SAMPLE PAPER TEST 04 FOR BOARD EXAM 2025

SUBJECT: PHYSICS **(QUESTION PAPER)** **MAX. MARKS : 70**

CLASS : XII **DURATION: 3 HRS**

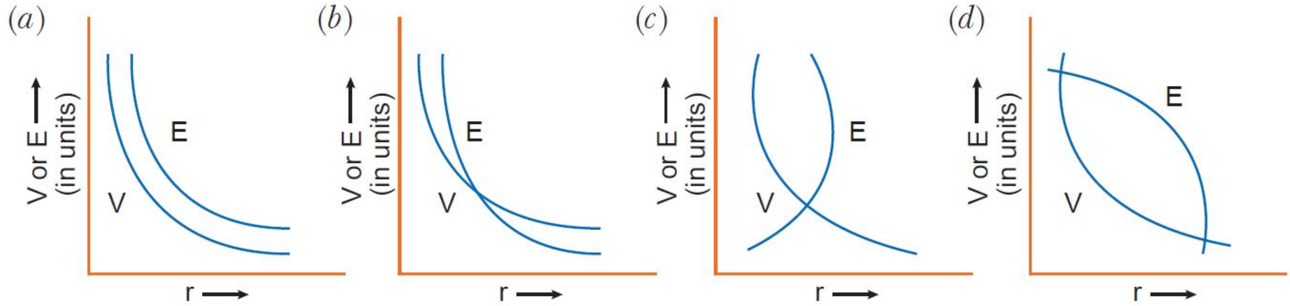
General Instructions:

1. There are 33 questions in all. All questions are compulsory
2. This question paper has five sections: Section A, Section B, Section C, Section D and Section E. All the sections are compulsory.
3. Section A contains sixteen questions, twelve MCQ and four Assertion-Reasoning based questions of 1 mark each, Section B contains five questions of two marks each, Section C contains seven questions of three marks each, section D contains three long questions of five marks each and Section E contains two case study based questions of 4 marks each.
4. There is no overall choice. However, an internal choice has been provided in section B, C, D and E. You have to attempt only one of the choices in such questions.
5. Use of calculators is not allowed.

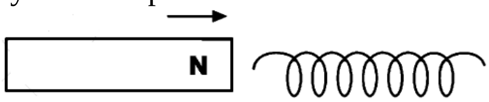
SECTION – A

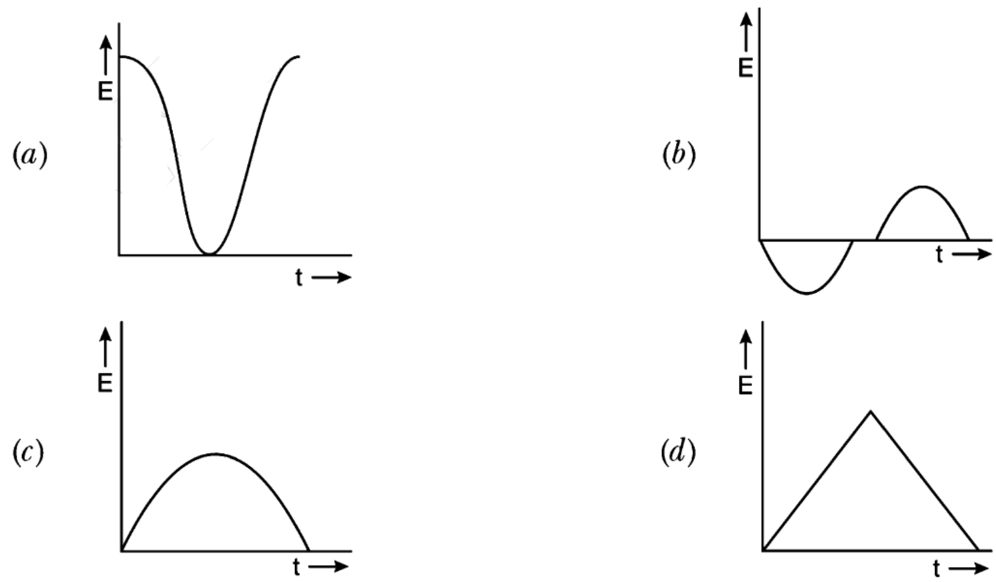
Questions 1 to 16 carry 1 mark each.

