solenoid.

Reason (R): Self inductance of a solenoid is independent of the number of turns per unit length.

Ans. (c) The self inductance of a long solenoid, the core of which consists of a magnetic material of permeability μ_r is given by

$L = \mu_r \mu_0 n^2 Al$

Q 139. Assertion (A): The quantity L/R possesses dimensions of time.

Reason (R): To reduce the rate of increases of current through a solenoid should increase the time constant (L/R).

Ans. (b) The relation of induced emf is $e = \frac{Ldl}{dt}$ and current I is given by $I = \frac{e}{R} = \frac{1}{R} \cdot \frac{Ldl}{dt} \Rightarrow \frac{dl}{dt} = I\frac{R}{L} = \frac{I}{L/R}$ in order to decreases the rate of increase of current through solenoid We have to increase the time constant $\frac{L}{R}$.

Q 140. Assertion (A): When the current in a coil changes, it induces a back emf in the same coil.

Reason (R): emf is a measure of the intertia of the coil against the change of current through it.

Ans. (a) The back emf induced in the coil is the measure of the intertia of the coil against the changes of current thrrough it.

Q 141. Assertion (A): Inductance coil are made of copper.

Reason (R): Induced current is more in wire having less resistance.

Ans. (a) The inductance coils made of copper will have very small ohmic resistance. Due to change in magnetic flux a large induced current will be produced in such an inductance, which will offer appreciable opposition to the flow of current.

TR!CK

More the resistance, less the current.

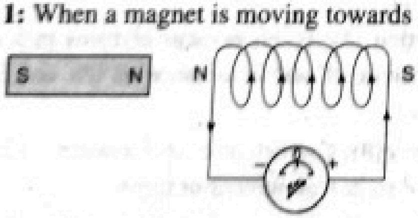
Case Study Based QUESTIONS

Case Study 1

The induced electromotive force with different polarities induces a current whose magnetic field opposes the change in magnetic flux through the loop in order to ensure that original flux is maintained through the loop when current flows in it.

To batter understand Lenz's law, let us consider two cases:

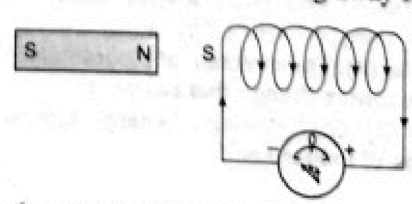
Case 1: When a magnet is moving towards the coil.



When the north pole of the magnet is approaching towards the coil, the magnetic flux linking to the coil increases. According to Faraday's law of electromagnetic induction, when there is a change in flux, an emf, and hence current is induced in the coil and this current will create its own magnetic field.

Now according to Lenz's law, this magnetic field created will oppose its own or we can say opposes the increase in flux through the coil and this is possible only if approaching coil side attains north polarity, as we know similar poles repel each other. Once we know the magnetic polarity of the coil side, we can easily determine the direction of the induced current by applying right hand rule. In this case, the current flows in the anticlockwise direction.

Case 2: When a magnet is moving away from the coil

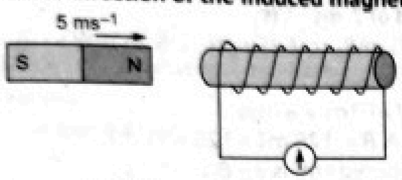


When the north pole of the magnet is moving away from the coil, the magnetic flux linking to the coil decreases. According to Faraday's law of electromagnetic induction, an emf and hence current is induced in the coil and this current will create its own magnetic field.

Now according to Lenz's law, this magnetic field created will oppose its own or we can say opposes the decrease in flux through the coil and this is possible only if approaching coil side attains south polarity, as we know dissimilar poles attract each other. Once we know the magnetic polarity of the coil side, we can easily determine the direction of the induced current by applying right hand rule. In this case, the current flows in a clockwise direction.

Read the above passage carefully and give the answer of the following questions:

Q 1. What is the direction of the induced magnetic field?

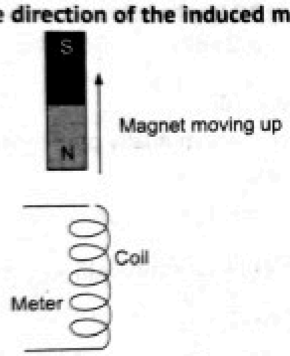


a. left b. right c. up d. down

Ans. (a) left

According to Lenz's the magnetic field created will oppose the increase in flux through the coil.

Q 2. What is the direction of the induced magnetic field?

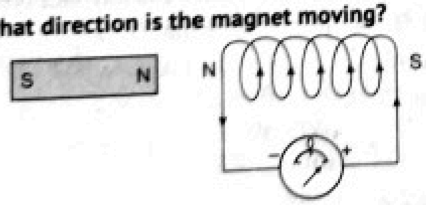


a. left b. right c. up d. down

Ans. (d) down

According to Lenz's law, the magnetic field created will oppose the increase in flux through the coil.

Q 3. In what direction is the magnet moving?

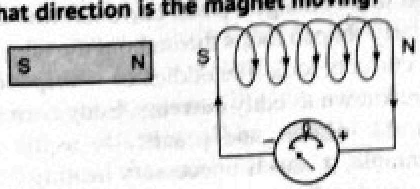


a. left b. right c. up d. down

Ans. (b) right

Since the current is increasing the polarity should be same so magnet should move towards right.

Q 4. In what direction is the magnet moving?



a. left b. right c. up d. down

Ans. (a) left

Since the current is decreasing the polarity should be opposite so magnet should move towards left.

Q 5. Which of the following is NOT an application of Lenz's Law

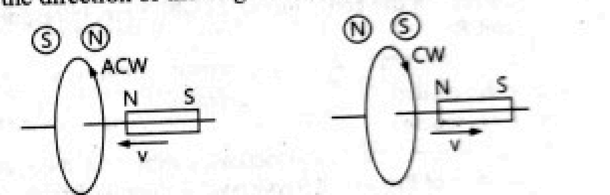
a. Transformer
b. AC Generator
c. DC Motor
d. A coil transversed by AC current

Ans. (c) DC Motor

DC motor works on Faraday's principle of electromagnetism which status that a current carrying conductor experiences a force when placed in a magnetic field.

Case Study 2

Lenz's law states that the direction of induced current in a circuit is such that it opposes the change which produces it. Thus, if the magnetic flux linked with a closed circuit increases, the induced current flows in such a direction that a magnetic flux is created in the opposite direction of the original magnetic flux. If the magnetic flux linked with the closed circuit decreases, the induced current flows in such a direction so as to create a magnetic flux in the direction of the original flux.



(Rest) (Coil face behaves as North pole to oppose the motion of magnet) (Rest) (Coil face behaves as South pole to oppose the motion of magnet)

Read the above passage carefully and give the answer of the following questions:

Q 1. Which of the following statement is correct?

a. The induced emf is not in the direction opposing the change in magnetic flux so as to oppose the cause which produces it.
b. The relative motion between the coil and magnet produces change in magnetic flux.
c. emf is induced only if the magnet is moved towards coil.
d. emf is induced only if the coil is moved towards magnet.

Ans. (b) The relative motion between the coil and magnet produces change in magnetic flux.

The relative motion between the coil and the magnet produces change in the magnetic flux in the coil. The induced emf is always in such a direction that it opposes the change in the flux.

Q 2. The polarity of induced emf is given by:

a. Ampere's circuital law
b. Biot-Savart law
c. Lenz's law
d. Fleming's right hand rule

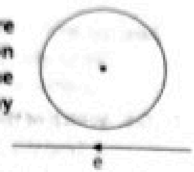
Ans. (c) Lenz's law

Q 3. Lenz's law is a consequence of the law of conservation of

a. charge b. mass c. momentum d. energy

Ans. (d) energy

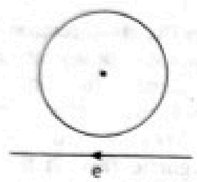
Q 4. Near a circular loop of conducting wire as shown in the figure, an electron moves along a straight line. The direction of the induced current if any in the loop is:



a. variable b. clockwise
c. anticlockwise d. zero

Ans. (a) variable

When an electron is moving from right to left, the flux linked with loop (which is going into the page) will first increase and then decrease as the electron passes by. So the induced current I_i in the loop will be first clockwise and will change direction (i.e., will become anticlockwise) as the electron passes by.



Q 5. Two identical circular coils *A* and *B* are kept in a horizontal tube side by side without touching each other. If the current in the coil *A* increases with time, in response, the coil *B*:

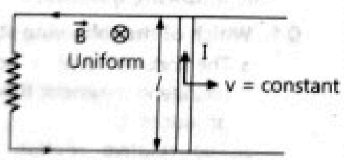
a. is attracted by *A* b. remains stationary
c. is repelled d. rotates

Ans. (c) is repelled

When current in coil *A* increases with time, there will be a change of flux in coil *B* which will induce a current in *B*. Now, according to Lenz's law, the direction of induced current in *B* will be opposite to the direction of current in *A*. Thus, they will repel each other.

Case Study 3

The emf induced across the ends of a conductor due to its motion in a magnetic field is called motional emf. It is produced due to the magnetic Lorentz force acting on the free electrons of the conductor. For a circuit shown in figure, if a conductor of length *l* moves with velocity *v* in a magnetic field *B* perpendicular to both its length and the direction of the magnetic field, then all the induced parameters are possible in the circuit.



Read the above passage carefully and give the answer of the following questions:

Q 1. Direction of current induced in a wire moving in a magnetic field is found using:

a. Fleming's left hand rule
b. Fleming's right hand rule
c. Ampere's rule
d. Right hand clasp rule

Ans. (b) Fleming's right hand rule

Direction of current induced in a wire moving in a magnetic field is found by using Fleming's right hand rule.

Q 2. A conducting rod of length *l* is moving in a transverse magnetic field of strength *B* with velocity *v*. The resistance of the rod is *R*. The current in the rod is:

a. $\frac{Blv}{R}$ b. Blv c. zero d. $\frac{B^2v^2l^2}{R}$

Ans. (a) $\frac{Blv}{R}$

Induced e.m.f. $\varepsilon = Blv$

Current in the rod, $I = \frac{\varepsilon}{R} = \frac{Blv}{R}$

Q 3. A 0.1 m long conductor carrying a current of 50 A is held perpendicular to a magnetic field of 1.25 mT. The mechanical power required to move the conductor with a speed of 1 ms^{-1} is:

a. 62.5 mW b. 625 mW c. 6.25 mW d. 12.5 mW

Ans. (c) 6.25 mW

Here, $l = 0.1\,\text{m}$, $v = 1\,\text{ms}^{-1}$

$I = 50\,\text{A}$, $B = 1.25\,\text{mT} = 1.25 \times 10^{-3}\,\text{T}$

The induced emf is $\varepsilon = Blv$

The mechanical power is

$$P = \varepsilon I = BlvI = 1.25 \times 10^{-3} \times 0.1 \times 1 \times 50$$
$$= 6.25 \times 10^{-3}\,\text{W} = 6.25\,\text{mW}$$

Q 4. A bicycle generator creates 1.5 V at 15 km/hr. The EMF generated at 10 km/hr is:

a. 1.5 volts b. 2 volts c. 0.5 volts d. 1 volt

Ans. (d) 1 volt

Emf induced, $\varepsilon = Blv$

Here, $\vec{B}$, $\vec{l}$ and $\vec{v}$ are mutually perpendicular

For given B and l, $\varepsilon \propto v$.

$$\therefore \quad \frac{\varepsilon_1}{\varepsilon_2} = \frac{v_1}{v_2}$$

Here, $\varepsilon_1 = 15\,\text{V}, v_1 = 15\,\text{km/hr} = 15 \times \frac{5}{18}\,\text{ms}^{-1}$

$v_2 = 10\,\text{km/hr} = 10 \times \frac{5}{18}\,\text{ms}^{-1}, \varepsilon_2 = ?$

So $$\frac{1.5}{\varepsilon_2} = \frac{15 \times \frac{5}{18}}{10 \times \frac{5}{18}} = \frac{3}{2};\ \varepsilon_2 = 1\text{V}$$

Q 5. The dimensional formula for emf ε in MKS system will be:

a. $[ML^2T^{-3}A^{-1}]$ b. $[ML^2T^{-1}A]$
c. $[ML^2A]$ d. $[MLT^{-2}A^{-2}]$

Ans. (a) $[ML^2T^{-3}A^{-1}]$

$$\varepsilon = \frac{[W]}{[q]} = \frac{ML^2T^{-2}}{AT} = ML^2T^{-3}A^{-1}$$

Case Study 4

Current can be induced not only in conducting coils, but also in conducting sheets or blocks. Current is induced in solid metallic masses when the magnetic flux threading through them changes. Such currents flow in the form of irregularly shaped loops throughout the body of the metal. These currents look like eddies or whirlpools in water so they are known as eddy currents. Eddy currents have both undesirable effects and practically useful applications. For example, it causes unecessary heating and wastage of power in electric motors, dynamos and in the cores of transformers.

Read the given passage cqarefully and give the answer of the following questions:

Q 1. The working of speedometers of trains is based on:

a. wattles currents b. eddy currents
c. alternating currents d. pulsating currents

Ans. (b) eddy currents

The working of speedometers is based on eddy currents.

Q 2. Identify the wrong statement:

a. Eddy currents are produced in a steady magnetic field.
b. Induction furnace use eddy currents to produce heat.
c. Eddy currents can be used to produce breaking force in moving trains.
d. Power meters work on the principle of eddy currents.

Ans. (a) Eddy currents are produced in a steady magnetic field.

Q 3. Which of the following is the best method to reduce eddy currents?

a. Laminating core
b. Using thick wires
c. By reducing hysteresis loss
d. None of these

Ans. (a) Laminating core

To reduce the eddy currents in the metal armature of motors, wire is wrapped around a number of thin metal sheets called lamination.

Q 4. The direction of eddy currents is given by:

a. Fleming's left hand rule
b. Biot-Savart law
c. Lenz's law
d. Ampere circuital law

Ans. (c) Lenz's law

Eddy currents also oppose the change in magnetic flux, so their direction is given by Lenz's law.

Q 5. Eddy currents can be used to heat localised tissues of the human body. This branch of medical therapy is called:

a. Hyperthermia b. Diathermy
c. Inductothermy d. none of these

Ans. (c) Inductothermy

Case Study 5

An eddy current is a current set up in a conductor in response to a changing magnetic field. They flow in closed loops in plane perpendicular to the magnetic field. By Lenz's law, the current swirls in such a way as to create a magnetic field opposing the change; for this to occur in a conductor, electrons swirl in a plane perpendicular to the magnetic field.

Because of the tendency of eddy currents to oppose, eddy currents cause a loss of energy. Eddy currents transform more useful forms of energy. Eddy currents can also be removed by cracks or slits in the conductor, which break the circuit and prevent the current loops from circulating. This means that eddy currents can be used to detect defects in materials. This is called non destructive testing and is often used in airplanes. The magnetic field produced by the eddy currents is measured, where a change in the field reveals the presence of an irregularity; a defect will reduce the size of the eddy current, which in turn reduces the magnetic field strength.

Another application of eddy currents is magnetic levitation. Conductors are exposed to varying magnetic fields which induce eddy currents within the conductor and produce a repulsive magnetic field, pushing the magnet and conductor apart. This alternating magnetic field can be caused by relative motion between the magnet and conductor (generally the magnet is stationary and the conductor moves) or with an electromagnet applied with a varying current to very the magnetic field strength.

Read the above passage carefully and give the answer of the following questions:

Q 1. What is the heat generated in eddy current operations?

a. VI b. VIR c. I^2RT d. I^2R

Ans. (d) I^2R

Eddy current method of inspection is used for heating metal. The heat generated by this method can be given by I^2R.

Q 2. With an increase in the density of the material, the power loss in eddy current:

a. increases b. decreases
c. does not change d. not related

Ans. (b) decreases

Eddy current is inversely proportional to density of the material

Q 3. Generation of eddy currents depends on the principle of:

a. wave guide theory
b. electromagnetic induction
c. magneto-restrictive force
d. All of the above

Ans. (b) electromagnetic induction

Eddy current is a result of EMI.

Q 4. Eddy currents generated in a test object flow:

a. in the same plane as magnetic flux
b. in the same plane as the coil is wound
c. 90° to the coil winding plane
d. Eddy currents have no predictable direction

Sol. (b) in the same plane as the coil is wound

Eddy current flows in the same plane as the coil is wound.

Q 5. The discovery of electromagnetic induction is credited to:

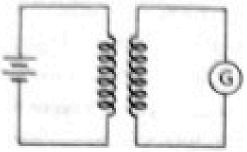
a. Arago b. Oersted
c. Maxwell d. Faraday

Ans. (d) Faraday

Faraday contributed in electromagnetic induction by his experimental theory.

Case Study 6

Mutual inductance is the phenomenon of inducing emf in a coil, due to a charge of current in the neighbouring coil. The amount of mutual inductance that links one coil to another depends very much on the relative positioning of the two coils, their geometry and relative separation between them. Mutual inductance between the two coils increases μ_r times if the coils are wound over an iron core of relative permeability μ_r.



Read the above passage carefully and give the answer of the following questions:

Q 1. A short solenoid of radius a, number of turns per unit length n_1, and length L is kept coaxially inside a very long solenoid of radius b, number of turns per unit length n_2. What is the mutual inductance of the system?

a. $\mu_0 \pi b^2 n_1 n_2 L$ b. $\mu_0 \pi a^2 n_1 n_2 L^2$
c. $\mu_0 \pi a^2 n_1 n_2 L$ d. $\mu_0 \pi b^2 n_1 n_2 L^2$

Ans. (c) $\mu_0 \pi a^2 n_1 n_2 L$

The mutual inductance of the system is $M = \mu_0 n_1 n_2 \pi a^2 L$

Q 2. If a change in current of 0.01 A in one coil produces a change in magnetic flux of 2×10^{-2} weber in another coil, then the mutual inductance between coils is:

a. 0 b. 0.5 H
c. 2 H d. 3 H

Ans. (c) 2 H

Here, $\phi_B = 2 \times 10^{-2}$ Wb, $I = 0.01$ A

as $\phi_B = MI$

∴ Mutual inductance between two coils is

$$M = \frac{\phi_B}{I} = \frac{2 \times 10^{-2} \text{Wb}}{0.01 \text{ A}} = 2 \text{ H}$$

Q 3. Mutual inductance of two coils can be increased by:

a. decreasing the number of turns in the coils
b. increasing the number of turns in the coils
c. Winding the coils on wooden cores
d. None of the above

Ans. (b) increasing the number of turns in the coils

Mutual inductance of coils, $M = \frac{\mu_0 \mu_r N_1 N_2 A}{l}$

It is clear that mutual inductance of coils can be increased by increasing the number of turns in the coils.

Q 4. When a sheet of iron is placed in between the two co-axial coils, then the mutual inductance between the coils will:

a. increase b. decrease
c. remains same d. cannot be predicted

Ans. (a) increase

We know that the mutual inductance depends (directly proportional) on the permeability of the medium surrounding the coils. When the permeability of the medium is increased by inserting a sheet of iron, then the mutual inductance between the coils also increases.

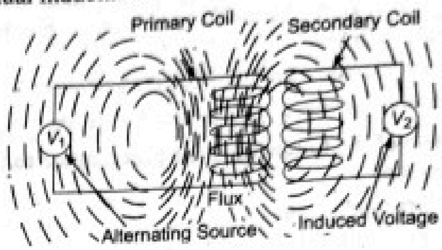
Q 5. The SI unit of mutual inductance is:

a. ohm b. mho c. henry d. None of these

Ans. (c) henry

Case Study 7

Mutual inductance between the two coils is defined as the property of the coil due to which it opposes the change of current in the other coil, or you can say in the neighbouring coil. When the current in the neighbouring coil changes, the flux sets up in the coil and because of this, changing flux emf is induced in the coil called mutually induced emf and the phenomenon is known as mutual inductance.



The value of mutual inductance (M) depends upon the following factors:

1. Number of turns in the secondary or neighbouring coil,
2. Cross-sectional area,
3. Closeness of the two coils.

When on a magnetic core, two or more than two coils are wound, the coils are said to be mutually coupled. The current, when passed in any of the coils wound around the magnetic core, produces flux which links all the coils together and also the one in which current is passed. Hence, there will be both self-induced emf and mutual induced emf in each of the coils.

The best example of the mutual inductance is the transformer, which works in the principle of Faraday's Law of Electromagnetic induction.

Faraday's law of electromagnetic induction states that, "the magnitude of voltage is directly proportional to the rate of change of flux."

Read the above passage carefully and give the answer of the following questions:

Q 1. The phenomenon due to which there is an induced current in one coil due to current in a neighbouring coil is?

a. Electromagnetism b. Susceptance
c. Mutual inductance d. Steady current

Ans. (c) Mutual inductance

Mutual inductance between the two coils is defined as the property of the coil due to which it opposes the change of current in the other coil, or you can say in the neighbouring coil.