1. The variation potential V with r and electric field E with r for a point charge is correctly shown in the graphs.



2. The variation of induced emf (E) with time t in a coil if a short bar magnet is moved along its axis with a constant velocity is best represented as:

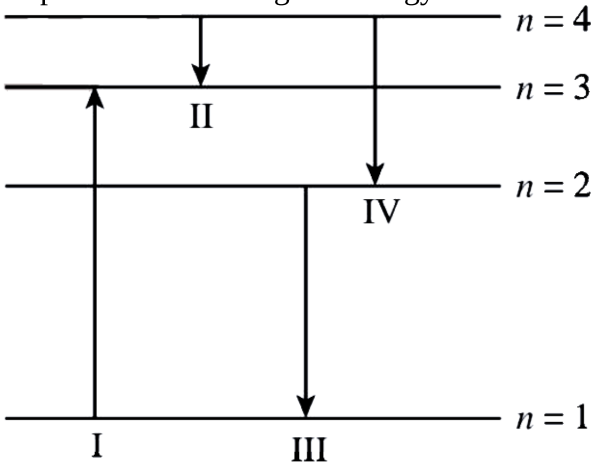




3. A resistance R is to be measured using a meter bridge. Student chooses the standard resistance S to be 100 Ω. He finds the null point at l_1 = 2.9 cm. He is told to attempt to improve the accuracy. Which of the following is a useful way?

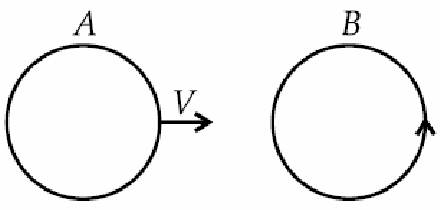
(a) He should measure l_1 more accurately.
(b) He should change S to 1000 Ω and repeat the experiment.
(c) He should change S to 3 Ω and repeat the experiment.
(d) He should give up hope of a more accurate measurement with a meter bridge.

4. The diagram shows the energy levels for an electron in a certain atom. The transition that represents the emission of a photon with the highest energy is



(a) I (b) II (c) III (d) IV

5. There are two coils A and B as shown in 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:

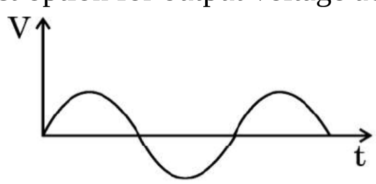


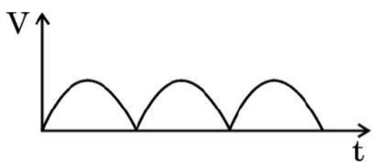
(a) there is a constant current in the clockwise direction in A.
(b) there is a varying current in A.
(c) there is no current in A.
(d) there is a constant current in the counter clockwise direction in A.

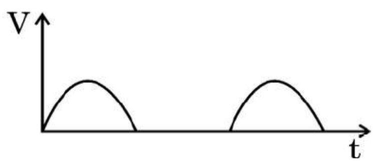
6. The mass density of a nucleus of mass number A is :
(a) proportional to $A^{1/3}$ (b) proportional to $A^{2/3}$ (c) proportional to A^3 (d) independent of A

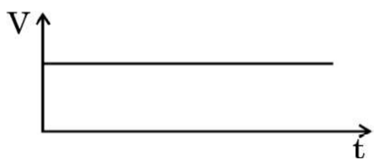
7. In the energy-band diagram of n-type Si, the gap between the bottom of the conduction band E_C and the donor energy level E_D is of the order of :
(a) 10 eV (b) 1 eV (c) 0 1 eV (d) 0 01 eV

8. An ac source of voltage is connected in series with a p-n junction diode and a load resistor. The correct option for output voltage across load resistance will be :

(a)


(b)


(c)


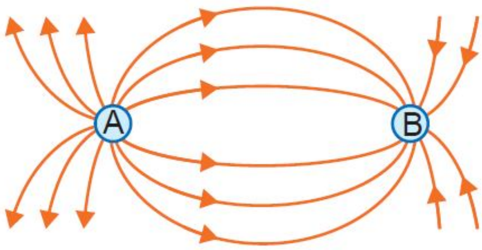
(d)


9. A diamagnetic substance is brought near the north or south pole of a bar magnet. It will be :
(a) repelled by both the poles.
(b) attracted by both the poles.
(c) repelled by the north pole and attracted by the south pole.
(d) attracted by the north pole and repelled by the south pole.

10. A circular coil of radius 8 0 cm and 40 turns is rotated about its vertical diameter with an angular speed of 25/π rad s-1 in a uniform horizontal magnetic field of magnitude 3.0 x 10-2 T. The maximum emf induced in the coil is:
(a) 0·12 V (b) 0·15 V (c) 0·19 V (d) 0·22 V

11. A square of side L metres lies in the x–y plane in a region where the magnetic field is given by $\vec{B} = B_0(2\hat{i} + 3\hat{j} + 4\hat{k})$ Tesla, where, B_0 is constant.
The magnitude of flux passing through the square is:
(a) $2B_0L^2Wb$ (b) $3B_0L^2Wb$ (c) $4B_0L^2Wb$ (d) $\sqrt{29}B_0L^2Wb$

12. The spatial distribution of the electric field due to two charges (A, B) is shown in figure. Which one of the following statements is correct?



(a) A is + ve and B is – ve and |A|>|B|
(b) A is – ve and B is + ve, |A|=|B|
(c) Both are + ve but A>B
(d) Both are – ve but A>B

ASSERTION-REASON BASED QUESTIONS

In the following questions, a statement of assertion (A) is followed by a statement of Reason (R). Choose the correct answer out of the following choices.
(a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).
(b) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).
(c) Assertion (A) is true, but Reason (R) is false.
(d) Assertion (A) is false and Reason (R) is also false.

13. Assertion (A): The phase difference between any two points on a wavefront is zero.
Reason (R): All points on a wavefront are at the same distance from the source and thus oscillate in the same phase.

14. Assertion (A): Photoelectric effect demonstrates the particle nature of light.
Reason (R): Photoelectric current is proportional to intensity of incident radiation for frequencies more than the threshold frequency.

15. Assertion (A): Bohr's postulate states that the electrons in stationary orbits around the nucleus do not radiate.
Reason (R): According to classical physics, all moving electrons radiate.

16. Assertion (A): When a bar of copper is placed in an external magnetic field, the field lines get concentrated inside the bar.
Reason (R): Copper is a paramagnetic substance.

SECTION – B

Questions 17 to 21 carry 2 marks each.

17. Distinguish between a metal and an insulator on the basis of energy band diagrams.

OR

(a) Which charge carriers in intrinsic semiconductor will have conduction?
(b) How does the resistance of a semiconductor change when heated?

18. Consider an induced magnetic field due to changing electric field and an induced electric field due to changing magnetic field. Which one is more easily observed? Justify your answer.

19. Two coherent monochromatic light beams of intensities I and 4I superpose each other. Find the ratio of maximum and minimum intensities in the resulting beam.

20. A charged particle enters perpendicularly a region having either (i) magnetic field or (ii) an electric field. How can the trajectory followed by the charged particle help us to know whether the region has an electric field or a magnetic field? Explain briefly.

21. The ground state energy of hydrogen atom is -13.6 eV. What is the potential energy and kinetic energy of an electron in the third excited state?

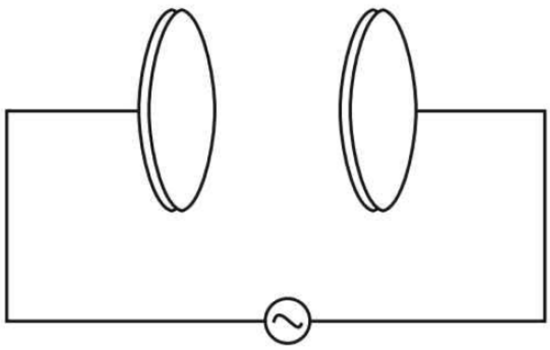
SECTION – C

Questions 22 to 28 carry 3 marks each.