Q 2. Mutual inductance between two magnetically coupled coils depends on:

a. permeability of the core material
b. number of the turns of the coils
c. cross sectional area of their common core
d. All of the above

Ans. (d) All of the above

All of the above factors are responsible for mutual induction.

Q 3. Which of the following is unit of inductance?

a. Ohm
b. Henry
c. Ampere
d. Webers/meter

Ans. (b) Henry

Q 4. Which of the following circuit elements will oppose the change in circuit current?

a. Capacitance
b. Inductance
c. Resistance
d. All of these

Ans. (b) Inductance

Q 5. If in an iron cored coil the iron core is removed so as to make the air cored coil, the inductance of the coil will be

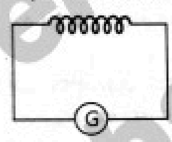
a. more
b. less
c. the same
d. None of these

Ans. (b) less

The inductance of air cored coil is less than that of Iron cored coil.

Case Study 8

When a current I flows through a coil, flux linked with it is $\phi = LI$, where L is a constant known as self inductance of the coil. Any change in current sets up an induced emf in the coil. Thus, self inductance of a coil is the induced emf set up in the coil when the current passing through it changes at the unit rate. It is a measure of the opposition to the growth or the decay of current flowing through the coil. Also, value of self inductance depends on the number of turns in the solenoid, its area of cross-section and the relative permeability of its core material.



Read the above passage carefully and give the answer of the following questions:

Q 1. The inductance in a coil plays the same role as:

a. inertia in mechanics
b. energy in mechanics
c. momentum in mechanics
d. force in mechanics

Ans. (a) inertia in mechanics

The inductance in a coil plays the same role as inertia in mechanics.

Q 2. A current of 2.5 A flows through a coil of inductance 5H. The magnetic flux linked with the coil is:

a. 0.5 Wb
b. 12.5 Wb
c. zero
d. 2 Wb

Ans. (b) 12.5 Wb

Here, $I = 2.5$ A, $L = 5$ H

Magnetic flux linked with the coil is

$$\phi_B = LI\,(5\text{H})\,(2.5\text{ A}) = 12.5\text{ Wb}$$

Q 3. The inductance L of a solenoid depends upon its radius R as:

a. $L \propto R$
b. $L \propto I/R$
c. $L \propto R^2$
d. $L \propto R^3$

Ans. (c) $L \propto R^2$

The inductance of a solenoid is

$L = \mu_0 n^2 Al$

where A is the area of cross-section of the solenoid, l its length and n is the number of turns per unit length.

As $A = \pi R^2$, where R is the radius of the solenoid.

$$\therefore \quad L = \mu_0 n^2 \pi R^2 l \Rightarrow L \propto R^2$$

Q 4. The unit of self-inductance is:

a. weber ampere
b. weber^{-1} ampere
c. ohm second
d. farad

Ans. (c) ohm second

The magnitude of induced emf is

$$|\varepsilon| = L\frac{dI}{dt} \Rightarrow L = \frac{|\varepsilon|\,dt}{dI}$$

or

$$L = \frac{\text{volt} \times \text{second}}{\text{ampere}} = \text{ohm second}$$

Q 5. The induced e.m.f. in a coil of 10 henry inductance in which current varies from 9 A to 4 A in 0.2 second is:

a. 200 V
b. 250 V
c. 300 V
d. 350 V

Ans. (b) 250 V

Here $L = 10$ henry, $I_1 = 9$ A, $I_2 = 4$ A

and $\Delta t = 0.2$ second

Then induced e.m.f.

$$\varepsilon_1 = -L\frac{dI}{dt} = -L\frac{(I_2 - I_1)}{\Delta t}$$

$$= \frac{-10 \times (4-9)}{0.2} = \frac{50}{0.2} = 250\text{ V}$$

CHAPTER 7

Alternating Current

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Fastrack REVISION

- **Alternating Current (AC):** The magnitude of AC or e.m.f. varies periodically with respect to time.

$$I = I_0 \sin \omega t \text{ or } I = I_0 \cos \omega t$$

The frequency of AC in India is 50 Hz.

- **Root Mean Square (RMS) Value of AC:** RMS value of AC is defined as that value of steady current, which would generate the same amount of heat in a given resistance in a given time, as done by the AC when passed through the same resistance for same time.

It is represented by I_{rms} or I_{eff} or I_v.

$$I_{rms}^2 = \frac{I_0}{\sqrt{2}} \text{ or } I_{rms}^2 = 0.707 I_0$$

- **Mean Value or Average Value of AC:** The mean or average value of AC over any half `is defined as that value of steady current which would send the same amount of charge through a circuit in the time of half cycle as sent by AC in the same circuit, in the same time.
- The average value of current for a complete cycle is zero.

$$I_{av} = 0.637 I_0$$

- **AC Circuits:** In an AC circuit, both e.m.f. and current change continuously w.r.t. time, so in circuit, we have to calculate average power in complete cycle $(0 \to T)$. $P_{av} = V_{rms} I_{rms} \cos \phi$ where, $\cos \phi =$ power factor.
- **Circuit Containing Resistance Only:** $I = I_0 \sin \omega t$

Thus, e.m.f. and current are in the same phase.

- **Circuit Containing Inductance Only:** $I = I_0 \sin(\omega t - \pi/2)$

Current (I) lags behind voltage (E) by a phase angle of 90°.

Inductance reactance $X_L = \omega L$

- **Circuit Containing Capacitance Only:** $I = I_0 \sin(\omega t + \pi/2)$

Current (I) leads e.m.f. by a phase angle of 90°.

Capacitive reactance, $X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$

- **Series *LCR* Circuit :** $I = I_m \sin(\omega t + \phi)$

where, $$I_m = \frac{V_m}{\sqrt{R^2 + (X_C - X_L)^2}} = \frac{V_m}{Z}$$

and $$\phi = \tan^{-1} \frac{X_C - X_L}{R}$$

- **Resonance:** A circuit in which inductance L, capacitance C and resistance R are connected and the circuit admits maximum current corresponding to a given frequency of AC is called resonance circuit.

$$Z = \sqrt{R^2 + (X_C - X_L)^2}$$

At resonance, $$X_L = X_C$$

$$\omega L = \frac{1}{\omega C}$$

or $$\omega = \frac{1}{\sqrt{LC}}$$

or $$f = \frac{1}{2\pi \sqrt{LC}}$$

This frequency is known as resonant frequency.

- ***Q*-Factor of Resonance Circuit or Sharpness of Resonance:** It is defined as the ratio of the voltage developed across L or C at resonance to the voltage applied across R.

Quality factor, $Q = \frac{\omega L}{R}$ or $Q = \frac{1}{\omega C R}$

Using $\omega = \frac{1}{\sqrt{LC}}$, $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$

Larger the value of Q, sharper is the resonance.

- ***LC* Oscillation:** As there is no current in the circuit, energy in the inductor is zero and energy stored in capacitor is $U_E = \frac{1}{2}\frac{q_m^2}{C}$, so total energy of LC circuit is:

$$U = U_E = \frac{1}{2}\frac{q_m^2}{C}$$

- **Transformers:** It is a device used to convert low voltage at high current into high voltage at low current and *vice-versa.*
- **Principle:** It works on the principle of mutual induction.
- **Types:**

1. Step-Up Transformer: It converts low voltage at high current into high voltage at low current. $(N_S > N_P)$ and $(E_P > E_S)$

2. Step-Down Transformer: It converts high voltage at low current into low voltage at high current. $(N_P > N_S)$ and $(E_S < E_P)$

$$I_P E_P = I_S E_S$$

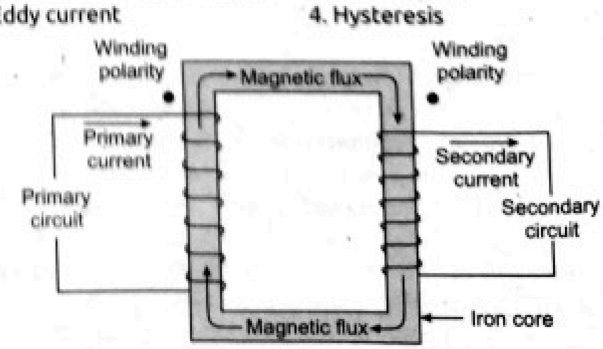
and $$\frac{I_P}{I_S} = \frac{E_S}{E_P} = \frac{N_S}{N_P}$$

Also, $$E_S = \left(\frac{N_S}{N_P}\right) E_P$$

and $$I_S = \left(\frac{N_P}{N_S}\right) I_P$$

- **Efficiency:** $$\eta = \frac{\text{Output power}}{\text{Input power}} = \frac{E_S I_S}{E_P I_P}$$
- **Energy Losses in Transformer:**

1. Resistance of the windings
2. Flux leakage
3. Eddy current
4. Hysteresis



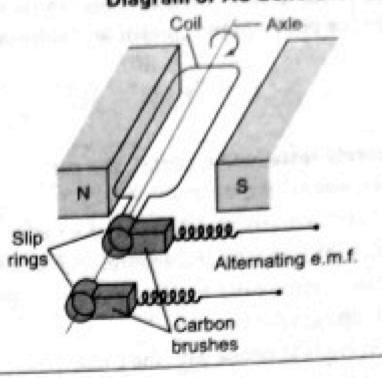
- **AC Generator:** It converts mechanical energy into electrical energy by virtue of electromagnetic induction.
- Instantaneous value of e.m.f. produced by AC generator $= NBA\omega \sin \omega t$.
- It is based on the principle of mutual induction. It has mainly three components:

(i) **Rotator coil:** It can rotate about an axis on a shaft.

(ii) **Stator coil:** It provides a magnetic field.

(iii) **Commutator:** It is a pair of slip rings and carbon brushes which facilitate flow of current.

Diagram of AC Generator



Objective TYPE QUESTIONS

Multiple Choice Questions

Q 1. Alternating current cannot be measured by DC ammeter because:

a. AC cannot pass through DC ammeter
b. AC changes direction
c. average value of current for complete cycle is zero
d. DC ammeter will get damaged

Ans. (c) average value of current for complete cycle is zero

Average value of AC for complete cycle is zero. Hence, AC cannot be measured by DC ammeter.

Q 2. The sum of average current values over on complete cycle is:

a. negative
b. positive
c. zero
d. Both a. and b.

Ans. (c) zero

The sum of the instantaneous current values over one complete cycle is zero and the average current is zero.

Q 3. Alternating voltage (V) is represented by the equation:

a. $V(t) = V_m e^{\omega t}$
b. $V(t) = V_m \sin \omega t$
c. $V(t) = V_m \cot \omega t$
d. $V(t) = V_m \tan \omega t$

where V_m is the peak voltage

Ans. (b) $V(t) = V_m \sin \omega t$

The equation of alternating voltage is

$$V(t) = V_m \sin \omega t$$

Q 4. A 100 Ω resistor is connected to a 220 V, 50 Hz AC supply. The rms value of current in the circuit is:

a. 1.56 A
b. 1.56 mA
c. 2.2 A
d. 2.2 mA

Ans. (c) 2.2 A

Here, $R = 100\ \Omega, V_{rms} = 220\text{ V}, \nu = 50\text{ Hz}$

$$\therefore \quad I_{rms} = \frac{V_{rms}}{R} = \frac{220}{100} = 2.2\text{ A}$$

Q 5. An alternating current is given by $I = I_1 \cos \omega t + I_2 \sin \omega t$. The root mean square current is given by:

a. $\frac{(I_1 + I_2)}{\sqrt{2}}$
b. $\frac{(I_1 + I_2)^2}{2}$
c. $\sqrt{\frac{I_1^2 + I_2^2}{2}}$
d. $\frac{\sqrt{I_1^2 - I_2^2}}{2}$

Ans. (c) $\sqrt{\frac{I_2^2 + I_2^2}{2}}$

Q 6. The peak voltage of an AC supply is 440 V, then its rms voltage is:

a. 31.11 V
b. 311.1 V
c. 41.11 V
d. 411.1 V

Ans. (b) 311.1 V

Here, $V_m = 440\text{ V}$

$$\therefore \quad V_{rms} = \frac{V_m}{\sqrt{2}} = \frac{440}{\sqrt{2}} = 311.1\text{ V}$$

Q 7. The rms value of current in an AC circuit is 25 A, then peak current is:

a. 35.36 mA
b. 35.36 A
c. 3.536 A
d. 49.38 A

Ans. (b) 35.36 A

Here, $I_{rms} = 25\text{ A}$

$$\therefore \quad I_m = \sqrt{2}\, I_{rms} = \sqrt{2} \times 25 = 35.36\text{ A}$$

Q 8. An alternating voltage given by $V = 140 \sin 314t$ is connected across a pure resistor of 50 Ω, the rms current through the resistor is:

a. 1.98 A
b. 5.63 A
c. 8.43 A
d. 2.39 A

Ans. (a) 1.98 A

Here, $R = 50\ \Omega, V_0 = 140\text{ V}$

$$\therefore \quad I_{rms} = \frac{V_{rms}}{R} = \frac{0.707 V_0}{R} = \frac{0.707 \times 140}{50} = 1.98\text{ A}$$

Q 9. If the rms current in a 50 Hz AC circuit is 5 A, the value of the current 1/300 seconds after its value becomes zero is: (NCERT EXEMPLAR)

a. $5\sqrt{2}$ A
b. $5\sqrt{\frac{3}{2}}$ A
c. $\frac{5}{6}$ A
d. $\frac{5}{\sqrt{2}}$ A

Ans. (b) $5\sqrt{\frac{3}{2}}$ A

Here, $I_{rms} = 5\text{ A}, \nu = 50\text{ Hz}, t = \frac{1}{300}\text{ s}$

$$I_0 = \sqrt{2}\, I_{rms} = 5\sqrt{2}\text{ A},$$

$$I = I_0 \sin \omega t = I_0 \sin 2\pi\nu t$$

$$= 5\sqrt{2} \sin\left(2\pi \times 50 \times \frac{1}{300}\right)$$

$$= 5\sqrt{2} \sin \frac{\pi}{3} = 5\sqrt{2}\, \frac{\sqrt{3}}{2} = 5\sqrt{\frac{3}{2}}\text{ A}$$

Q 10. When an AC is connected to a resistor what is the phase difference between the current and voltage?

a. 90° b. 180°
c. 0° d. 60°

Ans. (c) 0°

Q 11. In a purely resistive AC circuit, the current:

a. is in phase with the e.m.f.
b. leads the e.m.f. by a difference of π radian phase
c. leads the e.m.f. by a phase difference of $\pi/2$ radians
d. lags behind the e.m.f. by phase difference of $\pi/4$ radians

Ans. (a) is in phase with the e.m.f.

The current is in phase with the e.m.f.

Q 12. The voltage over a cycle varies as

$$V = V_0 \sin\omega t \text{ for } 0 \le t \le \frac{\pi}{\omega}$$
$$= -V_0 \sin\omega t \text{ for } \frac{\pi}{\omega} \le t \le \frac{2\pi}{\omega}$$

The average value of the voltage for one cycle is:

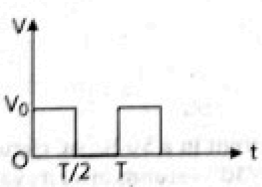
a. $\frac{V_0}{\sqrt{2}}$ b. $\frac{V_0}{2}$
c. zero d. $\frac{2V_0}{\pi}$

Ans. (d) $\frac{2V_0}{\pi}$

The average value of the voltage is

$$V_{av} = \frac{\int_0^{2\pi/\omega} V\,dt}{\int_0^{2\pi/\omega} dt}$$
$$= \frac{\int_0^{\pi/\omega} V_0 \sin\omega t\,dt + \int_{\pi/\omega}^{2\pi/\omega} (-V_0 \sin\omega t)\,dt}{\frac{2\pi}{\omega}}$$
$$= \frac{\omega}{2\pi}\left[\left|\frac{-V_0\cos\omega t}{\omega}\right|_0^{\pi/\omega} + \left|\frac{V_0\cos\omega t}{\omega}\right|_{\pi/\omega}^{2\pi/\omega}\right] = \frac{2V_0}{\pi}$$

Q 13. The rms value of potential difference V as shown in the figure is:



a. $\frac{V_0}{\sqrt{3}}$ b. V_0 c. $\frac{V_0}{\sqrt{2}}$ d. $\frac{V_0}{2}$

Ans. (c) $\frac{V_0}{\sqrt{2}}$

$$V = V_0 \text{ for } 0 \le t \le \frac{T}{2}$$
$$V = 0 \text{ for } \frac{T}{2} \le t \le T$$
$$V_{rms} = \left[\frac{\int_0^T V^2 dt}{\int_0^T dt}\right]^{1/2} = \left[\frac{\int_0^{T/2} V_0^2 dt + \int_{T/2}^{T} (0)\,dt}{\int_0^T dt}\right]^{1/2}$$
$$= \left[\frac{V_0^2}{T}[t]_0^{T/2}\right]^{1/2} = \left[\frac{V_0^2}{T}\left(\frac{T}{2}\right)\right]^{1/2} = \frac{V_0}{\sqrt{2}}$$

Q 14. The relation between an AC voltage source and time in SI units is $V = 120 \sin(100\pi t)\cos(100\pi t)$ V.

The value of peak voltage and frequency will be respectively:

a. 120 V and 100 Hz b. $\frac{120}{\sqrt{2}}$ V and 100 Hz
c. 60 V and 200 Hz d. 60 V and 100 Hz

Ans. (d) 60 V and 100 Hz

$$V = 120\sin(100\pi t)\cos(100\pi t) \text{ V}$$
$$= 60\sin(200\pi t) \text{ V} \qquad (\because \sin 2\theta = 2\sin\theta\cos\theta)$$

Compare it with standard equation, $V = V_0 \sin\omega t$

We get, $V_0 = 60$ V

and $\omega = 200\pi$ or $2\pi\nu = 200\pi$ or $\nu = 100$ Hz

Q 15. A light bulb is rated at 100 W for a 220 V AC supply. The resistance of the bulb is:

a. 284 Ω b. 384 Ω c. 484 Ω d. 584 Ω

Ans. (c) 484 Ω

Here, $P = 100$ W, $V_{rms} = 220$ V

Resistance of the bulb is

$$R = \frac{V_{rms}^2}{P} = \frac{(220)^2}{100} = 484\ \Omega$$

Q 16. An AC source is of $\frac{200}{\sqrt{2}}$ V, 50 Hz. The value of voltage after $\frac{1}{600}$ s from the start is:

a. 200 V b. $\frac{200}{\sqrt{2}}$ V c. 100 V d. 50 V

Ans. (c) 100 V

$$V_{rms} = \frac{200}{\sqrt{2}} \text{ V}$$
$$V_0 = \sqrt{2}\,V_{rms} = \sqrt{2} \times \frac{200}{\sqrt{2}} = 200 \text{ V}$$
$$V = V_0 \sin 2\pi\nu t = 200\sin\left(2\pi \times 50 \times \frac{1}{600}\right)$$
$$= 200\sin\frac{\pi}{6} = 200 \times \frac{1}{2} = 100 \text{ V}$$

Q 17. The peak value of domestic AC supply voltage is 325 V. What is the rms value?

a. 325 V b. 230 V c. 200 V d. 325 V

Ans. (b) 230 V

Q 18. The equation of AC is given by $I = 100 \sin 314t$. What is the frequency?

a. 314 Hz b. 100 Hz c. 50 Hz d. 100 Hz

Ans. (c) 50 Hz

Q 19. The line that draws power supply to your house from street has:

a. $220\sqrt{2}$ V average voltage
b. 220 V average voltage
c. voltage and current out of phase by $\pi/2$
d. voltage and current possibly differing in phase ϕ such that $|\phi| < \frac{\pi}{2}$

Ans. (d) voltage and current possibly differing in phase ϕ such that $|\phi| < \frac{\pi}{2}$.

As the line has some resistance ($R \ne 0$), voltage and current differ in phase ϕ such that $|\phi| < \frac{\pi}{2}$.

Q 20. When a voltage measuring device is connected to AC mains, the meter shows the steady input voltage of 220 V. This means: *(NCERT EXEMPLAR)*

a. input voltage cannot be AC voltage, but a DC voltage

b. maximum input voltage is 220 V

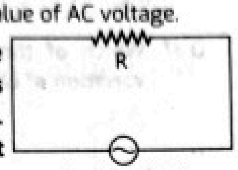
c. the meter reads not V but $< V^2 >$ and is calibrated to read $\sqrt{< V^2 >}$

d. the pointer of the meter is stuck by some mechanical defect

Ans. (c) the meter reads not V but $< V^2 >$ and is calibrated to read $\sqrt{< V^2 >}$

The voltmeter connected to AC mains is calibrated to read root mean square value or virtual value of AC voltage.