22. In a plane electromagnetic wave, the electric field oscillates sinusoidally at a frequency of 2.0×10^{10} Hz and amplitude 48 V/m.
(i) What is the wavelength of a wave?
(ii) What is the amplitude of the oscillating magnetic field?
(iii) Show that the average energy density of the electric field equals the average energy density of the magnetic field. [$c = 3 \times 10^8$ m/s]

OR

A parallel plate capacitor (fig.) made of circular plates each of radius R = 6.0 cm has a capacitance C = 100 pF. The capacitor is connected to a 230 V ac supply with an angular frequency of 300 rad/s.



(i) What is the rms value of the conduction current?
(ii) Is conduction current equal to the displacement current?
(iii) Determine the amplitude of magnetic field induction B at a point 3.0 cm from the axis between the plates.

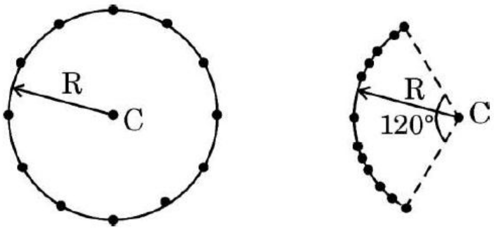
23. Draw the circuit arrangement for studying the V-I characteristics of a p-n junction diode in forward bias and reverse bias. Show the plot of V-I characteristic of a silicon diode.

24. Using Huygens' principle, draw a ray diagram showing ther propagation of a plane wave refracting at a plane surface separating two media. Also verify the Snell's law of refraction.

25. Draw the curve showing the variation of binding energy per nucleon with the mass number of nuclei. Using it explain the fusion of nuclei lying on ascending part and fission of nuclei lying on descending part of this curve.

26. (a) Twelve negative charges of same magnitude are equally spaced and fixed on the circumference of a circle of radius R as shown in Fig. (i). Relative to potential being zero at infinity, find the electric potential and electric field at the centre C of the circle.

(b) If the charges are unequally spaced and fixed on an arc of 120 of radius R as shown in Fig. (ii), find electric potential at the centre C.



(i) (ii)

27. A long solenoid of radius r consists of n turns per unit length. A current $I = I_0 \sin \omega t$ flows in the solenoid. A coil of N turns is wound tightly around it near its centre. What is :

(a) the induced emf in the coil?

(b) the mutual inductance between the solenoid and the coil?

28. How does Einstein's photoelectric equation explain the emission of electrons from a metal surface? Explain briefly.

Plot the variation of photocurrent with :

(a) collector plate potential for different intensity of incident radiation, and

(b) intensity of incident radiation.

SECTION – D (Case Study Based Questions)

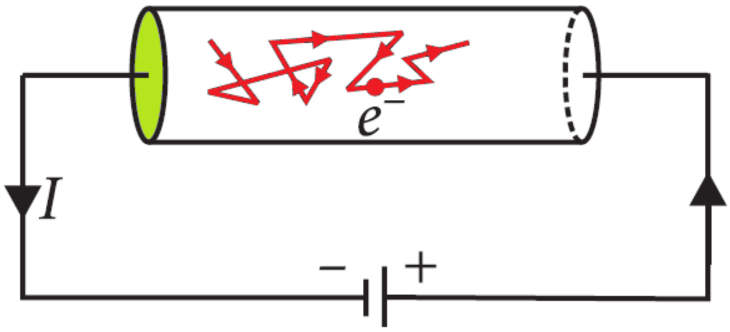
Questions 29 to 30 carry 4 marks each.

29. Case-Study 1:

Read the following paragraph and answer the questions

Mechanism of Current Flow in a Conductor

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 m s^{-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 again 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.



(i) Magnitude of drift velocity per unit electric field is
(a) current density (b) current (c) resistivity (d) mobility

(ii) 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)

(iii) 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 speeds 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.