Q 21. An AC source of voltage $V = V_m \sin \omega t$ is connected across the resistance R as shown in figure. The phase relation between current and voltage for this circuit is:



$V = V_m \sin\omega t$

a. both are in phase

b. both are out of phase by 90°

c. both are out of phase by 120°

d. both are out of phase by 180°

Ans. (a) both are in phase

The given circuit is a pure resistive circuit. In this circuit the voltage and current both are in phase.

Q 22. In an AC circuit, V and I are given by $V = 150 \sin(150t)$V and $I = 150 \sin\left(150t + \frac{\pi}{3}\right)$ A. The power dissipated in the circuit is:

a. 106 W
b. 150 W
c. 5625 W
d. zero

Ans. (c) 5625 W

Compare $V = 150 \sin(150t)$ with $V = V_0 \sin \omega t$,

we get. $V_0 = 150$ V

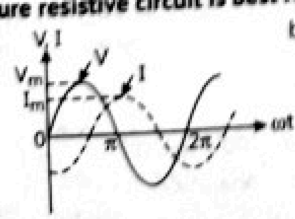
Compare $I = 150 \sin\left(150t + \frac{\pi}{3}\right)$ with $I = I_0 \sin(\omega t + \phi)$,

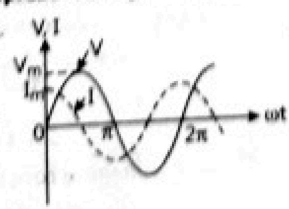
we get $I_0 = 150$ A, $\phi = \frac{\pi}{3} = 60°$

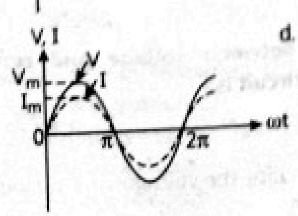
The power dissipated in AC circuit is

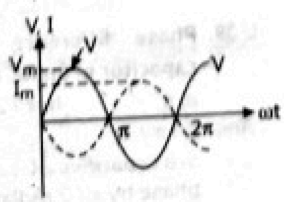
$$P = \frac{1}{2} V_0 I_0 \cos\phi = \frac{1}{2} \times 150 \times 150 \times \cos 60°$$
$$= \frac{1}{2} \times 150 \times 150 \times \frac{1}{2} = 5625 \text{ W}$$

Q 23. The phase relationship between current and voltage in a pure resistive circuit is best represented by:

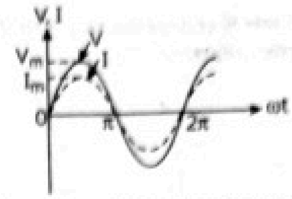
a.


b.


c.


d.


Ans. (c)



In the pure resistive circuit current and voltage both are in phase. Hence, graph (c) is correct.

Q 24. The projection of a phasor on any axis, always represents the:

a. rms value of a quantity

b. peak value of a quantity

c. mean value of a quantity

d. instantaneous value of a quantity

Ans. (d) instantaneous value of a quantity

Q 25. The time axis of an AC phasor represents:

a. time
b. phase angle
c. voltage
d. current

Ans. (b) phase angle

Q 26. A phasor is a:

a. scalar quantity
b. vector quantity
c. tensor quantity
d. None of these

Ans. (a) scalar quantity

Voltage and current in an AC circuit are represented by phasors-rotating vectors, they are not vectors themselves. They are scalar quantities.

Q 27. In the case of an inductor:

a. voltage lags the current by $\frac{\pi}{2}$

b. voltage leads the current by $\frac{\pi}{2}$

c. voltage leads the current by $\frac{\pi}{3}$

d. voltage leads the current by $\frac{\pi}{4}$

Ans. (b) voltage leads the current by $\frac{\pi}{2}$

In an inductor voltage leads the current by $\frac{\pi}{2}$ or current lags the voltage by $\frac{\pi}{2}$.

Q 28. An alternating voltage $V = V_0 \sin \omega t$ is applied across a circuit. As a result, the current $I = I_0 \sin(\omega t - \pi/2)$ flows in it. The power consumed in the circuit per cycle is:

a. $0.5 V_0 I_0$ W
b. $0.707 V_0 I_0$ W
c. $1.919 V_0 I_0$ W
d. zero

Ans. (d) zero

Q 29. An ideal inductor is in turn put across 220 V, 50 Hz and 220 V, 100 Hz supplies. The current flowing through it in the two cases will be:

a. equal
b. different
c. zero
d. infinite

Ans. (b) different

The current in the inductor coil is given by

$$I = \frac{V}{X_L} = \frac{V}{2\pi\nu L}$$

Since, frequency ν in the two cases is different, hence the current in two cases will be different.

Q 30. An inductor of 30 mH is connected to a 220 V, 100 Hz AC source. The inductive reactance is:

a. 10.58 Ω b. 12.64 Ω c. 18.85 Ω d. 22.67 Ω

Ans. (c) 18.85 Ω

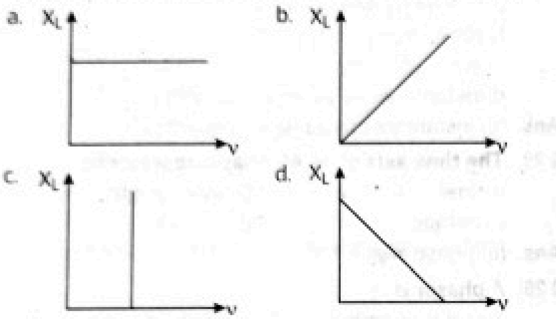
Here, $L = 30\text{ mH} = 30 \times 10^{-3}\text{ H}$

$V_{rms} = 220\text{ V}, \nu = 100\text{ Hz}$

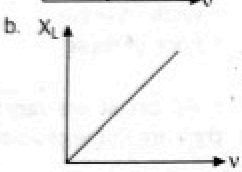
Inductive reactance,

$$X_L = 2\pi\nu L = 2 \times 3.14 \times 100 \times 30 \times 10^{-3} = 18.85\ \Omega$$

Q 31. Which of the following graphs represents the correct variation of inductive reactance X_L with frequency ν ?



Ans. (b)



Inductive reactance,

$$X_L = \omega L = 2\pi\nu L \Rightarrow X_L \propto \nu$$

Hence, inductive reactance increases linearly with frequency.

Q 32. What is the resistance offered by a pure inductor for DC?

a. Zero
b. Infinity
c. One
d. Depends on the material

Ans. (a) Zero

Q 33. A 44 mH inductor is connected to 220 V, 50 Hz AC supply. The rms value of the current in the circuit is:

a. 12.8 A b. 13.6 A c. 15.9 A d. 19.5 A

Ans. (c) 15.9 A

Here, $L = 44\text{ mH} = 44 \times 10^{-3}\text{ H}$

$V_{rms} = 220\text{ V}, \nu = 50\text{ Hz}$

The inductive reactance is

$$X_L = \omega L = 2\pi\nu L$$

$$= 2 \times 3.14 \times 50 \times 44 \times 10^{-3} = 13.82\ \Omega$$

$$\therefore \quad I_{rms} = \frac{V_{rms}}{X_L} = \frac{220}{13.82} = 15.9\text{ A}$$

Q 34. The reactance of a coil is 100 Ω, when used with an AC 240V – 100 Hz supply. The inductance of the coil is:

a. 0.16 H b. 0.22 H
c. 1.6 H d. 2.2 H

Ans. (a) 0.16 H

Q 35. In a circuit, the current lags behind the voltage by a phase difference of $\pi/2$. The circuit contains:

a. only R b. only C
c. only L d. R and C

Ans. (c) only L

Q 36. In a pure capacitive circuit, if the frequency of AC source is doubled, then its capacitive reactance will be:

a. remains same b. doubled
c. halved d. zero

Ans. (c) halved

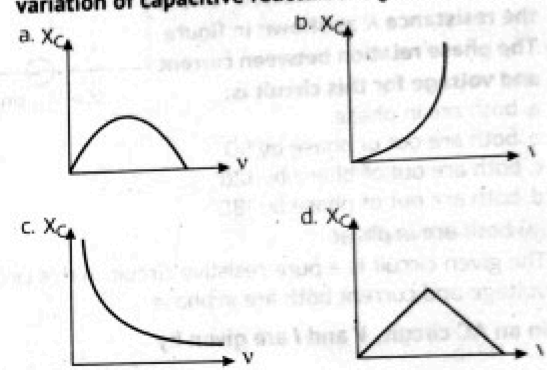
Capacitive reactance, $X_C = \dfrac{1}{2\pi\nu C}$

$$\Rightarrow \quad X_C \propto \frac{1}{\nu}$$

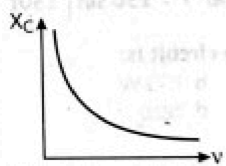
$$\therefore \quad \frac{X_{C_1}}{X_{C_2}} = \frac{\nu_2}{\nu_1} = \frac{2\nu}{\nu} = 2$$

$$\Rightarrow \quad X_{C_2} = \frac{X_{C_1}}{2}$$

Q 37. Which of the following graphs represents the correct variation of capacitive reactance X_C with frequency ν:



Ans. (c)



Capacitive reactance,

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi\nu C} \Rightarrow X_C \propto \frac{1}{\nu}$$

With increase in frequency, X_C decreases.

Hence, option (c) represents the correct graph.

Q 38. If a capacitor of 8 μF is connected to a 220 V, 100 Hz AC source and the current passing through it is 65 mA, then the rms voltage across it is:

a. 129.4 V b. 12.94 V c. 1.294 V d. 15 V

Ans. (b) 12.94 V

Here, $V_{rms} = 220\text{ V}, I_{rms} = 65\text{ mA} = 0.065\text{ A}$

$C = 8\ \mu\text{F} = 8 \times 10^{-6}\text{ F}, \nu = 100\text{ Hz}$

Capacitive reactance,

$$X_C = \frac{1}{2\pi\nu C}$$

$$= \frac{1}{2 \times 3.14 \times 100 \times 8 \times 10^{-6}} = 199\ \Omega$$

rms voltage across the capacitor is

$$V_{rms} = I_{rms} X_C = 0.065 \times 199 = 12.94\text{ V}$$

Q 39. Phase difference between voltage and current in a capacitor in an AC circuit is:

a. π b. π / 2 c. 0 d. π / 3

Ans. (b) π / 2

In a capacitive AC circuits, the voltage lags behind current in phase by π / 2 radian.

Q 40. In an alternating current circuit consisting of elements in series, the current increases on increasing the frequency of supply. Which of the following elements are likely to constitute the circuit?

a. Only resistor b. Resistor and inductor
c. Resistor and capacitor d. Only inductor

Ans. (c) Resistor and capacitor

Reactance of a capacitor,

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi\nu C}$$

As frequency increases, X_C decreases and therefore current increases. As R does not vary with frequency, therefore, likely currents constituting the circuit may be capacitor and resistor.

Q 41. A 30 μF capacitor is connected to a 150 V, 60 Hz AC supply. The rms value of current in the circuit is:

a. 17 A b. 1.7 A
c. 1.7 MA d. 2.7 A

Ans. (b) 1.7 A

Here, $C = 30 \times 10^{-6}$ F; $V_{rms} = 150$ V, $\nu = 60$ Hz

Capacitive reactance

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi\nu C} = 88.46\ \Omega$$

$$I_{rms} = \frac{V_{rms}}{X_C} = \frac{150}{88.46} = 1.7\text{ A}$$

Q 42. A 60 μF capacitor is connected to a 110 V (rms), 60 Hz AC supply. The rms value of current in the circuit is:

a. 1.49 A b. 14.9 A c. 2.49 A d. 24.9 A

Ans. (c) 2.49 A

Q 43. An inductor of reactance 1 Ω and a resistor of 2 Ω are connected in series to the terminals of a 6V (rms) AC source. The power dissipated in the circuit is:

a. 8 W b. 12 W c. 14.4 W d. 18 W

Ans. (c) 14.4 W

Here, $X_L = 1\ \Omega, R = 2\ \Omega, V_{rms} = 6$ V

Impedance of the circuit

$$Z = \sqrt{X_L^2 + R^2} = \sqrt{(1)^2 + (2)^2} = \sqrt{5}\ \Omega$$

$$I_{rms} = \frac{V_{rms}}{Z} = \frac{6}{\sqrt{5}}\text{ A}$$

Power dissipated

$$P = V_{rms} I_{rms} \cos\phi = V_{rms} I_{rms} \frac{R}{Z}$$

$$= 6 \times \frac{6}{\sqrt{5}} \times \frac{2}{\sqrt{5}} = \frac{72}{5} = 14.4\text{ W}$$

Q 44. In the question number 43, the net power absorbed by the circuit in one complete cycle is:

a. 5 W b. 10 W c. 15 W d. zero

Ans. (d) zero

As $P = V_{rms} I_{rms} \cos\phi$

In a pure capacitance circuit, the phase difference between alternating voltage and current is $\pi / 2$. Hence

$$P = V_{rms} I_{rms} \cos 90° = 0$$

Q 45. In which of the following circuits the maximum power dissipation is observed?

a. Pure capacitive circuit b. Pure inductive circuit
c. Pure resistive circuit d. None of these

Ans. (c) Pure resistive circuit

Q 46. A capacitor:

a. blocks AC but provides an easy path for DC
b. blocks DC but provides an easy path for AC
c. blocks both AC and DC
d. offers easy path for AC and DC

Ans. (b) blocks DC but prdvides an easy path for AC

Q 47. The rectance of a capacitor of capacitance C, is X. If both the frequency and capacitance are doubled, the new reactance will be:

a. X b. $2X$ c. $4X$ d. $X/4$

Ans. (d) $X/4$

Q 48. What is the resistance offered by a capacitor for the steady current?

a. One
b. Zero
c. Infinity
d. Depends on the voltage value

Ans. (c) Infinity

Q 49. When an AC is connected to a capacitor what happens?

a. Voltage is leading the current by 90°
b. Voltage and current are in phase with each other
c. Voltage and current are out of phase
d. Current leads the voltage by 90°

Ans. (d) Current leads the voltage by 90°

Q 50. Which can not allow AC to pass through?

a. resistor b. inductor c. capacitor d. transistor

Ans. (c) capacitor

Q 51. A capacitor of capacitance *C* has reactance *X*. If capacitance and frequency become double, then the capacitive reactance will be:

a. $2X$ b. $4X$ c. $\frac{X}{2}$ d. $\frac{X}{4}$

Ans. (d) $\frac{X}{4}$

$$X_C = \frac{1}{2\pi\nu C}$$

$$\Rightarrow \quad X'_C = \frac{1}{2\pi(2\nu)(2C)} = \frac{X_C}{4}$$

Q 52. When AC voltage of 220 V is applied to the capacitor C, then:

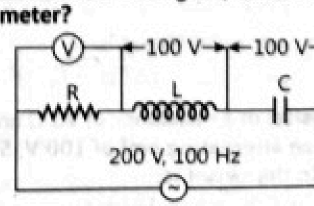
a. the maximum voltage between plates is 220 V
b. the current is in phase with the applied voltage
c. the charge on the plate is not in phase with the applied voltage
d. power delivered to the capacitor per cycle is zero

Ans. (d) power delivered to the capacitor per cycle is zero

When AC voltage of 220 V is applied to a capacitor C, the charge on the plates is in phase with the applied voltage. As the circuit is pure capacitive so, the current developed leads the applied voltage by a phase angle of 90°. Hence, power delivered to the capacitor per cycle is

$$P = V_{rms} I_{rms} \cos 90° = 0$$

Q 53. In the circuit shown in figure, what will be the reading of the voltmeter?



a. 300 V b. 900 V c. 200 V d. 400 V

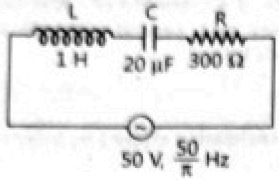
Ans. (c) 200 V

Here. $V_L = V_C = 100$ V, $V = 200$ V

As $V = \sqrt{V_R^2 + (V_L - V_C)^2}$

$\therefore$ $200 = \sqrt{V_R^2 + (100-100)^2}$ or $V_R = 200$ V

Q 54. In the series *LCR* circuit shown, the impedance is:



a. 200 Ω b. 100 Ω

c. 300 Ω d. 500 Ω

Ans. (d) 500 Ω

Here, $L = 1\text{H}, C = 20\,\mu\text{F} = 20 \times 10^{-6}$ F

$R = 300\ \Omega$, $v = \frac{50}{\pi}$ Hz

The inductive reactance is

$$X_L = 2\pi v L = 2 \times \pi \times \frac{50}{\pi} \times 1 = 100\ \Omega$$

The capacitive reactance is

$$X_C = \frac{1}{2\pi v C} = \frac{1}{2 \times \pi \times \frac{50}{\pi} \times 20 \times 10^{-6}} = 500\ \Omega$$

The impedance of the series *LCR* circuit is

$$Z = \sqrt{R^2 + (X_C - X_L)^2}$$
$$= \sqrt{(300)^2 + (500-100)^2}$$
$$= \sqrt{(300)^2 + (400)^2} = 500\ \Omega$$

Q 55. A circuit containing a 20 Ω resistor and 0.1 μF capacitor in series is connected to 230V AC supply of angular frequency 100 rad s^{-1}. The impedance of the circuit is:

a. 10^5 Ω b. 10^4 Ω c. 10^6 Ω d. 10^{10} Ω

Ans. (a) 10^5 Ω

Here. $R = 20\ \Omega, C = 0.1\,\mu\text{F}$

$= 0.1 \times 10^{-6}\ \text{F} = 10^{-7}$ F

Impedance, $Z = \sqrt{R^2 + \frac{1}{\omega^2 C^2}} = \sqrt{20^2 + \frac{1}{(100)^2 \times (10^{-7})^2}}$

$= \sqrt{400 + 10^{10}} \simeq 10^5\ \Omega$

Q 56. A 0.2 kΩ resistor and 15 μF capacitor are connected in series to a 220 V, 50 Hz source. The impedance of the circuit is:

a. 250 Ω b. 268 Ω c. 29.15 Ω d. 291.5 Ω

Sol. Here, $R = 0.2\ \text{k}\Omega = 200\ \Omega$

$C = 15\,\mu\text{F} = 15 \times 10^{-6}$ F, $V_{rms} = 220$ V, $v = 50$ Hz

Capacitive reactance,

$$X_C = \frac{1}{2\pi v C} = \frac{1}{2 \times 3.14 \times 50 \times 15 \times 10^{-6}} = 212\ \Omega$$

The impedance of the *RC* circuit is

$$Z = \sqrt{R^2 + X_C^2} = \sqrt{(200)^2 + (212)^2} = 291.5\ \Omega$$

Q 57. A circuit consists of a resistance of 10 Ω and a capacitance of 0.1 μF. If an alternating emf of 100 V, 50 Hz is applied, the current in the circuit is:

a. 3.14 mA b. 6.28 mA c. 1.51 mA d. 7.36 mA

Ans. (a) 3.14 mA

$$X_C = \frac{1}{2\pi v C}$$
$$= \frac{1}{2 \times 3.14 \times 50 \times 0.1 \times 10^{-6}}$$
$$= 3.2 \times 10^4\ \Omega$$
$$Z = \sqrt{R^2 + X_C^2} = \sqrt{100 + 10.28 \times 10^8}$$
$$= 3.2 \times 10^4\ \Omega$$
$$I_{rms} = \frac{V_{rms}}{Z} = \frac{100}{3.2 \times 10^4}$$
$$= 3.14 \times 10^{-3}\ \text{A} = 3.14\ \text{mA}$$

Q 58. 200 V AC source is fed to series *LCR* circuit having $X_L = 50\ \Omega$, $X_C = 50\ \Omega$ and $R = 25\ \Omega$. Potential drop across the inductor is:

a. 100 V b. 200 V c. 400 V d. 10 V

Ans. (c) 400 V

Here, $V_{rms} = 200$ V, $X_L = 50\ \Omega$, $X_C = 50\ \Omega$, $R = 25\ \Omega$

Impedance of the circuit,

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$
$$= \sqrt{25^2 + (50-50)^2} = 25\ \Omega$$

Current in the circuit,

$$I_{rms} = \frac{V_{rms}}{Z} = \frac{200\ \text{V}}{25\ \Omega} = 8\ \text{A}$$

Voltage drop across the inductor is

$$V_L = I_{rms} X_L = 8\ \text{A} \times 50\ \Omega = 400\ \text{V}$$

Q 59. In series *R-L-C* circuit, quality factor can be improved by:

a. decreasing *L* b. increasing *C*

c. decreasing *R* d. increasing *R* and *L*

Ans. (c) decreasing *R*

$$Q = \left[\frac{1}{R}\sqrt{\frac{L}{C}}\right]$$

Q 60. When AC source is connected across series *R-L-C* combination, maximum power loss will occur provided:

a. current and voltage are in phase

b. current from source is minimum

c. inductance is minimum

d. capacitance is maximum

Ans. (a) current and voltage are in phase

$$I_0 = (I_0)_{max} = \frac{E_0}{R}$$

Q 61. In *R-L-C* series AC circuit, impedance cannot be increased by:

a. increasing frequency of source

b. decreasing frequency of source

c. increasing the resistance

d. increasing the voltage of the source

Ans. (a) increasing the voltage of the source

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

Q 62. A 100 μF capacitor is in series with a 40 Ω resistor, connected to a 100V, 60Hz supply. The time lag between the current maximum and the voltage maximum is:

a. 15.5 ms b. 155 ms c. 1.55 ms d. 1.55 s

Ans. (c) 1.55 ms

In series *RC* circuit voltage lags behind the current by phase angle ϕ.

Then, $\tan\phi = \frac{X_C}{R} = \frac{1/\omega C}{R} = \frac{1}{\omega CR} = \frac{1}{2\pi v CR}$

$$\tan\phi = \frac{1}{2\pi \times 60 \times 10^{-4} \times 40}$$

$$\tan\phi = (0.6634): \phi = \tan^{-1}(0.6634)$$

$$= 33.56° = 33.56 \times \frac{\pi}{180} \text{ rad}$$

$\therefore$ Time lag, $\Delta T = \frac{\phi}{\omega}$

$$= \frac{\frac{33.56 \times \pi}{180}}{120\pi} = 1.55 \times 10^{-3} \text{ s} = 1.55 \text{ ms}$$

$[\because \omega = 2\pi\nu = 120\pi]$

Q 63. In series *LCR* circuit, the phase angle between supply voltage and current is:

a. $\tan\phi = \frac{X_L - X_C}{R}$ b. $\tan\phi = \frac{R}{X_L - X_C}$

c. $\tan\phi = \frac{R}{X_L + X_C}$ d. $\tan\phi = \frac{X_L + X_C}{R}$

Ans. (a) $\tan\phi = \frac{X_L - X_C}{R}$

Q 64. An *LCR* circuit is predominantly capacitive if:

a. $X_L > X_C$ b. $X_L < X_C$

c. $X_L = X_C$ d. None of these

Ans. (b) $X_L < X_C$

Q 65. To reduce the resonant frequency in an *LCR* series circuit with a generator: *(NCERT EXEMPLAR)*

a. the generator frequency should be reduced

b. another capacitor should be added in parallel to the first

c. the iron core of the inductor should be removed

d. dielectric in the capacitor should be removed

Ans. (b) another capacitor should be added in parallel to the first

Q 66. When an AC voltage is applied to a *L-C-R* circuit, which of the following is true?

a. *I* and *V* are out of phase with each other in *R*

b. *I* and *V* are in phase in *L* with in *C*, they are out of phase

c. *I* and *V* are out of phase in both, *C* and *L*

d. *I* and *V* are out of phase in *L* and in phase in *C*

Ans. (c) *I* and *V* are out of phase in both, *C* and *L*

Q 67. An *LCR* series AC circuit is at resonance with 10 V each across *L*, *C* and *R*. If the resistance is halved, the respective voltages across *L*, *C* and *R* are:

a. 10 V, 10 V and 5 V b. 10 V, 10 V and 10 V

c. 20 V, 20 V and 5 V d. 20 V, 20 V and 10 V

Ans. (d) 20 V, 20 V and 10 V

Q 68. In a series *LCR* circuit the voltage across an inductor, capacitor and resistor are 20 V, 20 V and 40 V respectively. The phase difference between the applied voltage and the current in the circuit is:

a. 30° b. 45°

c. 60° d. 0°

Ans. (d) 0°

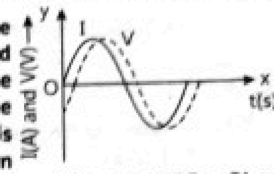
Let ϕ be the phase difference between the applied voltage and current. Then

$$\tan\phi = \frac{X_L - X_C}{R} = \frac{I_V(X_L - X_C)}{I_V R}$$

$$= \frac{V_L - V_C}{V_R} = \frac{20\text{ V} - 20\text{ V}}{40\text{ V}} = 0$$

$\therefore$ $\phi = \tan^{-1}(0) = 0°$

Q 69. When an AC source of voltage $V = V_0 \sin 100t$ is connected across a circuit, the phase difference between the voltage *V* and current *I* in the circuit is observed to be $\pi/4$, as shown in figure. If the circuit consists possibly only of *RC* or *RL* or *LC* in series, find possible values of two elements.



a. $R = 1\text{k}\Omega, C = 10\,\mu\text{F}$ b. $R = 1\text{k}\Omega, C = 1\,\mu\text{F}$

c. $R = 1\text{k}\Omega, L = 10\text{ mH}$ d. $R = 10\text{ k}\Omega, L = 10\text{ mH}$

Ans. (a) $R = 1\text{k}\Omega, C = 10\,\mu\text{F}$

Figure given in the question shows that current *I* leads the voltage *V* by a phase angle $\pi/4$. Therefore, the circuit can be *RC* circuit alone.

$$\tan\phi = \frac{X_C}{R} = \frac{1}{\omega CR} \quad \left(\because X_C = \frac{1}{\omega C}\right)$$

$$\tan\frac{\pi}{4} = \frac{1}{\omega CR}; 1 = \frac{1}{\omega CR} \quad ...(1)$$

From $V = V_0 \sin 100t$, we get, $\omega = 100 \text{ rad s}^{-1}$

$$\therefore \quad CR = \frac{1}{\omega} = \frac{1}{100} \quad \text{(Using eq. (1))}$$

When $R = 1\text{k}\Omega = 10^3\,\Omega, C = \frac{1}{10^5} = 10^{-5}\text{ F} = 10\,\mu\text{F}$

Q 70. In a circuit, *L*, *C* and *R* are connected in series with an alternating voltage source of frequency ν. The current leads the voltage by 45°. The value of *C* is:

a. $\frac{1}{\pi\nu(2\pi\nu L - R)}$ b. $\frac{1}{2\pi\nu(2\pi\nu L - R)}$

c. $\frac{1}{\pi\nu(2\pi\nu L + R)}$ d. $\frac{1}{2\pi\nu(2\pi\nu L + R)}$

Ans. (d) $\frac{1}{2\pi\nu(2\pi\nu L + R)}$

As the current leads the voltage by 45°, therefore,

$$X_C > X_L, \tan\phi = \frac{X_C - X_L}{R} = \tan 45° = 1$$

$$\Rightarrow \quad X_C - X_L = R \text{ or } X_C = X_L + R = \omega L + R$$

$$\frac{1}{\omega C} = \omega L + R, C = \frac{1}{\omega(\omega L + R)}$$

$$= \frac{1}{2\pi\nu(2\pi\nu L + R)}$$

Q 71. At resonance frequency the impedance in series *LCR* circuit is:

a. maximum b. minimum c. zero d. infinity

Ans. (b) minimum

At resonance frequency, the inductive and capacitive reactance are equal.

$\therefore$ $X_L = X_C$

Impedance, $Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + 0^2} = R$

Q 72. An *LCR* series circuit is under resonance. If I_m is current amplitude, V_m is voltage amplitude, *R* is the resistance, *Z* is the impedance, X_L is the inductive reactance and X_C is the capacitive reactance, then:

a. $I_m = \frac{Z}{V_m}$ b. $I_m = \frac{V_m}{X_L}$ c. $I_m = \frac{V_m}{X_C}$ d. $I_m = \frac{V_m}{R}$

Ans. (d) $I_m = \frac{V_m}{R}$

Impedance of the circuit,

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

Resonance, $X_L = X_C$

$Z = R$

$\therefore \quad I_m = \frac{V_m}{Z} = \frac{V_m}{R}$

Q 73. At resonant frequency the current amplitude in series *LCR* circuit is:

a. maximum b. minimum c. zero d. infinity

Ans. (a) maximum

Q 74. The resonant frequency of a series *LCR* circuit with $L = 2.0$ H, $C = 32\,\mu$F and $R = 10\,\Omega$ is:

a. 20 Hz b. 30 Hz c. 40 Hz d. 50 Hz

Ans. (a) 20 Hz

Here, $L = 2$ H, $C = 32\,\mu F = 32 \times 10^{-6}$ F;

$R = 10\,\Omega$

$$\omega_r = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{2 \times 32 \times 10^{-6}}} = 125 \text{ rad s}^{-1}$$

$$\nu_r = \frac{\omega_r}{2\pi} = \frac{125}{2 \times 3.14} = 20 \text{ Hz}$$

Q 75. Which of the following combinations should be selected for better tuning of an *LCR* circuit used for communication? *(NCERT EXEMPLAR)*

a. $R = 20\,\Omega$, $L = 1.5$ H, $C = 35\,\mu$F

b. $R = 25\,\Omega$, $L = 2.5$ H, $C = 45\,\mu$F

c. $R = 15\,\Omega$, $L = 3.5$ H, $C = 30\,\mu$F

d. $R = 25\,\Omega$, $L = 1.5$ H, $C = 45\,\mu$F

Ans. (c) $R = 15\,\Omega$, $L = 3.5$ H, $C = 30\,\mu$F

For better tuning of an *LCR* circuit used for communication the circuit should possess high quality factor of resonance.

i.e., $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$ should be high.

For it *R* should be low, *L* should be high and *C* should be low, therefore combination in option (c) is correct.

Q 76. The *Q* factor of a series *LCR* circuit with $L = 2$ H, $C = 32\,\mu$F and $R = 10\,\Omega$ is:

a. 15 b. 20 c. 25 d. 30

Ans. (c) 25

Here, $L = 2$ H, $C = 32\,\mu F = 32 \times 10^{-6}$ F; $R = 10\,\Omega$

Resonance frequency,

$$\omega_r = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{2 \times 32 \times 10^{-6}}} = \frac{10^3}{8} \text{ rad s}^{-1}$$

$$\text{Quality factor} = \frac{\omega_r L}{R} = \frac{10^3 \times 2}{8 \times 10} = 25$$

Q 77. In a series *LCR* circuit, resistance, voltage and frequency of the main supply is 200 Ω, 220 V and 50 Hz respectively. If capacitor is taken out from the circuit, the current lags behind the voltage by 30°. If inductor is taken out from the circuit, the current leads the voltage by 30°. The power dissipated in *LCR*-circuit is:

a. zero b. 210 W c. 242 W d. 305 W

Ans. (c) 242 W

Q 78. A series *LCR* circuit with $C = 10\,\mu$F and $\omega = 1000$ rad/s, has maximum current flowing through it. The value of inductance will be:

a. 100 mH

b. 10 mH

c. 1 mH

d. cannot be calculated, unless *R* is known

Ans. (a) 100 mH

Q 79. In a series *LCR* circuit at resonance, the circuit is purely:

a. resistive

b. inductive

c. capacitive

d. either capacitive or inductive

Ans. (a) resistive

Q 80. In a *LCR* circuit the net reactance is equal to ohmic resistance. What is the phase difference between current and voltage?

a. 0° b. 45° c. 90° d. 30°

Ans. (b) 45°

Q 81. Find the impedance of a series *LCR* circuit if the inductive reactance, capacitive reactance and resistance are 6Ω, 3Ω and 4Ω respectively. Calculate the impedance of the circuit.

a. 5Ω b. 25Ω c. 0Ω d. 13Ω

Ans. (a) 5Ω

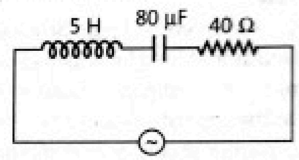
Q 82. At resonance in *LCR* circuit what happens to the impedance?

a. becomes zero b. becomes ohmic resistance

c. becomes high d. becomes infinity

Ans. (b) becomes ohmic resistance

Q 83. Figure shows a series *LCR* circuit connected to a variable frequency 230 V source.



The source frequency which drives the circuit in resonance is:

a. 4 Hz b. 5 Hz c. 6 Hz d. 8 Hz

Ans. (d) 8 Hz

Here, $L = 5$ H, $C = 80\,\mu F = 80 \times 10^{-6}$ F; $R = 40\,\Omega$

$V_{rms} = 230$ V

The resonant angular frequency is

$$\omega_r = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{5 \times 80 \times 10^{-6}}} = 50 \text{ rad s}^{-1}$$

$$\therefore \quad \nu_r = \frac{\omega_r}{2\pi} = \frac{50}{2\pi} = 8 \text{ Hz}$$

Q 84. In *LCR*-circuit if resistance increases, quality factor:

a. increases finitely b. decreases finitely

c. remains constant d. None of these

Ans. (b) decreases finitely

Here, $Q = \frac{\omega^2 L}{R}$

If *R* resistance increases, quality factor *Q* decreases finitely.

Q 85. In a series *LCR* circuit having $L = 30$ mH, $R = 8\,\Omega$ and the resonant frequency is 50 Hz. The quality factor of the circuit is:

a. 0.118 b. 11.8 c. 118 d. 1.18

Ans. (d) 1.18

Q 86. A series resonant *LCR* circuit has a quality factor (*Q*-factor) = 0.4. If $R = 2$ kΩ, $C = 0.1\,\mu$F, then the value of inductance is:

a. 0.1 H b. 0.064 H c. 2 H d. 5 H

Ans. (b) 0.064 H

Quality factor, $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$ or $\frac{L}{C} = (QR)^2$

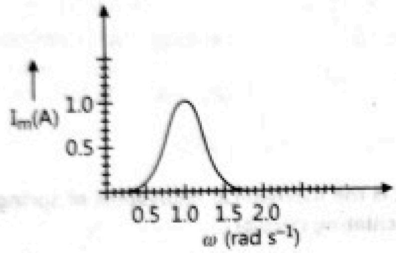
Here, $Q = 0.4, R = 2\ k\Omega = 2 \times 10^3\ \Omega$

$C = 0.1\mu F = 0.1 \times 10^{-6}$ F

$\therefore\ L = (QR)^2 C$

$\therefore\ L = (0.4 \times 2 \times 10^3)^2 \times 0.1 \times 10^{-6} = 0.064$ H

Q 87. In a series *LCR* circuit, the plot of I_m vs ω is shown in the figure. The bandwidth of this plot will be:

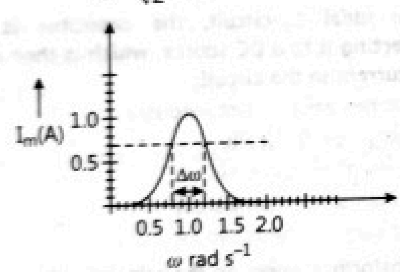


a. zero b. 0.1 rad s^{-1} c. 0.2 rad s^{-2} d. 0.4 rad s^{-1}

Ans. (d) 0.4 rad s^{-1}

Bandwidth is the frequency range at which current amplitude,

$$I_m = \frac{1}{\sqrt{2}} I_{max} = 0.7 I_{max}$$



From figure,

Bandwidth, $\Delta\omega = 1.2 - 0.8 = 0.4$ rad s^{-1}

Q 88. A series *LCR* circuit with $R = 20\ \Omega$, $L = 1.5$ H and $C = 35\ \mu$F is connected to a variable frequency 200 V AC supply. When the frequency of the supply equals the natural frequency of the circuit, the average power transferred to the circuit in one complete cycle is:

a. 200 W b. 2000 W c. 100 W d. 4000 W

Ans. (b) 2000 W

If the frequency of an AC source equals the natural frequency of the circuit, the impedance

$$Z = R = 20\ \Omega$$

The average power dissipated per cycle,

$$P_{av} = \frac{V_{rms}^2}{Z} = \frac{V_{rms}^2}{R} = \frac{(200)^2}{20} = 2000 \text{ W}$$

Q 89. The equations of instantaneous voltage and current are given as

$v = 100 \sin 314t$ and $I = 100 \sin (314t + 60°)$

What is the power factor of the circuit?

a. 5000 W b. 10000 W
c. 0 W d. 2500 W

Ans. (d) 2500 W

Q 90. A series *LCR* circuit with $R = 22\ \Omega$, $L = 1.5$ H and $C = 40\ \mu$F is connected to a variable frequency 220 V AC supply. When the frequency of the supply equals the natural frequency of the circuit, what is the average power transferred to the circuit in one complete cycle?

a. 2000 W b. 2200 W c. 2400 W d. 2500 W

Ans. (b) 2200 W

When the frequency of the supply equals to the natural frequency of circuit, resonance occurs.

$\therefore\ Z = R = 22\ \Omega$ and $I_{rms} = \frac{V_{rms}}{Z} = \frac{220}{22} = 10$ A

Average power transferred per cycle,

$$P = V_{rms} I_{rms} \cos 0° = 220 \times 10 \times 1 = 2200 \text{ W}$$

Q 91. An alternating supply of 220 V is applied across a circuit with resistance 22 Ω and impedance 44 Ω. The power dissipated in the circuit is:

a. 1100 W b. 550 W
c. 2200 W d. (2200/3) W

Ans. (b) 550 W

Here, $V = 220$ V

Resistance, $R = 22\ \Omega$

Impedance, $Z = 44\ \Omega$

Current in circuit, $I = \frac{V}{Z} = \frac{220 \text{ V}}{44\ \Omega} = 5$ A

Power dissipated in the circuit,

$$P = I^2 R = (5)^2 \times 22 = 550 \text{ W}$$

Q 92. An alternating current generator has an internal resistance R_g and an internal reactance X_g. It is used to supply power to a passive load consisting of a resistance R_g and a reactance X_L. For maximum power to be delivered from the generator to the load, the value of X_L is equal to:

(NCERT EXEMPLAR)

a. zero b. X_g c. $-X_g$ d. R_g

Ans. (c) $-X_g$

For maximum power to be delivered from the generator to the load, the total reactance must vanish.

i.e., $X_L + X_g = 0$ or $X_L = -X_g$

Q 93. For an *LCR* circuit, the power transferred from the driving source to the driven oscillator is $P = I^2 Z \cos\phi$. Then:

a. the power factor $\cos\phi \geq 0$, $P \geq 0$

b. the driving force can give no energy to the oscillator ($P = 0$) in some cases

c. the driving force cannot siphon out ($P < 0$) the energy out of oscillator

d. All of the above

Ans. (d) All of the above

Here, $P = I^2 Z \cos\phi$

(a) If power factor $\cos\phi \geq 0 \Rightarrow P \geq 0$

(b) For wattless component the driving force shall give no energy to the oscillator. So, at $\phi = 90°$, $P = 0$

(c) The driving force cannot siphon out the energy out of oscillator, *i.e.*, *P* cannot be negative.

Hence, all options are correct.