(iv) Drift speed of electrons in a conductor is very small *i.e.*, $i = 10^{-4}$ m s^{-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.

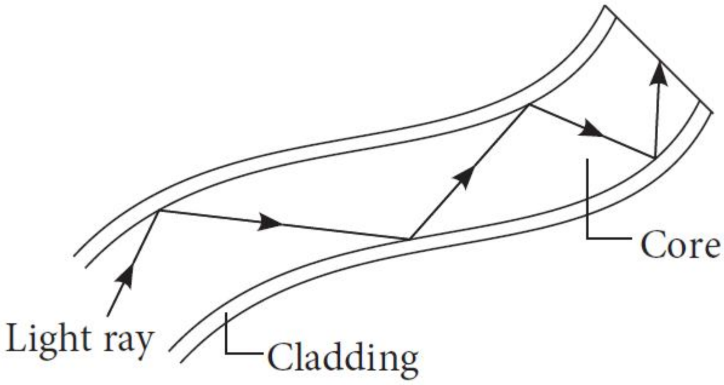
OR

(v) 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

30. Case-Study 2:

Read the following paragraph and answer the questions.

An optical fibre is a thin tube of transparent material that allows light to pass through, without being refracted into the air or another external medium. It make use of total internal reflection. These fibres are fabricated in such a way that light reflected at one side of the inner surface strikes the other at an angle larger than critical angle. Even, if fibre is bent, light can easily travel along the length.

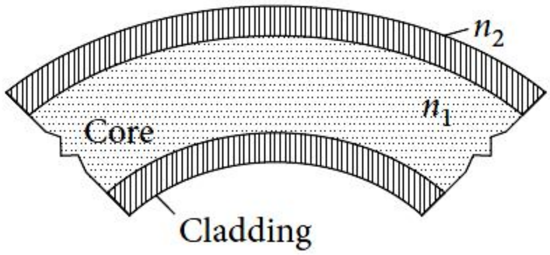


(i) Which of the following is based on the phenomenon of total internal reflection of light?
(a) Sparkling of diamond
(b) Optical fibre communication
(c) Instrument used by doctors for endoscopy
(d) All of these

(ii) A ray of light will undergo total internal reflection inside the optical fibre, if it
(a) goes from rarer medium to denser medium
(b) is incident at an angle less than the critical angle
(c) strikes the interface normally
(d) is incident at an angle greater than the critical angle

(iii) If in core, angle of incidence is equal to critical angle, then angle of refraction will be
(a) 0°
(b) 45°
(c) 90°
(d) 180°

(iv) In an optical fibre (shown), correct relation for refractive indices of core and cladding is



(a) $n_1 = n_2$
(b) $n_1 > n_2$
(c) $n_1 < n_2$
(d) $n_1 + n_2 = 2$

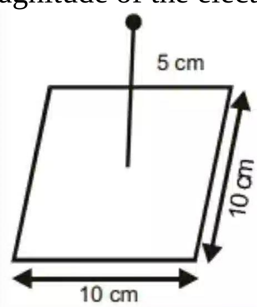
OR

(v) If the value of critical angle is 30° for total internal reflection from given optical fibre, then speed of light in that fibre is
(a) 3×10^8 m s^{-1}
(b) 1.5×10^8 m s^{-1}
(c) 6×10^8 m s^{-1}
(d) 4.5×10^8 m s^{-1}

SECTION – E

Questions 31 to 33 carry 5 marks each.

31. (i) Define electric flux. Write its SI unit.
(ii) "Gauss's law in electrostatics is true for any closed surface, no matter what its shape or size is." Justify this statement with the help of a suitable example.
(iii) A point charge + 10 μC is at a distance 5 cm directly above the centre of a square of side 10 cm as shown in figure. What is the magnitude of the electric flux through the square?