Q 94. A voltage of peak value 283 V and varying frequency is applied to series *LCR* combination in which $R = 3\ \Omega$, $L = 25$ mH and $C = 400\ \mu$F. Then the frequency (in Hz) of the source at which maximum power is dissipated in the above is:

a. 51.5 b. 50.7 c. 51.1 d. 50.3

Ans. (d) 50.3

Here, $V_0 = 283$ V, $R = 3\ \Omega$, $L = 25 \times 10^{-3}$ H
$C = 400\ \mu F = 4 \times 10^{-4}$ F

Maximum power is dissipated at resonance, for which

$$v = \frac{1}{2\pi\sqrt{LC}} = \frac{1 \times 7}{2 \times 22\sqrt{25 \times 10^{-3} \times 4 \times 10^{-4}}}$$

$$= \frac{7 \times 10^3}{44\sqrt{10}} = 50.3 \text{ Hz}$$

Q 95. The natural frequency (ω_0) of oscillations in LC circuit is given by:

a. $\frac{1}{2\pi}\frac{1}{\sqrt{LC}}$ b. $\frac{1}{\pi}\frac{1}{\sqrt{2LC}}$ c. $\frac{1}{\sqrt{LC}}$ d. $\sqrt{LC}$

Ans. (c) $\frac{1}{\sqrt{LC}}$

Q 96. What is the analogy of force constant in electrical system?

a. capacitance b. reciprocal of capacitance
c. inductance d. reciprocal of inductance

Ans. (b) reciprocal of capacitance

Q 97. A charged 30 μF capacitor is connected to a 27 mH inductor. The angular frequency of free oscillations of the circuit is:

a. 1.1×10^3 rad s^{-1} b. 2.1×10^3 rad s^{-1}
c. 3.1×10^3 rad s^{-1} d. 4.1×10^3 rad s^{-1}

Ans. (a) 1.1×10^3 rad s^{-1}

Here, $C = 30\ \mu F = 30 \times 10^{-6}$ F
$L = 27$ mH $= 27 \times 10^{-3}$ H

$$\therefore \quad \omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{27 \times 10^{-3} \times 30 \times 10^{-6}}} = \frac{1}{\sqrt{81 \times 10^{-8}}}$$

$$= \frac{10^4}{9} = 1.1 \times 10^3 \text{ rad s}^{-1}$$

Q 98. An LC circuit contains a 20 mH inductor and a 50 μF capacitor with an initial charge of 10 mC. The resistance of the circuit is negligible. Let the instant at which the circuit which is closed be $t = 0$. At what time the energy stored is completely magnetic?

a. $t = 0$ b. $t = 1.57$ ms
c. $t = 3.14$ ms d. $t = 6.28$ ms

Ans. (b) $t = 1.57$ ms

At time $t = \frac{T}{4}$, energy stored is completely magnetic.

$$\text{Time, } t = \frac{T}{4} = \frac{2\pi\sqrt{LC}}{4}$$

$$\Rightarrow \quad t = \frac{\pi\sqrt{20 \times 10^{-3} \times 50 \times 10^{-6}}}{2}$$

$$t = \frac{\pi\sqrt{1000 \times 10^{-9}}}{2} = \frac{\pi\sqrt{1 \times 10^{-6}}}{2} = 1.57 \text{ ms}$$

Q 99. An LC circuit contains a 20 mH inductor and a 25 μF capacitor with an initial charge of 5 mC. The total energy stored in the circuit initially is:

a. 5 J b. 0.5 J c. 50 J d. 500 J

Ans. (b) 0.5 J

Here, $C = 25\ \mu F = 25 \times 10^{-6}$ F,
$L = 20$ mH $= 20 \times 10^{-3}$ H, $q_0 = 5$ mC $= 5 \times 10^{-3}$ C

Total energy stored in the circuit initially is

$$U = \frac{q_0^2}{2C} = \frac{(5 \times 10^{-3})^2}{2 \times 25 \times 10^{-6}}$$

$$= \frac{25 \times 10^{-6}}{2 \times 25 \times 10^{-6}} = \frac{1}{2} = 0.5 \text{ J}$$

Q 100. An LC-circuit contains 10 mH inductor and 25 mF capacitor with given initial charge. The resistance of the circuit is negligible. The energy stored in circuit is completely magnetic at time (in millisecond) the time is measured from the instant when the circuit is closed:

a. $0, \frac{\pi}{2}, \frac{2\pi}{2}, \ldots$ etc b. $\frac{\pi}{3}, \frac{2\pi}{3}, \frac{5\pi}{3}, \ldots$ etc.
c. $\frac{\pi}{4}, \frac{3\pi}{4}, \frac{5\pi}{5}, \ldots$ etc d. $0, \frac{\pi}{8}, \frac{\pi}{4}, \ldots$ etc.

Ans. (c) $\frac{\pi}{4}, \frac{3\pi}{4}, \frac{5\pi}{5}, \ldots$ etc.

[at $t = 0, \frac{T}{2}, T, \frac{3T}{2} \ldots$ energy is electrostatic and at $t = \frac{T}{4}, \frac{3T}{4}, \frac{5T}{4} \ldots$ energy is totally magnetic. Here $T = \frac{1}{v} = 2\pi\sqrt{LC} = \pi/1000$]

Q 101. What is the mechanical equivalent of spring constant k in LC oscillating circuit?

a. $\frac{1}{L}$ b. $\frac{1}{C}$ c. $\frac{L}{C}$ d. $\frac{1}{LC}$

Ans. (b) $\frac{1}{C}$

The mechanical equivalent of spring constant in LC oscillating circuit is, $k = \frac{1}{C}$.

Q 102. In an ideal LC-circuit, the capacitor is charged by connecting it to a DC source, which is then disconnected. The current in the circuit:

a. becomes zero instantaneously
b. grows monotonically
c. decays monotonically
d. oscillates instantaneously

Ans. (d) oscillates instantaneously

Q 103. A transformer works on the principle of:

a. self induction
b. electrical inertia
c. mutual induction
d. magnetic effect of the electrical current

Ans. (c) mutual induction

A transformer is based on the principle of mutual induction.

Q 104. Transformer is used to:

a. convert AC to DC voltage
b. convert DC to AC voltage
c. obtain desired DC power
d. obtain desired AC voltage and current

Ans. (d) obtain desired AC voltage and current

Transformer is used to obtain desired AC voltage and current.

Q 105. For an ideal step-down transformer, the quantity which is constant for both the coils is:

a. current in the coils b. voltage across the coils
c. resistance of coils d. power in the coils

Ans. (d) power in the coils

For an ideal step-down transformer, power is constant for both the coils.

i.e., Input power = Output power

$$\therefore \quad V_P I_P = V_S I_S \text{ or } \frac{V_P}{V_S} = \frac{I_S}{I_P}$$

Q 106. High voltage transmission line is preferred, as:

a. its appliances are less costly

b. thin power cables are required

c. idle current very low

d. power loss is very less

Ans. (d) power loss is very less

Weak current flows through the transmission line hence low power loss I^2R

Q 107. In a transformer, the no. of turns of primary and secondary coils are 500 and 400 respectively. If 220 V is supplied to the primary coil, then ratio of currents in primary and secondary coils is:

a. 4 : 5 b. 5 : 4 c. 5 : 9 d. 9 : 5

Ans. (a) 4 : 5

$$\frac{I_P}{I_S} = \frac{V_S}{V_P} = \frac{N_S}{N_P} = 4:5$$

Q 108. Quantity that remains unchanged in a transformer is:

a. voltage b. current

c. frequency d. None of these

Ans. (c) frequency

A transformer does not change the frequency of AC.

Q 109. The core of a transformer is laminated to reduce:

a. flux leakage b. hysteresis

c. copper loss d. eddy current

Ans. (d) eddy current

The core of a transformer is laminated to reduce eddy current.

Q 110. The loss of energy in the form of heat in the iron core of a transformer is:

a. iron loss b. copper loss

c. mechanical loss d. None of these

Ans. (a) iron loss

Iron loss is the energy loss in the form of heat due to the formation of eddy currents in the iron core of the transformer.

Q 111. The output of a step down transformer is measured to be 24 V when connected to a 12W light bulb. The value of the peak current is: *(NCERT EXEMPLAR)*

a. $\frac{1}{\sqrt{2}}$ A b. $\sqrt{2}$ A c. 2 A d. $2\sqrt{2}$ A

Ans. (a) $\frac{1}{\sqrt{2}}$ A

Here, $V_s = 24$ V, $P_s = 12$ W

$$I_s = \frac{P_s}{V_s} = \frac{12}{24} = 0.5 \text{ A}$$

$$I_m = \sqrt{2}\, I_s = \sqrt{2} \times 0.5 = \frac{1}{\sqrt{2}} \text{ A}$$

Q 112. In a transformer the transformation ratio is 0.3. If 220 V AC is fed to the primary, then the voltage across the secondary is:

a. 44 V b. 55 V c. 60 V d. 66 V

Ans. (d) 66 V

Here, Transformation ratio, $k = 0.3$

As, $k = \frac{N_S}{N_P} = \frac{V_S}{V_P}$

$\therefore$ $V_S = kV_P = 0.3 \times 220 = 66$ V

Q 113. The ratio of number of turns of primary coil to secondary coil in a transformer is 2 : 3. If a cell of 6 V is connected across the primary coil, then voltage across the secondary coil will be:

a. 3 V b. 6 V c. 9 V d. 12 V

Ans. (c) 9 V

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$

$$\frac{V_S}{6} = \frac{3}{2} \Rightarrow V_S = \frac{6 \times 3}{2} = 9 \text{ V}$$

Q 114. A transformer is used to light 140 W, 24 V lamp from a 240V AC mains. If the main current is 0.7 A, the efficiency of the transformer is:

a. 63.8% b. 74% c. 83.3% d. 48%

Ans. (c) 83.3%

Output power = 140 W

Input power = $240 \times 0.7 = 168$ W

$$\text{Efficiency} = \frac{\text{output power}}{\text{input power}} \times 100 = \frac{140}{168} \times 100 = 83.3\%$$

Q 115. In a step up transformer the turn ratio is 1 : 2. A Leclanche cell (emf = 1.5 V) is connected across the primary. The voltage across the secondary is:

a. 3 V b. 1.5 V c. 0.75 V d. zero

Ans. (a) 3 V

$$\frac{V_S}{V_P} = \frac{N_S}{N_P} = \frac{V_S}{1.5} = \frac{2}{1} = V_S = 3 \text{ V}$$

Q 116. A transformer has primary and secondary winding as 2000 and 200 respectively. It is connected to a Lechlanche cell of 1.5V. What is the output voltage of the transformer?

a. 0.15 V b. 1.5 V c. 0.1 V d. 0 V

Ans. (d) 0 V

Q 117. A transformer has 100 turns in the primary coil and carries 8 A current. If input power is 1 kW, the number of turns in secondary coil to have 500 V output will be:

a. 100 b. 200 c. 400 d. 300

Ans. (c) 400

Q 118. A 60 W load is connected to the secondary of an ideal transformer whose primary draws line voltage. If a current of 0.54 A flows in the load, the current in the primary coil is:

a. 0.27 mA b. 2.7 A c. 0.27 A d. 10 A

Ans. (c) 0.27 A

Here, $P_S = 60$ W, $I_S = 0.54$ A, $V_P = 220$ V

$$V_S = \frac{P_S}{I_S} = \frac{60}{0.54} = 111 \text{ V}$$

As $\frac{V_S}{V_P} = \frac{I_P}{I_S}$, for an ideal transformer

$\therefore$ $$I_P = \frac{V_S}{V_P} \times I_S = \frac{111}{220} \times 0.54 = 0.27 \text{ A}$$

Q 119. The turns ratio of a transformer is given as 2 : 3. If the current through the primary coil is 3 A, thus calculate the current through the resistance.

a. 1 A b. 4.5 A c. 2 A d. 1.5 A

Ans. (c) 2 A

Q 120. When power is drawn from the secondary coil of the transformer, the dynamic resistance:

a. increases b. decreases
c. remains unchanged d. changes erratically

Ans. (a) increases

Q 121. A step down transformer converts transmission line voltage from 11000V to 220V. The primary of the transformer has 6000 turns and efficiency of the transformer is 60%. If the output power is 9 kW, then the input power will be:

a. 11 kW b. 12 kW c. 14 kW d. 15 kW

Ans. (d) 15 kW

Here, $V_P = 11000\text{ V}, V_S = 220\text{ V}$

$N_P = 6000, \eta = 60\%; P_o = 9\text{ kW} = 9 \times 10^3\text{ W}$

$$\text{Efficiency, } \eta = \frac{\text{Output power}}{\text{Input power}} = \frac{P_o}{P_i}$$

$$\therefore \quad P_i = \frac{P_o}{\eta} = \frac{9 \times 10^3}{60/100} = 1.5 \times 10^4 = 15\text{ kW}$$

Q 122. In the question number 121, the number of turns in the secondary is:

a. 20 b. 80 c. 120 d. 160

Ans. (c) 120

As, $$\frac{V_S}{V_P} = \frac{N_S}{N_P} \Rightarrow N_S = \frac{V_S}{V_P} \times N_P = \frac{220}{11000} \times 6000 = 120$$

Q 123. A power transmission line feeds input power at 2400 V to a step down transformer with its primary windings having 4000 turns. What should be the number of turns in the secondary windings in order to get output power at 240 V?

a. 400 b. 420 c. 424 d. 436

Ans. (a) 400

Q 124. The current drawn by the primary of a transformer, which step down 200 V to 20 V to operate a device of resistance 20 Ω is (Assume the efficiency of the transformer to be 80%):

a. 0.125 A b. 0.225 A c. 0.325 A d. 0.425 A

Ans. (a) 0.125 A

Given: $V_P = 200\text{ V}, R = 20\,\Omega, V_S = 20\text{ V}, \eta = 80\%$

Current through the secondary coil is

$$I_S = \frac{V_S}{R} = \frac{20\text{ V}}{20\,\Omega} = 1\text{ A}$$

$$\text{Efficiency of transformer, } \eta = \frac{\text{Output power}}{\text{Input power}} = \frac{V_S I_S}{V_P I_P}$$

or $$I_P = \frac{V_S I_S}{V_P \eta} = \frac{20 \times 1 \times 100}{200 \times 80} = 0.125\text{ A}$$

Q 125. The primary and secondary coils of a transformer have 50 and 1500 turns respectively. The magnetic flux linked with the primary coil is given by $\phi = \phi_0 + 4t$, where ϕ_0 is a constant. The output voltage across the secondary coil is:

a. 30 V b. 90 V c. 120 V d. 220 V

Ans. (c) 120 V

Assertion and Reason Type Questions

Directions (Q.Nos. 126 to 159): In the following questions, a statement of Assertion (A) is followed by a statement of Reason (R). Mark the correct choice as:

a. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A)
b. Both Assertion (A) and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A)
c. Assertion (A) is true but Reason (R) is false
d. Assertion (A) is false and Reason (R) is also false

Q 126. Assertion (A): An alternating current does not show any magnetic effect.
Reason (R): Alternating current does not vary with time.

Ans. (c)

Like direct current, an alternating current also produces magnetic field. But the magnitude and direction of the field goes on changing continuously with time.

Q 127. Assertion (A): Average value of AC over a complete cycle is always zero.
Reason (R): Average value of AC is always defined over half cycle.

Ans. (b)

The mean or average value of alternating current or e.m.f during a half cycle is given by

$$I_m = 0.636 I_0 \text{ or } E_m = 0.636 E_0$$

During the next half cycle, the mean value of AC will be equal in magnitude but opposite in direction. For this reason the average value of AC over a complete cycle is always zero. So the average value is always defined over a half cycle of AC.

Q 128. Assertion (A): The DC and AC both can be measured by a hot wire instrument.
Reason (R): The hot wire instrument is based on the principle of magnetic effect of current.

Ans. (c)

Both AC and DC produce heat, which is proportional to square of the current. The reversal of direction of current in AC is immaterial as far as production of heat is concerned.

Q 129. Assertion (A): AC is more dangerous than DC.
Reason (R): Frequency of AC is dangerous for human body.

Ans. (a)

The effect of AC on the body depends largely on the frequency. Low frequency currents of 50 to 60 Hz (cycles/sec), which are commonly used, are usually more dangerous than high frequency currents and are 3 to 5 times more dangerous than DC of same voltage of amperage (current). The usual frequency of 50 cps (or 60 cps) is extremely dangerous as it corresponds to the fibrillation frequency of the myocardium. This results in ventricular fibrillation and instant death.

Common ⚠ Error

Often students think DC is more dangerous.

Q 130. Assertion (A): Long distance transmission of AC is carried out at extremely high voltage.
Reason (R): For large distance, voltage has to be large.

Ans. (c) The transmission is done at high voltage due to which current through the wire is reduced. By reduction in current corresponding dissipation of energy is also reduced (as $H \propto I^2R$). If transmission is done at low voltage, then we have to use thick wire in order to reduce the dissipation of energy. This increase the cost of transmission lines wires. In order to reduce both energy dissipation and cost of transmission wire, transmission is done at high voltage by using step up transformers.

Q 131. Assertion (A): The capacitive reactance limits the amplitude of the current in a purely capacitive circuit.

Reason (R): Capacitive reactance is proportional to the frequency and the capacitance.

Ans. (c) The capacitive reactance limits the amplitude of the current in a purely capacitive circuit in the same way as the resistance limits the current in a purely resistive circuit.

i.e., $I_0 = \frac{\varepsilon_0}{X_C}$

But it is inversely proportional to the frequency and the capacitance.

Q 132. Assertion (A): Capacitor serves as a block for DC and offers an easy path to AC.

Reason (R): Capacitive reactance is inversely proportional to frequency.

Ans. The capacitive reactance of capacitor is given by

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}$$

So this is infinite for DC ($f = 0$) and has a finite value for AC Therefore a capacitor blocks DC and offers an easy path for AC.

Q 133. Assertion (A): When capacitive reactance is smaller than the inductive reactance in *LCR* series circuit, e.m.f. leads the current.

Reason (R): The phase angle is the angle between the alternating e.m.f. and alternating current of the circuit.

Ans. (b) The phase angle for the *LCR* series circuit is given by

$$\tan\theta = \frac{X_L - X_C}{R} = \frac{\omega L - 1/\omega C}{R}$$

where X_L, X_C are inductive reactance and capacitive reactance respectively. When $X_L > X_C$ then $\tan\theta$ is positive *i.e.*, θ is positive (between 0 and $\pi/2$). Hence emf leads the current.

Q 134. Assertion (A): The inductive reactance limits amplitude of the current in a purely inductive circuit.

Reason (R): The inductive reactance is independent of the frequency of the current.

Ans. (c) The inductive reactance limits the amplitude of current in a purely inductive circuit in the same way as the resistance limits the current in a purely resistive circuit.

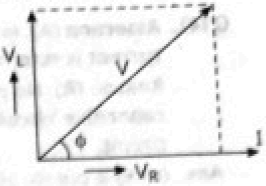
i.e., $I_0 = \frac{\varepsilon_0}{X_L}$

The inductive reactance is directly proportional to the inductance and the frequency of the circuit.

Q 135. Assertion (A): An inductance and a resistance are connected in series with an AC circuit. In this circuit the current and the potential difference across the resistance lags behind potential difference across the inductance by an angle $\pi/2$.

Reason (R): In *L-R* circuit voltage leads the current by phase angle which depends on the value of inductance and resistance both.

Ans. (b) As both the inductance and resistance are joined in series, hence current through both will be same. But in case of resistance, both the current and potential vary simultaneously, hence they are in same phase. While in case of an inductance when current is zero, potential difference across it is maximum and when current reaches maximum (at $\omega t = \pi/2$), potential difference across it becomes zero *i.e.*, potential difference leads the current by $\pi/2$ or current lags behind the potential difference by $\pi/2$. Phase angle in case of *LR* circuit is given as $\phi = \tan^{-1}\left(\frac{\omega L}{R}\right)$



Q 136. Assertion (A): Capacitor serves as a block for DC and offers an easy path to AC.

Reason (R): Capacitive reactance is inversely proportional to frequency.

Ans. (a) The capacitive reactance of capacitor is given by:

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}$$

So, this is infinite for DC ($f = 0$) and has a very small value for AC. Therefore a capacitor blocks DC.

Q 137. Assertion (A): If the frequency of alternating current in an AC circuit consisting of an inductance coil is increased, then current gets decreased.

Reason (R): The current is inversely proportional to frequency of alternating current.

Ans. (a) When frequency of alternating current is increased, the effective resistance of the inductive coil increases. Current ($X_L = \omega L = 2\pi fL$) in the circuit containing inductor is given by $I = \frac{V}{X_L} = \frac{V}{2\pi fL}$. As, inductive resistance of the inductor increases, current in the circuit decreases.

Q 138. Assertion (A): When capacitive reactance is smaller than the inductive reactance in *LCR* current, e.m.f. leads the current.

Reason (R): The phase angle is the angle between the alternating e.m.f. and alternating current of the circuit.

Ans. (b) The phase angle for the *LCR* circuit is given by

$$\tan\phi = \frac{X_L - X_C}{R} = \frac{\omega L - 1/\omega C}{R}$$

where X_L, X_C are inductive reactance and capacitive reactance respectively when $X_L > X_C$, then $\tan\phi$ is positive *i.e.*, ϕ is positive (between 0 and $\pi/2$). Hence e.m.f. leads the current.

Q 139. Assertion (A): A capacitor of suitable capacitance can be used in an AC circuit in place of the choke coil.

Reason (R): A capacitor blocks DC and allows AC only.

Ans. (b) We can use a capacitor of suitable capacitance as a choke coil, because average power consumed per cycle in an ideal capacitor is zero. Therefore, like a choke coil, a condenser can reduce AC without power dissipation.

Q 140. Assertion (A): In series *LCR* resonance circuit, the impedance is equal to the ohmic resistance.

Reason (R): At resonance, the inductive reactance exceeds the capacitive reactance.

Ans. (c) In series resonance circuit, inductive reactance is equal to capacitive reactance.

i.e., $\omega L = \frac{1}{\omega C}$

$$\therefore \quad Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2} = R$$

Q 141. Assertion (A): In a purely inductive or capacitive circuit, the current is referred to as wattless current.
Reason (R): No power is dissipated in a purely inductive or capacitive circuit even though a current is flowing in the circuit.

Ans. (a) In a purely inductive or capacitive circuit, power factor, $\cos\phi = 0$ and no power is dissipated even though a current is flowing in the circuit. In such cases, current is referred to as wattless current.

Q 142. Assertion (A): The only element that dissipates energy in an AC circuit is the resistive element.
Reason (R): There are no power losses associated with pure capacitances and pure inductances in an AC circuit.

Ans. (a)

Q 143. Assertion (A): The power in an AC circuit is minimum, if the circuit has only a resistor.
Reason (R): Power of a circuit is independent of the phase angle.

Ans. (d) Power in a series AC circuit consisting of L, C and R is given by

$$P = I_{rms}V_{rms}\cos\phi \text{ where } \phi = \tan^{-1}\left(\frac{|X_L - X_C|}{R}\right)$$

For a purely resistive circuit, $X_L = 0$ and $X_C = 0$
Therefore, $\tan\phi = 0$ or $\phi = 0$ and thereby $\cos\phi = 1$
and $P = IV$.
The power is maximum as $\cos\phi$ is maximum. Power depends on the phase angle through the power factor $\cos\phi$.

Q 144. Assertion (A): Resonance is exhibited by a circuit only, if both L and C are present in the circuit.
Reason (R): Only then the voltage across L and C cancel each other, both being out of phase.

Ans. (a) The resonance phenomenon is exhibited by a circuit only if both L and C are present in the circuit. Only then the voltages across L and C cancel each other, since both being out of phase and current amplitudes is $V_m/_R$, the total source voltage appearing across R. This means that we cannot have resonance in a RL or RC circuit.

Q 145. Assertion (A): An electric heater is heated first by direct and then by alternating currents. For both the currents, the potential difference across the ends of the heater is the same. The rate of production of heat will be different in two cases.
Reason (R): The resistance of a coil in alternating current will be more than the resistance of a coil in direct current, hence heat produced in case of direct current will be low.

Ans. (a) The element of the heater is in the form of a coil so that it has inductance L also besides the resistance R. So, for the alternating current, the effective resistance of the heater would be $\sqrt{R^2 + (\omega L)^2}$ which is larger than the resistance R for the direct current. Hence on heating by alternating current, heat produced per second would be less.
($H = V^2/R$ and V is same in both the cases).

Q 146. Assertion (A): In series LCR circuit resonance can take place.
Reason (R): Resonance takes place if inductance and capacitive reactances are equal and opposite.

Ans. (a) At resonant frequency, $X_L = X_C$.
$\therefore Z = R$ (minimum) therefore current in the circuit is maximum.

Q 147. Assertion (A): The AC lags behind the e.m.f. by a phase angle of $\pi/2$, when AC flows through an inductor.
Reason (R): The inductive reactance increases as the frequency of AC source decreases.

Ans. (c) When AC flows through an inductor current lags behind the e.m.f. by phase of $\pi/2$. inductive reactance $X_L = \omega L = 2\pi\nu h$, so when frequency increases correspondingly inductive reactance also increases.

Q 148. Assertion (A): An electric lamp connected in series with a variable capacitor and AC source, its brightness increases with increase in capacitance.
Reason (R): Capacitive reactance decreases with increase in capacitance of capacitor.

Ans. (a) Capacitive reactance $X_C = \frac{1}{\omega C}$ when capacitance (C) increases, the capacitive reactance decreases due to decrease in its values, the current in the circuit will increase $\left(I = \frac{E}{\sqrt{R^2 + X_C^2}}\right)$ and hence brightness of source (electric lamp) will also increase.

Q 149. Assertion (A): At resonance, LCR series circuit have a maximum current.
Reason (R): At resonance, in LCR series circuit, the current and e.m.f. are in phase with each other.

Ans. (b) At resonance, $X_L = X_C$ or $\omega L = \frac{1}{\omega C}$. Because of this impedance of LCR series circuit become equal to resistance of circuit $(Z = \sqrt{R^2 + (X_L - X_C)^2})$. Therefore from $I = \frac{E}{Z} = \frac{E}{R}$ at resonance, current in LCR series circuit is maximum. Correspondingly phase angle is also equal to zero. Therefore emf and current are in phase in LCR series circuit.

Q 150. Assertion (A): When a current flows in the coil of a transformer then its core becomes hot.
Reason (R): The core of transformer is made of softiron.

Ans. (b) When alternating current flows through the coil of a transformer, the core of transformer, is magnetised and demagnetised repeatedly. The electrical energy taken by the core during magnetisation is not returned fully in demagnetisation. The energy remaining in the core appears in the form of heat.

Q 151. Assertion (A): An ideal transformer does not vary the power.
Reason (R): A transformer is used to step-up or step-down AC voltages.

Ans. (b) By using a transformer, voltage can be increased or decreased. An ideal transformer is one in which there is no energy loss. If there is no loss of energy, then the entire input power is transferred from the primary to the secondary *i.e.* output.

Q 152. Assertion (A): A step-up transformer changes a low voltage into a high voltage.
Reason (R): This violate the law of conservation of energy.

Ans. (c) A step up transformer changes a low voltage into a high voltage. This does not violate the law of conservation of energy, because the current is reduced by the same proportion.

Q 153. Assertion (A): A given transformer can be used to step-up or step-down the voltage.

Reason (R): The output voltage depends upon the ratio of the number of turns of the two coils of the transformer.

Ans. (a)

Q 154. Assertion (A): A laminated core is used in transformers to increase eddy currents.

Reason (R): The efficiency of a transformer increases with increase in eddy currents.

Ans. (d) Large eddy currents are produced in non-laminated iron core of the transformer by the induced emf, as the resistance of bulk iron core is very small. By using thin iron sheets as core the resistance is increased. Laminating the core substantially reduces the eddy currents. Eddy current heats up the core of the transformer. More the eddy currents greater is the loss of energy and the efficiency goes down.

Q 155. Assertion (A): A transformer cannot work on DC supply.

Reason (R): DC changes neither in magnitude nor in direction.

Ans. (a)

Q 156. Assertion (A): Step-down transformer increases the current.

Reason (R): Transformer obeys the law of conservation of energy.

Ans. (b) If there is no loss of energy in transformer, then instantaneous output power is equal to instantaneous input power. From this we get $\frac{e_S}{e_P} = \frac{i_P}{i_S}$. So in step up transformer voltage increases by decreasing the current. Similarly, step-down transformer decreases the voltage by increasing current. Therefore transformer simply transforms the voltage and current, obeying the law of conservation of energy.

Q 157. Assertion (A): Soft iron is used as a core of transformer.

Reason (R): Area of hysteresis loop for soft iron is small.

Ans. (a) The alternating current flowing through the coils, magnetises and demagnetises the iron core again and again over complete cycles. During each cycle of magnetisation, some energy is lost due to hysteresis, the energy lost during a cycle of magnetisation being equal to area of hysteresis loop (in magnitude). Energy loss can be reduce by selecting the material core, which has narrow hysteresis loop, that is why soft iron core is used.

Q 158. Assertion (A): The core of transformer is made laminated in order to increase the eddy currents.

Reason (R): The sensitivity of transformer increases with increase in the eddy currents.

Ans. (d) Eddy current is produced in the iron core due to induced e.m.f. Since, resistance of the iron core is quite small, the magnitude of eddy currents is quite large. As a result, large amount of heat is produced. To avoid it, a laminated core is used in a transformer. In laminated core iron strips are quite thin and each strip possesses very large resistance, the magnitude of eddy currents very large resistance, the magnitude of eddy currents produced is quite small and hence only a small amount of heat is produced.

Q 159. Assertion (A): We use a thick wire in the secondary coil of a step down transformer to reduce the production of heat.

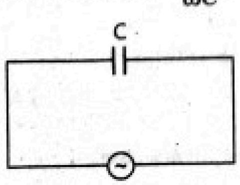
Reason (R): When the plane of the armature is parallel to the line of force of magnetic field, the magnitude of induced e.m.f. is maximum.

Ans. (b) A step-down transformer converts electrical energy from a high voltage to low voltage. Accordingly the current in the secondary will be larger than that in the primary. In order to produce less heat in the secondary, we use a wire of lesser resistance *i.e.*, thick wire. We also know that when the plane of the armature is parallel to the lines of force of magnetic field, the rate of change of magnetic flux linked with it is maximum. Therefore the e.m.f. induced in the armature in this orientation is maximum.

Case Study Based QUESTIONS

Case Study 1

Let a source of alternating e.m.f. $E = E_0 \sin \omega t$ be connected to a capacitor of capacitance C. If 'I' is the instantaneous value of current in the circuit as instant t, then $I = \frac{E_0}{1/\omega C} \sin\left(\omega t + \frac{\pi}{2}\right)$. The capacitive reactance limits the amplitude of current in a purely capacitive circuit and it is given by $X_C = \frac{1}{\omega C}$.



Read the above passage carefully and give the answer of the following questions:

Q 1. What is the unit of capacitive reactance?

a. farad b. ampere c. ohm d. ohm^{-1}

Ans. (c) ohm

Ohm is the unit of capacitive reactance.

Q 2. The capacitive reactance of a 5 μF capacitor for a frequency of 10^6 Hz is:

a. 0.032 Ω b. 2.52 Ω c. 1.25 Ω d. 4.51 Ω

Ans. (a) 0.032 Ω

Capacitive reactance, $X_C = \frac{1}{\omega C} = \frac{1}{2\pi\nu C}$

$$= \frac{1}{2\pi \times 10^6 \times 5 \times 10^{-6}} = 0.032\ \Omega$$

Q 3. In a capacitive circuit, resistance to the flow of current is offered by:

a. resistor b. capacitor c. inductor d. frequency

Ans. (b) capacitor

In capacitive circuit, resistance to the flow of current is offered by the capacitor.

Q 4. In a capacitive circuit, by what value of phase angle does alternating current leads the e.m.f.?

a. 45°　b. 90°　c. 75°　d. 60°

Ans. (b) 90°

Q 5. One microfarad capacitor is joined to a 200V, 50Hz alternator. The rms current through capacitor is:

a. 6.28×10^{-2} A　b. 7.5×10^{-4} A

c. 10.52×10^{-2} A　d. 15.25×10^{-2} A

Ans. (a) 6.28×10^{-2} A

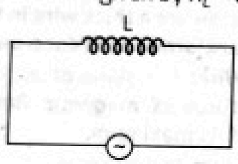
Current, $I_v = \frac{E_v}{X_C} = \frac{E_v}{1/2\pi\nu C} = (2\pi\nu C)E_v$

$$I_v = 2 \times 3.14 \times 50 \times 10^{-6} \times 200 = 6.28 \times 10^{-2} \text{ A}$$

Case Study 2

Let a source of alternating e.m.f. $E = E_0 \sin \omega t$ be connected to a circuit containing a pure inductance L. If I is the value of instantaneous current in the circuit, then $I = I_0 \sin\left(\omega t - \frac{\pi}{2}\right)$.

The inductive reactance limits the current in a purely inductive circuit and is given by $X_L = \omega L$.



Read the above passage carefully and give the answer of the following questions:

Q 1. A 100 hertz AC is flowing in 14 mH coil. The reactance is:

a. 15 Ω　b. 7.5 Ω　c. 8.8 Ω　d. 10 Ω

Ans. (c) 8.8 Ω

Inductive reactance,

$$X_L = \omega L = 2\pi\nu L = 2\pi \times 100 \times 14 \times 10^{-3}$$
$$X_L = 8.8\ \Omega$$

Q 2. In a pure inductive circuit, resistance to the flow of current is offered by:

a. resistor　b. inductor

c. capacitor　d. resistor and inductor

Ans. (b) inductor

Q 3. In a inductive circuit, by what value of phase angle does alternating current lags behind e.m.f.?

a. 45°　b. 90°　c. 120°　d. 75°

Ans. (b) 90°

In an inductor voltage leads the current by $\frac{\pi}{2}$ or current lags the voltage by $\frac{\pi}{2}$.

Q 4. How much inductance should be connected to 200 V, 50 Hz AC supply so that a maximum current of 0.9 A flows through it?

a. 5 H　b. 1 H　c. 10 H　d. 4.5 H

Ans. (b) 1 H

The current in the inductor coil is given by

$$I_0 = \frac{E_0}{X_L} = \frac{\sqrt{2}\,E_v}{2\pi\nu L}$$

$$L = \frac{\sqrt{2}\,E_v}{2\pi\nu I_0} = \frac{1.414 \times 200}{2 \times 3.14 \times 50 \times 0.9} = 1\text{H}$$

Q 5. The maximum value of current when inductance of 2 H is connected to 150V, 50 Hz supply is:

a. 0.337 A　b. 0.721 A　c. 1.521 A　d. 2.522 A

Ans. (a) 0.337 A

Inductive reactance,

$$X_L = \omega L = 2\pi\nu L$$
$$= 2 \times 3.14 \times 50 \times 2 = 628\ \Omega$$
$$I_0 = \frac{E_0}{X_L} \Rightarrow I_0 = \frac{\sqrt{2} \times E_v}{X_L} = \frac{\sqrt{2} \times 150}{628} = 0.337 \text{ A}$$

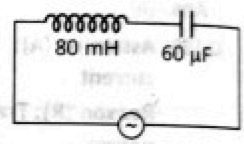
Case Study 3

The power averaged over one full cycle of AC is known as average power. It is also known as true power.

$$P_{av} = V_{rms} I_{rms} \cos\phi = \frac{V_0 I_0}{2} \cos\phi.$$

Root mean square or simply rms watts refer to continuous power.

A circuit containing a 80 mH inductor and a 60 µF capacitors in series is connected to a 230 V, 50 Hz supply. The resistance of the circuit is negligible.



Read the above passage carefully and give the answer of the following questions:

Q 1. The value of current amplitude is:

a. 15 A　b. 11.63 A　c. 17.65 A　d. 6.33 A

Ans. (b) 11.63 A

Inductance, $L = 80 \text{ mH} = 80 \times 10^{-3}$ H

Capacitance, $C = 60\,\mu\text{F} = 60 \times 10^{-6}$ F, $V = 230$ V

Frequency, $\nu = 50$ Hz

$$\omega = 2\pi\nu = 100\pi \text{ rad s}^{-1}$$

Peak voltage, $V_0 = V\sqrt{2} = 230\sqrt{2}$ V

Maximum current is given by, $I_0 = \frac{V_0}{\left(\omega L - \frac{1}{\omega C}\right)}$

$$I_0 = \frac{230\sqrt{2}}{\left(100\pi \times 80 \times 10^{-3} - \frac{1}{100\pi \times 60 \times 10^{-6}}\right)}$$

$$I_0 = \frac{230\sqrt{2}}{\left(8\pi - \frac{1000}{6\pi}\right)} = -11.63 \text{ A}$$

Amplitude of maximum current, $I_0 = 11.63$ A

Q 2. Find rms value.

a. 6 A　b. 5.25 A　c. 8.23 A　d. 7.52 A

Ans. (c) 8.23 A

rms value of current,

$$I = \frac{I_0}{\sqrt{2}} = \frac{-11.63}{\sqrt{2}} = -8.23 \text{ A}$$

Negative sign appears as $\omega L < \frac{1}{\omega C}$.

Q 3. The average power transferred to inductor is:

a. zero
b. 7 W
c. 2.5 W
d. 5 W

Ans. (a) zero

Average power consumed by the inductor is zero because of phase difference of $\frac{\pi}{2}$ between voltage and current through inductor.

Q 4. The average power transferred to the capacitor is:

a. 5 W
b. zero
c. 11 W
d. 15 W

Ans. (b) zero

Average power consumed by the capacitor is zero because of phase difference of $\frac{\pi}{2}$ between voltage and current through capacitor.

Q 5. What is the total average power absorbed by the circuit?

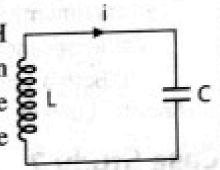
a. zero b. 10 W c. 2.5 W d. 15 W

Ans. (a) zero

Case Study 4

An *LC* circuit also called a resonant circuit, tank circuit or tuned circuit is an electric circuit consisting of an inductor represented by the letter *L* and a capacitor, represented by the letter *C* connected together. An *LC* circuit is an idealised model since it assumes there is no dissipation of energy due to resistance.

An *LC* circuit contains a 20 mH inductor and a 50 μF capacitor with an initial charge of 10 mC. The resistance of the circuit is negligible. Let the instant the circuit is closed be $t = 0$.



Based on the above information, answer the following questions.

Q 1. The total energy stored initially is:

a. 5 J b. 3 J c. 10 J d. 1 J

Ans. (d) 1 J

$$\text{Energy, } E = \frac{1}{2}\frac{Q^2}{C} = \frac{(10\times10^{-3})^2}{2\times50\times10^{-6}} = 1\text{ J}$$

Q 2. The natural frequency of the circuit is:

a. 159.24 Hz
b. 200.12 Hz
c. 110.25 Hz
d. 95 Hz

Ans. (a) 159.24 Hz

$$\text{Frequency, } \nu = \frac{1}{2\pi\sqrt{LC}}$$
$$= \frac{1}{2\pi\sqrt{20\times10^{-3}\times50\times10^{-6}}}$$
$$= \frac{10^3}{2\pi} = 159.24\text{ Hz}$$

Q 3. At what time is the energy stored completely electrical?

a. $T, 5T, 9T$
b. $\frac{T}{2}, \frac{5T}{2}, \frac{9T}{2}$
c. $0, T, 2T, 3T$
d. $0, \frac{T}{2}, T, \frac{3T}{2}$

Ans. (d) $0, \frac{T}{2}, T, \frac{3T}{2}$

Total time period,

$$T = \frac{1}{\nu} = \frac{1}{159.24} = 6.28\text{ ms}$$

Total charge on capacitor at time, t,

$$Q' = Q\cos\frac{2\pi}{T}t$$

For energy stored is electrircal, we can write $Q' = \pm Q$

Hence, energy stored in the capacitor is completely electrical at, $t = 0, \frac{T}{2}, T, \frac{3T}{2}, \ldots\ldots$

Q 4. At what time is the energy stored completely magnetic?

a. $\frac{T}{2}, \frac{3T}{2}, \frac{T}{4}$
b. $\frac{T}{3}, \frac{T}{9}, \frac{T}{12}$
c. $0, 2T, 3T$
d. $\frac{T}{4}, \frac{3T}{4}, \frac{5T}{4}$

Ans. (d) $\frac{T}{4}, \frac{3T}{4}, \frac{5T}{4}$

Magnetic energy is maximum when electrical energy is equal to zero.

Hence, $t = \frac{T}{4}, \frac{3T}{4}, \frac{5T}{4}, \ldots\ldots$

Q 5. The value of X_L is:

a. 20 Ω
b. 40 Ω
c. 60 Ω
d. 50 Ω

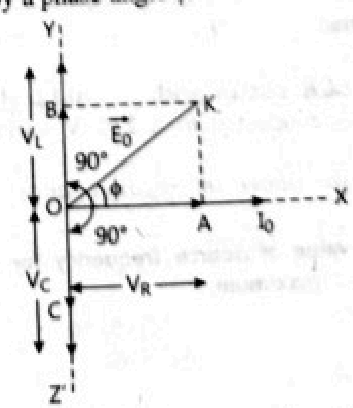
Ans. (a) 20 Ω

$$X_L = \omega L = 2\pi\nu L$$
$$= 2\times3.14\times159.24\times20\times10^{-3}$$
$$\Rightarrow X_L = 20\ \Omega$$

Case Study 5

When a pure resistance *R*, pure inductor *L* and an ideal capacitor of capacitance *C* is connected in series to a source of alternating e.m.f.,then current at any instant through the three elements has the same amplitude and is represented as $I = I_0 \sin \omega t$. However, voltage across each element has a different phase relationship with the current as shown in graph.

The effective resistance of *RLC* circuit is called impedance (*Z*) of the circuit and the voltage leads the current by a phase angle ϕ.



A resistor of 12 Ω, a capacitor of reactance 14 Ω and a pure inductor of inductance 0.1 H are joined in series and placed across 200 V, 50 Hz AC supply.

Based on the above information, answer the following questions.

Q 1. The value of inductive reactance is:

a. 15 Ω b. 31.4 Ω c. 20 Ω d. 30 Ω

Ans. (b) 31.4 Ω

Given: $R = 12\ \Omega, X_C = 14\ \Omega, L = 0.1\text{H}$

$$X_L = \omega L = 2\pi\nu l$$
$$= 2 \times 3.14 \times 50 \times 0.1 = 31.4\ \Omega$$

Q 2. The value of impedance is:

a. 20 Ω b. 15 Ω c. 30 Ω d. 21.13 Ω

Ans. (d) 21.13 Ω

$$\text{Impedance, } Z = \sqrt{R^2 + (X_L - X_C)^2}$$
$$= \sqrt{(12)^2 + (31.4 - 14)^2} = 21.13\ \Omega$$

Q 3. What is the value of current in the circuit?

a. 5 A b. 15 A c. 10 A d. 9.46 A

Ans. (d) 9.46 A

$$I_v = \frac{E_v}{Z} = \frac{200\text{ V}}{21.13} = 9.46\text{ A}$$

Q 4. What is the value of the phase angle between current and voltage?

a. 53°9′ b. 63°9′ c. 55°4′ d. 50°

Ans. (c) 55°4′

$$\tan\phi = \frac{X_L - X_C}{R} = \frac{31.4 - 14}{12} = 1.45$$
$$\phi = \tan^{-1}(1.45) = 55°4'$$

Q 5. From graph, which one is true from following?