OR

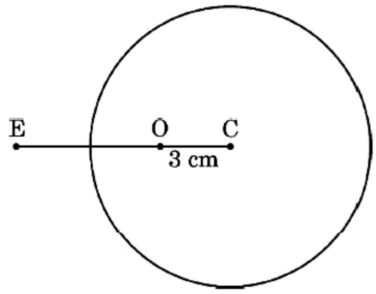
(i) Consider a system of n charges q_1, q_2, ... q_n, with position vectors relative $\vec{r_1}, \vec{r_2}, \vec{r_3}, ...\vec{r_n}$ to some origin 'O'. Deduce the expression for the net electric field $\vec{E}$ at a point P with position vector $\vec{r_p}$, due to this system of charges.

(ii) Two charges of value 2 μC and -50 μC are placed 80 cm apart. Calculate the distance of the point from the smaller charge where the intensity is zero.

32. (a) (i) (1) Write two points of difference between an interference pattern and a diffraction pattern.
(2) Name any two factors on which the fringe width in a Young's double-slit experiment depends.
(ii) In Young's double-slit experiment, the two slits are separated by a distance equal to 100 times the wavelength of light that passes through the slits. Calculate:
(1) the angular separation in radians between the central maximum and the adjacent maximum.
(2) the distance between these two maxima on a screen 50 cm from the slits.

OR

(b) (i) A spherical surface of radius of curvature R separates two media of refractive indices n_1 and n_2. A point object is placed in front of the surface at distance u in medium of refractive index n_1 and its image is formed by the surface at distance v, in the medium of refractive index n_2. Derive a relation between u and v.
(ii) A solid glass sphere of radius 6.0 cm has a small air bubble trapped at a distance 3.0 cm from its centre C as shown in the figure. The refractive index of the material of the sphere is 1.5. Find the apparent position of this bubble when seen through the surface of the sphere from an outside point E in air.



33. (a) (i) State Biot-Savart's law for the magnetic field due to a current carrying element. Use this law to obtain an expression for the magnetic field at the centre of a circular loop of radius 'a' and carrying a current 'I'. Draw the magnetic field lines for a current loop indicating the direction of magnetic field.
(ii) An electron is revolving around the nucleus in a circular orbit with a speed of 10^{-7} m s^{-1}. If the radius of the orbit is 10^{-10} m, find the current constituted by the revolving electron in the orbit.

OR

(b) (i) Derive an expression for the force acting on a current carrying straight conductor kept in a magnetic field. State the rule which is used to find the direction of this force. Give the condition under which this force is (1) maximum, and (2) minimum.
(ii) Two long parallel straight wires A and B are 2.5 cm apart in air. They carry 5.0 A and 2.5 A currents respectively in opposite directions. Calculate the magnitude of the force exerted by wire A on a 10 cm length of wire B.

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CLASS : XII **DURATION: 3 HRS**