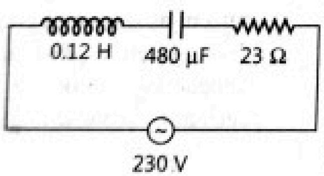
a. $V_L \geq V_C$ b. $V_L < V_C$ c. $V_L > V_C$ d. $V_L = V_C$

Ans. (c) $V_L > V_C$

Case Study 6

When the frequency of AC supply is such that the inductive reactance and capacitive reactance become equal, the impedance of the series *LCR* circuit is equal to the ohmic resistance in the circuit. Such a series *LCR* circuit is known as resonant series *LCR* circuit and the frequency of the AC supply is known as resonant frequency.

Resonance phenomenon is exhibited by a circuit only if both *L* and *C* are present in the circuit. We cannot have resonance in a *RL* or *RC* circuit.



A series *LCR* circuit with $L = 0.12$ H, $C = 480$ nF, $R = 23\ \Omega$ is connected to a 230 V variable frequency supply.

Based on the above information, answer the follwing questions.

Q 1. Find the value of source frequency for which current amplitude is maximum.

a. 222.32 Hz b. 550.52 Hz

c. 663.48 Hz d. 770 Hz

Ans. (c) 663.48 Hz

Here, $L = 0.12\text{ H}, C = 480\text{ nF} = 480 \times 10^{-9}\text{ F}$

$R = 23\ \Omega, V = 230\text{ V}$

$$V_0 = \sqrt{2} \times 230 = 325.22\text{ V}$$

$$I_0 = \frac{V_0}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$$

At resonance, $\omega L - \frac{1}{\omega C} = 0$

$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.12 \times 480 \times 10^9}} = 4166.67\text{ rad s}^{-1}$$

$$\nu_R = \frac{4166.67}{2 \times 3.14} = 663.48\text{ Hz}$$

Q 2. The value of maximum current is:

a. 14.14 A b. 22.52 A c. 50.25 A d. 47.41 A

Ans. (a) 14.14 A

$$\text{Current, } I_0 = \frac{V_0}{R} = \frac{325.22}{23} = 14.14\text{ A}$$

Q 3. The value of maximum power is:

a. 2200 W b. 2299.3 W c. 5500 W d. 4700 W

Ans. (b) 2299.3 W

$$\text{Maximum power, } P_{max} = \frac{1}{2}(I_0)^2 R$$
$$= \frac{1}{2} \times (14.14)^2 \times 23 = 2299.3\text{ W}$$

Q 4. What is the *Q*-factor of the given circuit?

a. 25 b. 42.21 c. 35.42 d. 21.74

Ans. (d) 21.74

$$\text{Quality factor, } Q = \frac{X_L}{R} = \frac{\omega_r L}{R} = \frac{4166.67 \times 0.12}{23} = 21.74$$

Q 5. At resonance which of the following physical quantity is maximum?

a. Impedance b. Current

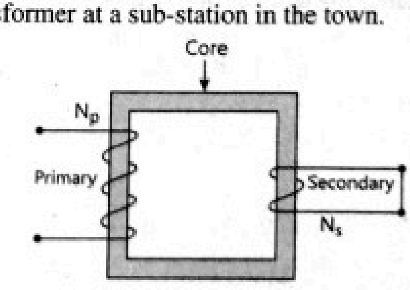
c. Both a. and b. d. Neither a. nor b.

Ans. (b) Current

Case Study 7

Step-down transformers are used to decrease or step-down voltages. These are used when voltages need to be lowered for use in homes and factories.

A small town with a demand of 800 kW of electric power at 220 V is situated 15 km away from an electric plant generating power at 440 V. The resistance of the two wire line carrying power is 0.5 Ω per km. The town gets power from the line through a 4000-220 V step-down transformer at a sub-station in the town.



Based on the above information, answer the follwing questions.

Q 1. The value of total resistance of the wire is:

a. 25 Ω b. 30 Ω c. 35 Ω d. 15 Ω

Ans. (d) 15 Ω

Resistance of the two wire lines carrying power = 0.5 Ω/km

Total resistance = (15 + 15) 0.5 = 15 Ω

Q 2. The line power loss in the form of heat is:
a. 550 kW b. 650 kW c. 600 kW d. 700 kW

Ans. (c) 600 kW
Line power loss = I^2R
RMS current in the coil,
$$I = \frac{P}{V_1} = \frac{800 \times 10^3}{4000} = 200 \text{ A}$$
$\therefore$ Power loss = $(200)^2 \times 15 = 600$ kW

Q 3. How much power must the plant supply, assuming there is negligible power loss due to leakage?
a. 600 kW b. 1600 kW c. 500 W d. 1400 kW

Ans. (d) 1400 kW
Assuming that the power loss is negligible due to the leakage of the current.
The total power supplied by the plant
= 800 kW + 600 kW = 1400 kW

Q 4. The voltage drop in the power line is:
a. 1700 V b. 3000 V c. 2000 V d. 2800 V

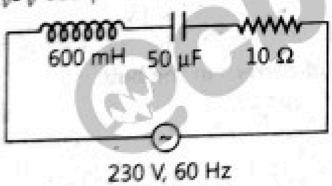
Ans. (b) 3000 V
Voltage drop in the power line = $IR = 200 \times 15 = 3000$ V

Q 5. The total value of voltage transmitted from the plant is:
a. 500 V b. 4000 V c. 3000 V d. 7000 V

Ans. (d) 7000 V
Total voltage transmitted from the plant
= 3000 V + 4000 V = 7000 V

Case Study 8

In an AC circuit, values of voltage and current change every instant. Therefore, power of an AC circuit at any instant is the product of instantaneous voltage (E) and instantaneous current (I). The average power supplied to a pure resistance R over a complete cycle as AC is $P = E_v I_v$. When circuit is inductive, average power per cycle is $E_v I_v \cos\phi$.



In an AC circuit, 600 mH inductor and a 50 µF capacitor are connected in series with 10 Ω resistance. The AC supply to the circuit is 230 V, 60 Hz.

Based on the above information, answer the following questions.

Q 1. The average power transferred per cycle to resistance is:
a. 10.42 W b. 15.25 W c. 17.42 W d. 13.45 W

Ans. (c) 17.42 W
Average power transferred per cycle to resistance is $P_v = I_v^2 R$
As $X_L = \omega L = 2\pi \nu L$
$$= 2 \times \frac{22}{7} \times 60 \times 0.6 = 226.28 \ \Omega$$
$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi \nu C} = \frac{1}{2 \times 22/7 \times 60 \times 50 \times 10^{-6}}$$
$$= 53.03 \ \Omega$$
$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$
$$= \sqrt{(10)^2 + (226.28 - 53.03)^2} = 173.53 \ \Omega$$
$$I_v = \frac{E_v}{Z} = \frac{230}{173.53} = 1.32 \text{ A}$$
$$P_v = I_v^2 R = (1.32)^2 \times 10 = 17.42 \text{ W}$$

Q 2. The average power transferred per cycle to capacitor is:
a. zero b. 10.42 W c. 17.42 W d. 15 W

Ans. (a) zero
$$P_C = E_v I_v \cos\phi$$
In a capacitor, phase difference, $\phi = 90°$
$\therefore$ $P_L = E_v I_v \cos 90° = \text{zero}$

Q 3. The average power transferred per cycle to inductor is:
a. 25 W b. 17.42 W c. 16.52 W d. zero

Ans. (d) zero
$$P_L = E_v I_v \cos\phi$$
In an inductor, phase difference, $\phi = 90°$
$$P_L = E_v I_v \cos 90° = \text{zero}$$

Q 4. The total power transferred per cycle by all the three circuit elements is:
a. 17.42 W b. 10.45 W c. 12.45 W d. zero

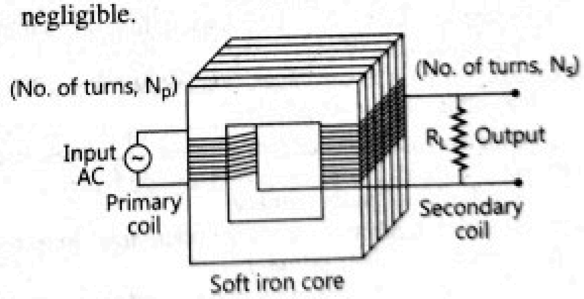
Ans. (a) 17.42 W
Total power absorbed per cycle
$$P = P_R + P_C + P_L = 17.42 + 0 + 0 = 17.42 \text{ W}$$

Q 5. The electrical energy spend in running the circuit for one hour is:
a. 7.5×10^5 J b. 10×10^3 J c. 9.4×10^3 J d. 6.2×10^4 J

Ans. (d) 6.2×10^4 J
Energy spent = power × time
$= 17.42 \times 60 \times 60 = 6.2 \times 10^4$ J

Case Study 9

A transformer is an electrical device which is used for changing the AC voltages. It is based on the phenomenon of mutual induction *i.e.*, whenever the amount of magnetic flux linked with a coil changes, an e.m.f. is induced in the neighbouring coil. For an ideal transformer, the resistances of the primary and secondary windings are negligible.



It can be shown that $\frac{E_S}{E_P} = \frac{I_P}{I_S} = \frac{n_S}{n_P} = k$

where the symbols have their standard meanings.
For a step up transformer,
$$n_S > n_P; E_S > E_P; k > 1;$$
$\therefore$ $I_S < I_P$
For a step down transformer,
$$n_S < n_P; E_S < E_P; k < 1$$
The above relations are on the assumptions that efficiency of transformer is 100%.
Infact, efficiency $\eta = \frac{\text{output power}}{\text{input power}} = \frac{E_S I_S}{E_P I_P}$

Based on the above information, answer the folloiwng questions.

Q 1. Which of the following quantity remains constant in an ideal transformer?

a. Current b. Voltage c. Power d. All of these

Ans. (c) Power

In an ideal transformer, there is no power loss. The efficiency of an ideal transformer is $\eta = 1$ (i.e., 100%)

i.e., input power = output power

Q 2. Transformer is used to:

a. convert AC to DC voltage
b. convert DC to AC voltage
c. obtain desired DC power
d. obtain desired AC voltage and current

Ans. (d) obtain desired AC voltage and current

Transformer is used to obtain desired AC voltage and current.

Q 3. The number of turns in primary coil of a transformer is 20 and the number of turns in a secondary is 10. If the voltage across the primary is 220 AC V, what is the voltage across the secondary?

a. 100 AC V b. 120 AC V c. 110 AC V d. 220 AC V

Ans. (c) 110 AC V

For a transformer, $\frac{V_S}{V_P} = \frac{N_S}{N_P}$

where, N denotes number of turns and V = voltage.

$\therefore \quad \frac{V_S}{220} = \frac{10}{20} \qquad \therefore V_S = 110$ AC V

Q 4. In a transformer the number of primary turns is four times that of the secondary turns. Its primary is connected to an AC source of voltage V. Then:

a. current through its secondary is about four times that of the current through its primary
b. voltage across its secondary is about four times that of the voltage across its primary
c. voltage across its secondary is about two times that of the voltage across its primary
d. voltage across its secondary is about $\frac{1}{2\sqrt{2}}$ times that of the voltage across its primary

Ans. (a) current through its secondary is about four times that of the current through its primary

In a transformer, the primary and secondary currents are related by

$$I_S = \left(\frac{N_P}{N_S}\right) I_P$$

and the voltages are related by

$$V_S = \left(\frac{N_S}{N_P}\right) V_P$$

where, subscripts p and s refer to the primary and secondary of the transformer.

Here, $\quad V_P = V, \frac{N_P}{N_S} = 4$

$\therefore \quad I_S = 4I_P$

and $\quad V_S = \left(\frac{1}{4}\right) V = \frac{V}{4}$

Q 5. A transformer is used to light 100 W–110 V lamp from 220V mains. If the main current is 0.5 A, the efficiency of the transformer is:

a. 95% b. 99% c. 90% d. 96%

Ans. (c) 90%

The efficiency of the transformer is

$$\eta = \frac{\text{Output power } (P_{out})}{\text{Input power } (P_{in})} \times 100$$

Here, $\quad P_{out} = 100$ W, $P_{in} = (220 \text{ V})(0.5 \text{ A}) = 110$ W

$\therefore \quad \eta = \frac{100 \text{ W}}{110 \text{ W}} \times 100 \approx 90\%$

Case Study 10

A transformer is essentially an AC device. It cannot work on DC. It changes alternating voltages or currents. It does not affect the frequency of AC. It is based on the phenomenon of mutual induction. A transformer essentially consists of two coils of insulated copper wire having different number of turns and wound on the same soft iron core.

The number of turns in the primary and secondary coils of an ideal transformer are 2000 and 50 respectively. The primary coil is connected to a main supply of 120 V and secondary coil is connected to a bulb of resistance 0.6 Ω.

Based on the above information, answer the following questions.

Q 1. The value of voltage across the secondary coil is:

a. 5 V b. 2 V c. 3 V d. 10 V

Ans. (c) 3 V

As $\quad \frac{E_S}{E_P} = \frac{n_S}{n_P} \Rightarrow E_S = E_P \cdot \frac{n_S}{n_P}$

$$= \frac{120 \times 50}{2000} = 3 \text{ V}$$

Q 2. The value of current in the bulb is:

a. 7 A b. 15 A c. 3 A d. 5 A

Ans. (d) 5 A

$$I_S = \frac{E_S}{R} \Rightarrow I_S = \frac{3}{0.6} = 5 \text{ A}$$

Q 3. The value of current in primary coil is:

a. 0.125 A b. 2.52 A c. 1.51 A d. 3.52 A

Ans. (a) 0.125 A

As $\quad \frac{I_P}{I_S} = \frac{E_S}{E_P} \Rightarrow I_P = \frac{E_S}{E_P} \times I_S = \frac{3}{120} \times 5 = 0.125$ A

Q 4. Power in primary coil is:

a. 20 W b. 5 W c. 10 W d. 15 W

Ans. (d) 15 W

Power in primary,

$$P_p = E_p \times I_p = 120 \times 0.125 = 15 \text{ W}$$

Q 5. Power in secondary coil is:

a. 15 W b. 20 W c. 7 W d. 8 W

Ans. (a) 15 W

Power in secondary coil,

$$P_S = E_S \times I_S = 3 \times 5 = 15 \text{ W}$$

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222(AA)

Sample Question Paper-1 and OMR Answer Sheet

20XX

Physics

Class 12

Term-1

Time : 90 minutes **Marks : 35**

Instructions

1. Do not open the question booklet until you are asked to do so.
2. There are 35 Questions in the question booklet. Students will mark their answers on the **OMR** answer sheet only, not on the question booklet. All questions carry equal marks.
3. Check the question booklet and the **OMR** answer sheet carefully before marking your answer. Change your question booklet if there is any omission or repetition of questions or any other kind of error in it.
4. Each question has four possible answer— **A, B, C** and **D**. Students are required to choose the most appropriate answer out of the four alternatives. The answer should be filled in the **OMR** answer sheet in the following way:

Example:

Question 1	●	Ⓑ	Ⓒ	Ⓓ
Question 2	Ⓐ	●	Ⓒ	Ⓓ
Question 3	Ⓐ	Ⓑ	●	Ⓓ
Question 4	Ⓐ	Ⓑ	Ⓒ	●

5. If a student doesn't fill the appropriate circle in the OMR answer sheet and leaves it empty or unfilled, he will get a zero for it.
6. Only a black or blue ballpoint pen has to be used for marking the answers on the OMR answer sheet.
7. There will be no negative marking.
8. Students have to submit the OMR answer sheet to the invigilator before leaving the examination hall.
9. Any kind of rough work should be done on the blank page given at the end of the question booklet.

Q 1. When two bodies are rubbed against each other, they acquire:

a. equal and similar charges
b. equal and opposite charges
c. unequal and similar charges
d. unequal and opposite charges

Q 2. When a body is charged by induction, then the body:

a. becomes neutral
b. loses whole of the charge on it
c. does not lose any charge
d. loses part of the charge on it

Q 3. In superposition principle, the force acting on the given charge by other charges is:

a. proportional to the given number charges
b. inversely proportional to the given number charges
c. unaffected by other charges
d. None of the above

Q 4. Work done in bringing a unit positive charge from infinity to a point is:

a. potential energy
b. electrostatic potential
c. electric field
d. work

Q 5. A hollow metal sphere of radius 10 cm is charged such that the potential on its surface becomes 80 V. The potential at the centre of the sphere is:

a. 80 V b. 800 V
c. 8 V d. zero

Q 6. What is the angle between electric field and equipotential surface?

a. 90° always b. 0° always
c. 0° to 90° d. 0° to 180°

Q 7. A charge of 60 C passes through an electric lamp in 2 minutes. Then the current in the lamp is:

a. 30 A b. 1 A c. 0.5 A d. 5 A

Q 8. There are three copper wires of equal length and the ratio of their radii is 1 : 2 : 3. What is the ratio of their resistivity?

a. 1 : 2 : 3 b. 3 : 2 : 1 c. 1 : 1 : 1 d. 1 : 4 : 9

Q 9. The basic laws for analyzing an electric circuit are:

a. Einstein's theory b. Newton's laws
c. Kirchhoff's laws d. Faraday's laws

Q 10. In a meter bridge experiment, the ratio of the left gap resistance to right gap resistance is 2 : 3, the balance point from left is:

a. 60 cm b. 50 cm c. 40 cm d. 20 cm

Q 11. A current or a field going into the plane of the paper is depicted by a/an ....

a. cross b. dot
c. both a. and b. d. arrow

Q 12. If distance between two current carrying wires is doubled, then force between them is:

a. halved b. doubled
c. tripled d. quadrupled

Q 13. A closely wound solenoid of 3000 turns and area of cross-section $2 \times 10^{-4}\ m^2$, carrying a current of 6 A is suspended through its centre allowing it to turn in a horizontal plane. The magnetic moment associated with this solenoid is:

a. $1.2\ J\ T^{-1}$ b. $2.4\ J\ T^{-1}$
c. $3.0\ J\ T^{-1}$ d. $3.6\ J\ T^{-1}$

Q 14. The area of *B-H* loop for soft iron, as compared to that for steel is:

a. more b. less
c. equal d. zero

Q 15. Electromagnetic induction is the:

a. charging of a body with a positive charge
b. production of current by relative motion between magnet and a coil
c. rotation of the coil of an electric motor
d. generation of magnetic field due to current carrying solenoid.

Q 16. Which of the following is found using Lenz's law?

a. induced emf
b. induced current
c. direction of induced emf
d. direction of alternating current

Q 17. Eddy currents do not cause:

a. heating b. loss of energy
c. sparking d. damping

Q 18. The sum of average current values over on complete cycle is:

a. negative b. positive
c. zero d. Both a. and b.

Q 19. When an AC is connected to a resistor what is the phase difference between the current and voltage?

a. 90° b. 180°
c. 0° d. 60°

Q 20. The reactance of a coil is 100 Ω, when used with an AC 240V – 100 Hz supply. The inductance of the coil is:

a. 0.16 H b. 0.22 H
c. 1.6 H d. 2.2 H

Directions (Q.Nos. 21 to 25): In the following questions, a statement of Assertion (A) is followed by a statement of Reason (R). Mark the correct choice as:

a. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A)
b. Both Assertion (A) and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A)
c. Assertion (A) is true but Reason (R) is false
d. Assertion (A) is false and Reason (R) is also false

Q 21. Assertion (A): An alternating current does not show any magnetic effect.
Reason (R): Alternating current does not vary with time.

Q 22. Assertion (A): Changing magnetic flux can produced induced emf.,
Reason (R): Faraday established induced emf experimentally.

Q 23. Assertion (A): The Earth's magnetic field does not affect the working of a moving coil galvanometer.
Reason (R): Earth's magnetic field is very weak.

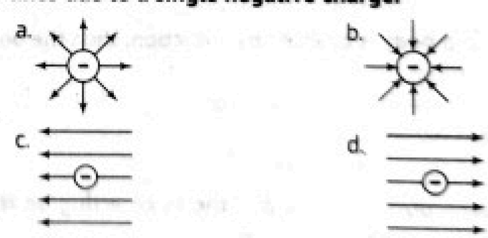
Q 24. Assertion (A): Electric field is always normal to equipotential surfaces and along the direction of decreasing order of potential.
Reason (R): Negative gradient of electric potential is electric field.

Q 25. Assertion (A): When air between the plates of a parallel plate condenser is replaced by an insulating medium of dielectric constant its capacity increases.
Reason (R): Electric field intensity between the plates with dielectric in between it is reduced.

Direction (Q.Nos. 26-30): Read the case given below and answer the questions on the basis ofthe same:

Photocopiers work on the principle that 'opposites attract'. Toner is a powder that is used to create the printed text and images on paper. The powder is negatively charged, and so it is attracted to something positive—the paper. The drum, which is located in the heart of a photocopier, is positively charged using static electricity. An image of the master copy is transferred onto the drum using a laser. The light parts of the image (the white areas on a piece of paper) lose their charge so becomes more negative, and the black areas of the image (where the text is) remain positively charged.

Q 26. Which of the following figures represent the electric field lines due to a single negative charge.



Q 27. Consider a region inside which, there are various types of charges but the total charge is zero. At points outside the region:

a. the electric field is necessarily zero
b. the electric field is due to the dipole moment of the charge distribution only
c. the dominant electric field is inversely proportional to r^3. for larger r (distance from origin)
d. the work done to move a charged particle along a closed path, away from the region will not be zero

Q 28. If a body is negatively charged, then it has:

a. excess of electrons b. excess of protons
c. deficiency of electron d. deficiency of neutron

Q 29. A charged particle is free to move in an electric field. It will travel:

a. always along a line of force
b. along a line of force, if its initial velocity is zero
c. along a line of force, if it has some initial velocity in the direction of an acute angle with the line of force
d. None of the above

Q 30. Which of the following statements is incorrect?

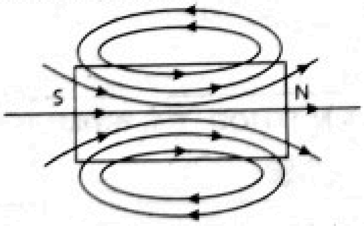
(i) The charge q on a body is always given by $q = ne$, where n is any integer, positive or negative.
(ii) By convention, the charge on an electron is taken to be negative.
(iii) The fact that electric charge is always an integral multiple of e is termed as quantisation of charge.
(iv) The quantisation of charge was experimentally demonstrated by Newton in 1912.

a. Only (i) b. Only (ii)
c. Only (iv) d. Only (iii)

Direction (Q.Nos. 31-35): Read the case given below and answer the questions on the basis ofthe same:

By analogy to Gauss's law of electrostatics, we can write Gauss's law of magnetism as $\oint \vec{B} \cdot d\vec{S} = \mu_0 \, m_{inside}$ where $\oint \vec{B} \cdot d\vec{S}$ is the magnetic flux and m_{inside} is the net pole strength inside the closed surface.

We do not have an isolated magnetic pole in nature. At least one has been found to exist till date. The smallest unit of the source of magnetic field is a magnetic dipole where the net magnetic pole is zero. Hence, the net magnetic pole enclosed by any closed surface is always zero. Correspondingly, the flux of the magnetic field through any closed surface is zero.



Q 31. Consider the two idealised systems

(i) A parallel plate capacitor with large plates and small separation and
(ii) a long solenoid of length $L >> R$, radius of cross-section.

In (i) $\vec{E}$ is ideally treated as a constant between plates and zero outside. In (ii) magnetic field is constant inside the solenoid and zero outside. These idealised assumptions, however, contradict fundamental laws as below:

a. case (i) contradicts Gauss's law for electrostatic fields.
b. case (ii) contradicts Gauss's law for magnetic fields.
c. case (i) agrees with $\oint \vec{E} \cdot d\vec{l} = 0$.
d. case (ii) contradicts $\oint \vec{E} \cdot d\vec{l} = I_{en}$

Q 32. The net magnetic flux through any closed surface, kept in a magnetic field is:

a. zero b. $\frac{\mu_0}{4\pi}$
c. $4\pi\mu_0$ d. $\frac{4\mu_0}{\pi}$

Q 33. A closed surface S encloses a magnetic dipole of magnetic moment $2ml$. The magnetic flux emerging from the surface is:

a. $\mu_0 m$ b. zero
c. $2\mu_0 m$ d. $\frac{2m}{\mu_0}$

Q 34. Which of the following is not a consequence of Gauss's law?

a. The magnetic poles always exist as unlike pairs of equal strength.
b. If several magnetic lines of force enter in a closed surface, then an equal number of lines of force must leave that surface.
c. There are abundant sources or sinks of the magnetic field inside a closed surface.
d. Isolated magnetic poles do not exist.

Q 35. The surface integral of a magnetic field over a surface:

a. is proportional to mass enclosed.
b. is proportional to charge enclosed.
c. is zero.
d. equal to its magnetic flux through that surface.

OMR ANSWER SHEET

टेस्ट फॉर्म सं०
Test Form No.

☐	☐	☐	☐	☐	☐
0	A	A	A	0	0
1	B	B	B	1	1
2	C	C	C	2	2
3	D	D	D	3	3
4	E	E	E	4	4
5	F	F	F	5	5
6	G	G	G	6	6
7	H	H	H	7	7
8	I	I	I	8	8
9	J	J	J	9	9

Name of the Candidate/परीक्षार्थी का नाम ....

Roll Number/अनुक्रमांक ....

City/Centre Code ☐☐☐☐☐☐

Booklet I.D. ☐☐☐☐☐☐☐☐☐☐

ANSWER

Q. 1. ⓐ ⓑ ⓒ ⓓ	**Q. 11.** ⓐ ⓑ ⓒ ⓓ	**Q. 21.** ⓐ ⓑ ⓒ ⓓ	**Q. 31** ⓐ ⓑ ⓒ ⓓ
Q. 2. ⓐ ⓑ ⓒ ⓓ	**Q. 12.** ⓐ ⓑ ⓒ ⓓ	**Q. 22.** ⓐ ⓑ ⓒ ⓓ	**Q. 32** ⓐ ⓑ ⓒ ⓓ
Q. 3. ⓐ ⓑ ⓒ ⓓ	**Q. 13.** ⓐ ⓑ ⓒ ⓓ	**Q. 23.** ⓐ ⓑ ⓒ ⓓ	**Q. 33** ⓐ ⓑ ⓒ ⓓ
Q. 4. ⓐ ⓑ ⓒ ⓓ	**Q. 14.** ⓐ ⓑ ⓒ ⓓ	**Q. 24.** ⓐ ⓑ ⓒ ⓓ	**Q. 34** ⓐ ⓑ ⓒ ⓓ
Q. 5. ⓐ ⓑ ⓒ ⓓ	**Q. 15.** ⓐ ⓑ ⓒ ⓓ	**Q. 25.** ⓐ ⓑ ⓒ ⓓ	**Q. 35** ⓐ ⓑ ⓒ ⓓ
Q. 6. ⓐ ⓑ ⓒ ⓓ	**Q. 16.** ⓐ ⓑ ⓒ ⓓ	**Q. 26.** ⓐ ⓑ ⓒ ⓓ	
Q. 7. ⓐ ⓑ ⓒ ⓓ	**Q. 17.** ⓐ ⓑ ⓒ ⓓ	**Q. 27.** ⓐ ⓑ ⓒ ⓓ	
Q. 8. ⓐ ⓑ ⓒ ⓓ	**Q. 18.** ⓐ ⓑ ⓒ ⓓ	**Q. 28.** ⓐ ⓑ ⓒ ⓓ	
Q. 9. ⓐ ⓑ ⓒ ⓓ	**Q. 19.** ⓐ ⓑ ⓒ ⓓ	**Q. 29.** ⓐ ⓑ ⓒ ⓓ	
Q. 10. ⓐ ⓑ ⓒ ⓓ	**Q. 20.** ⓐ ⓑ ⓒ ⓓ	**Q. 30.** ⓐ ⓑ ⓒ ⓓ	

Result/रिजल्ट

No. of Question/प्रश्नों की संख्या ....

Total Marks/कुल अंक ....

Attempted Questions/हल किए गए प्रश्न ....

Right Answers/सही उत्तर ....

Wrong Answers/गलत उत्तर ....

Marks Obtained/प्राप्त अंक ....

CORRECT METHOD/सही तरीका

ⓐ ● ⓒ ⓓ

WRONG METHOD/गलत तरीका

ⓐ ✓ ⓒ ⓓ	ⓐ ✗ ⓒ ⓓ	ⓐ • ⓒ ⓓ	ⓐ ⓑ ⓒ ⓓ	ⓐ ⓑ ⓒ ⓓ

Candidate's Signature		**Invigilator's Signature**	

Scan the QR Code
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Roll No. ______________

Name ______________

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Printed Pages No. xxx

222(AA)

Sample Question Paper-2 and OMR Answer Sheet

20XX

Physics

Class 12

Term-1

Time : 90 minutes

Marks : 35

Instructions

1. Do not open the question booklet until you are asked to do so.
2. There are 35 Questions in the question booklet. Students will mark their answers on the **OMR** answer sheet only, not on the question booklet. All questions carry equal marks.
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4. Each question has four possible answer— **A, B, C** and **D**. Students are required to choose the most appropriate answer out of the four alternatives. The answer should be filled in the **OMR** answer sheet in the following way:

Example:

Question 1	●	Ⓑ	Ⓒ	Ⓓ
Question 2	Ⓐ	●	Ⓒ	Ⓓ
Question 3	Ⓐ	Ⓑ	●	Ⓓ
Question 4	Ⓐ	Ⓑ	Ⓒ	●

5. If a student doesn't fill the appropriate circle in the OMR answer sheet and leaves it empty or unfilled, he will get a zero for it.
6. Only a black or blue ballpoint pen has to be used for marking the answers on the OMR answer sheet.
7. There will be no negative marking.
8. Students have to submit the OMR answer sheet to the invigilator before leaving the examination hall.
9. Any kind of rough work should be done on the blank page given at the end of the question booklet.

Q 1. The electric field at a point is:

a. always continuous
b. continuous, if there is no charge at that point
c. discontinuous, if there is a charge at that point
d. Both b. and c. are correct

Q 2. An electron initially at rest falls a distance of 1.5 cm in a uniform electric field of magnitude 2×10^4 N/C. The time taken by the electron to fall this distance is:

a. 1.3×10^2 s b. 2.1×10^{-12} s
c. 1.6×10^{-10} s d. 2.9×10^{-9} s

Q 3. Object may acquire an excess or deficiency of charge by:

a. hammering b. heating
c. shaking d. rubbing

Q 4. Which of the following is true about electrostatic potential?

a. It is conservative in nature
b. It is the ratio of work and charge
c. Both a. and b.
d. It is not conservative in nature

Q 5. Which among the following is an example of polar molecule?

a. O_2 b. H_2
c. N_2 d. HCl

Q 6. The capacitance of a parallel plate condenser does not depend on:

a. area of the plates
b. medium between the plates
c. distance between the plates
d. metal of the plates

Q 7. Wheatstone bridge works on the principle of ....

a. full deflection b. partial deflection
c. no deflection d. null deflection

Q 8. When there is an electric current through a conducting wire along its length, then an electric field must exist:

a. outside the wire but normal to it
b. outside the wire but parallel to it
c. inside the wire but parallel to it
d. inside the wire but normal to it

Q 9. The condition for the validity of Ohm's law is that the:

a. temperature should remain constant
b. current should be proportional to voltage
c. resistance must be wire wound type
d. all of the above

Q 10. The dimensions of mobility of charge carriers are:

a. $[M^{-2}T^2A]$ b. $[M^{-1}T^2A]$
c. $[M^{-2}T^3A]$ d. $[M^{-1}T^3A]$

Q 11. When a magnetic field is applied on a stationary electron, it:

a. remains stationary
b. spins about its own axis
c. moves in the direction of the field
d. moves perpendicular to the direction of the field

Q 12. In which form the field lines inside the infinite solenoid are present?

a. Perpendicular straight lines
b. Circular lines
c. Ellipsoidal lines
d. Parallel straight lines

Q 13. A closely wound solenoid of 3000 turns and area of cross-section 2×10^{-4} m^2, carrying a current of 6 A is suspended through its centre allowing it to turn in a horizontal plane. The magnetic moment associated with this solenoid is:

a. 1.2 J T^{-1} b. 2.4 J T^{-1} c. 3.0 J T^{-1} d. 3.6 J T^{-1}

Q 14. The Earth behaves as a magnet with magnetic field pointing approximately from the geographic:

a. North to South b. South to North
c. East to West d. West to East

Q 15. In Faraday's experiment, current is not produced when:

a. the coil is moved and bar magnet is kept stationary
b. the bar magnet is moved and the coil is kept station
c. both coil and bar magnet are kept stationary
d. both a. and b.

Q 16. According to Lenz's law of electromagnetic induction:

a. the induced emf is not in the direction opposing the change in magnetic flux
b. the relative motion between the coil and magnet produces change in magnetic flux
c. only the magnet should be moved towards coil
d. only the coil should be moved towards magnet

Q 17. Eddy current can be minimised by using:

a. thick wires b. thin sheets of metal
c. thick sheets d. laminated sheets

Q 18. The equation of AC is given by $I = 100 \sin 314t$. What is the frequency?

a. 314 Hz b. 100 Hz c. 50 Hz d. 100 Hz

Q 19. The peak value of domestic AC supply voltage is 325 V. What is the rms value?

a. 325 V b. 230 V c. 200 V d. 325 V

Q 20. In a circuit, the current lags behind the voltage by a phase difference of $\pi/2$. The circuit contains:

a. only R b. only C
c. only L d. R and C

Directions (Q.Nos. 21 to 25): In the following questions, a statement of Assertion (A) is followed by a statement of Reason (R). Mark the correct choice as:

a. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A)
b. Both Assertion (A) and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A)
c. Assertion (A) is true but Reason (R) is false
d. Assertion (A) is false and Reason (R) is also false

Q 21. Assertion (A): The ends of a magnet suspended freely point out always along north south.

Reason (R): Earth behaves as a huge magnet.

Q 22. Assertion (A): Inductance coil are made of copper.

Reason (R): Induced current is more in wire having less resistance.

Q 23. Assertion (A): Magnetic field lines always form closed loops.

Reason (R): Moving charges or currents produce a magnetic field.

Q 24. Assertion (A): In a uniform electric field electron move in the opposite direction of electric field.

Reason (R): This is because of the negative charge of an electron.

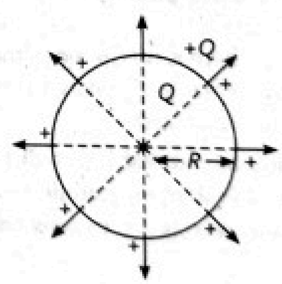
Q 25. Assertion (A): Surface of a symmetrical conductor can be treated as equipotential surface.

Reason (R): Charges can easily flow in a conductor.

Direction (Q.Nos. 26-30): Read the case given below and answer the questions on the basis ofthe same:

The electrical capacitance of a conductor is the measure of its ability to hold electric charge.

An isolated spherical conductor of radius R. The charge Q is uniformly distributed over its entire surface. It can be assumed to be concentrated at the centre of the sphere. The potential at any point on the surface of the spherical conductor will be $V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R}$.



Capacitance of the spherical conductor situated in vacuum is

$$C = \frac{Q}{V} = \frac{Q}{\frac{1}{4\pi\varepsilon_0}\cdot\frac{Q}{R}} \quad \text{or} \quad C = 4\pi\varepsilon_0 R$$

Clearly, the capacitance of a spherical conductor is proportional to its radius.

The radius of the spherical conductor is 1 F capacitance is $R = \frac{1}{4\pi\varepsilon_0}\cdot C$ and this radius is about 1500 times the radius of earth ($\sim 6 \times 10^3$ km).

Q 26. If an isolated sphere has a capacitance 50 pF then radius is:

a. 90 cm b. 45 cm
c. 45 m d. 90 m

Q 27. How much charge should be placed on a capacitance of 25 pF to raise its potential to 10^5 V?

a. 1 μC b. 1.5 μC
c. 2 μC d. 2.5 μC

Q 28. Dimensions of capacitance is:

a. $[ML^{-2}T^4A^2]$ b. $[M^{-1}L^{-1}T^3A^1]$
c. $[M^{-1}L^{-2}T^4A^2]$ d. $[M^0L^{-2}T^4A^1]$

Q 29. Metallic sphere of radius R is charged to potential V. Then charge q is proportional to:

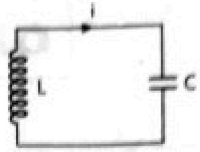
a. V b. R
c. Both a. and b. d. None of these

Q 30. If 64 identical spheres of charge q and capacitance C each are combined to form a large sphere. The charge and capacitance of the large sphere is:

a. $64q$, C b. $16q$, $4C$
c. $64q$, $4C$ d. $16q$, $64C$

ection (Q.Nos. 31-35): Read the case given below and answer questions on the basis ofthe same:

An LC circuit also called a resonant circuit, tank circuit or tuned circuit is an electric circuit consisting of an inductor represented by the letter L and a capacitor, represented by the letter C connected together. An LC circuit is an idealised model since it assumes there is no dissipation of energy due to resistance.



An LC circuit contains a 20 mH inductor and a 50 μF capacitor with an initial charge of 10 mC. The resistance of the circuit is negligible. Let the instant the circuit is closed be $t = 0$.

Q 31. The total energy stored initially is:

a. 5 J b. 3 J c. 10 J d. 1 J

Q 32. The natural frequency of the circuit is:

a. 159.24 Hz b. 200.12 Hz
c. 110.25 Hz d. 95 Hz

Q 33. At what time is the energy stored completely electrical?

a. $T, 5T, 9T$ b. $\frac{T}{2}, \frac{5T}{2}, \frac{9T}{2}$
c. $0, T, 2T, 3T$ d. $0, \frac{T}{2}, T, \frac{3T}{2}$

Q 34. At what time is the energy stored completely magnetic?

a. $\frac{T}{2}, \frac{3T}{2}, \frac{T}{4}$ b. $\frac{T}{3}, \frac{T}{9}, \frac{T}{12}$
c. $0, 2T, 3T$ d. $\frac{T}{4}, \frac{3T}{4}, \frac{5T}{4}$

Q 35. The value of X_L is:

a. 20 Ω b. 40 Ω
c. 60 Ω d. 50 Ω

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Test Form No.

0	A	A	A	0	0
1	B	B	B	1	1
2	C	C	C	2	2
3	D	D	D	3	3
4	E	E	E	4	4
5	F	F	F	5	5
6	G	G	G	6	6
7	H	H	H	7	7
8	I	I	I	8	8
9	J	J	J	9	9

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ANSWER

Q. 1. ⓐ ⓑ ⓒ ⓓ	Q. 11. ⓐ ⓑ ⓒ ⓓ	Q. 21. ⓐ ⓑ ⓒ ⓓ	Q. 31 ⓐ ⓑ ⓒ ⓓ
Q. 2. ⓐ ⓑ ⓒ ⓓ	Q. 12. ⓐ ⓑ ⓒ ⓓ	Q. 22. ⓐ ⓑ ⓒ ⓓ	Q. 32 ⓐ ⓑ ⓒ ⓓ
Q. 3. ⓐ ⓑ ⓒ ⓓ	Q. 13. ⓐ ⓑ ⓒ ⓓ	Q. 23. ⓐ ⓑ ⓒ ⓓ	Q. 33 ⓐ ⓑ ⓒ ⓓ
Q. 4. ⓐ ⓑ ⓒ ⓓ	Q. 14. ⓐ ⓑ ⓒ ⓓ	Q. 24. ⓐ ⓑ ⓒ ⓓ	Q. 34 ⓐ ⓑ ⓒ ⓓ
Q. 5. ⓐ ⓑ ⓒ ⓓ	Q. 15. ⓐ ⓑ ⓒ ⓓ	Q. 25. ⓐ ⓑ ⓒ ⓓ	Q. 35 ⓐ ⓑ ⓒ ⓓ
Q. 6. ⓐ ⓑ ⓒ ⓓ	Q. 16. ⓐ ⓑ ⓒ ⓓ	Q. 26. ⓐ ⓑ ⓒ ⓓ	
Q. 7. ⓐ ⓑ ⓒ ⓓ	Q. 17. ⓐ ⓑ ⓒ ⓓ	Q. 27. ⓐ ⓑ ⓒ ⓓ	
Q. 8. ⓐ ⓑ ⓒ ⓓ	Q. 18. ⓐ ⓑ ⓒ ⓓ	Q. 28. ⓐ ⓑ ⓒ ⓓ	
Q. 9. ⓐ ⓑ ⓒ ⓓ	Q. 19. ⓐ ⓑ ⓒ ⓓ	Q. 29. ⓐ ⓑ ⓒ ⓓ	
Q. 10. ⓐ ⓑ ⓒ ⓓ	Q. 20. ⓐ ⓑ ⓒ ⓓ	Q. 30. ⓐ ⓑ ⓒ ⓓ	

Result/रिजल्ट

No. of Question/प्रश्नों की संख्या ....

Total Marks/कुल अंक ....

Attempted Questions/हल किए गए प्रश्न ....

Right Answers/सही उत्तर ....

Wrong Answers/गलत उत्तर ....

Marks Obtained/प्राप्त अंक ....

CORRECT METHOD/सही तरीका

ⓐ ● ⓒ ⓓ

WRONG METHOD/गलत तरीका

ⓐ ✓ ⓒ ⓓ	ⓐ ✗ ⓒ ⓓ	ⓐ • ⓒ ⓓ	ⓐ ⓑ ⓒ ⓓ	ⓐ ⓑ ⓒ ⓓ

Candidate's Signature		Invigilator's Signature	

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