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SECTION – A

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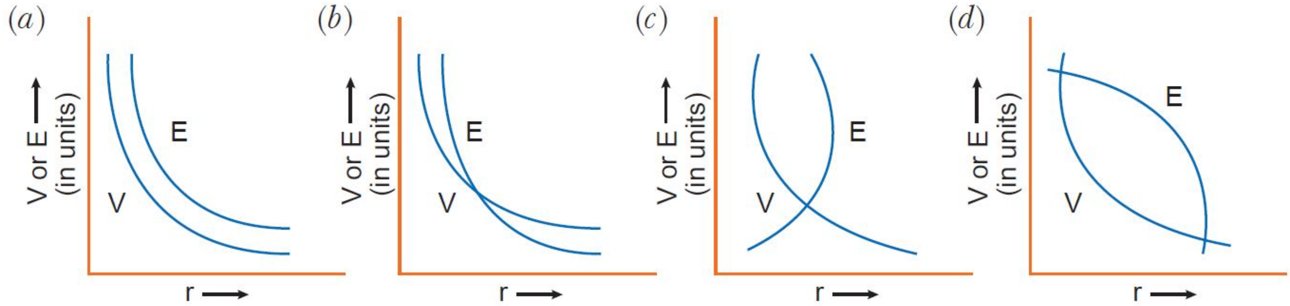
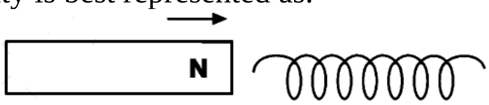
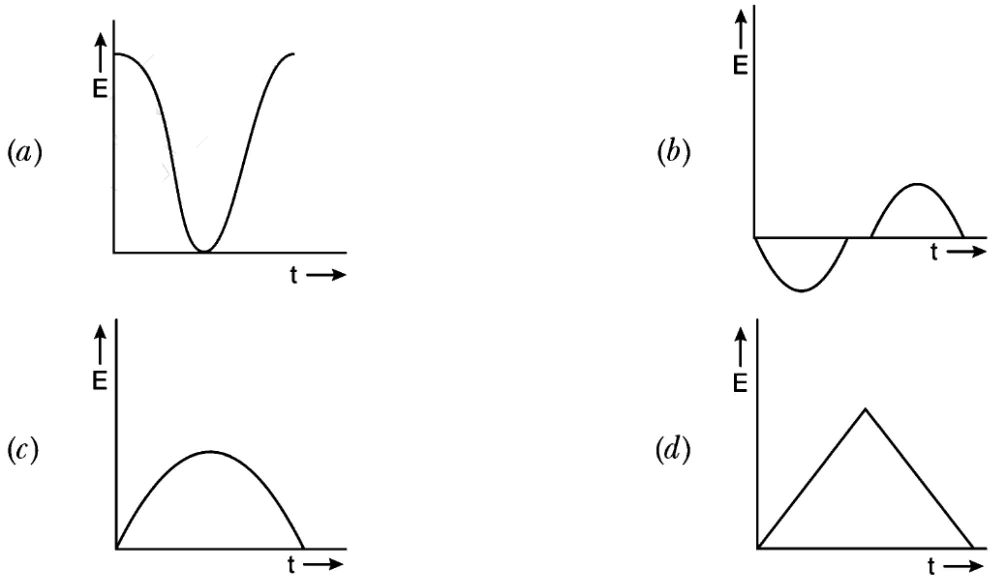


Ans: (b)

2. The variation of induced emf (E) with time t in a coil if a short bar magnet is moved along its axis with a constant velocity is best represented as:





Ans: (b)

3. 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?

(a) He should measure l_1 more accurately.

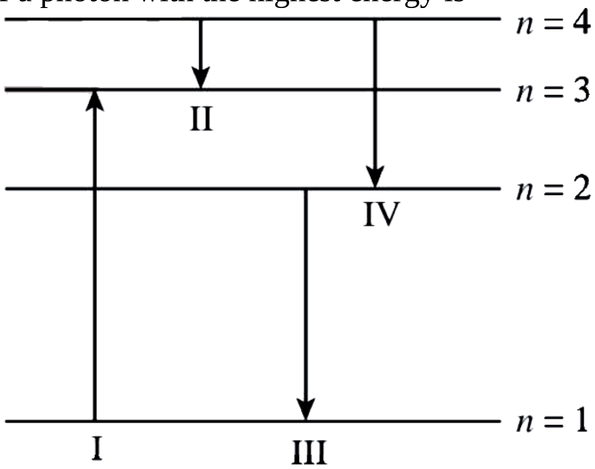
(b) He should change S to 1000 Ω and repeat the experiment.

(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.

4. The diagram shows the energy levels for an electron in a certain atom. The transition that represents the emission of a photon with the highest energy is

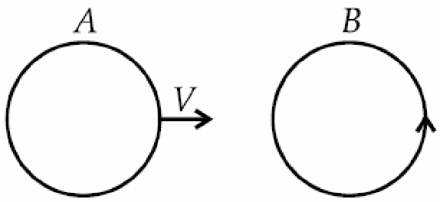


(a) I (b) II (c) III (d) IV

Ans: (c) III

In emission line I, energy is absorbed and not emitted. While in the emission lines II, III and IV, energy is emitted. The line having maximum energy is III, because energy difference between successive levels decreases rapidly with increase of n.

5. There are two coils A and B as shown in 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:



(a) there is a constant current in the clockwise direction in 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.

6. The mass density of a nucleus of mass number A is :

(a) proportional to $A^{1/3}$ (b) proportional to $A^{2/3}$

(c) proportional to A3 (d) independent of A

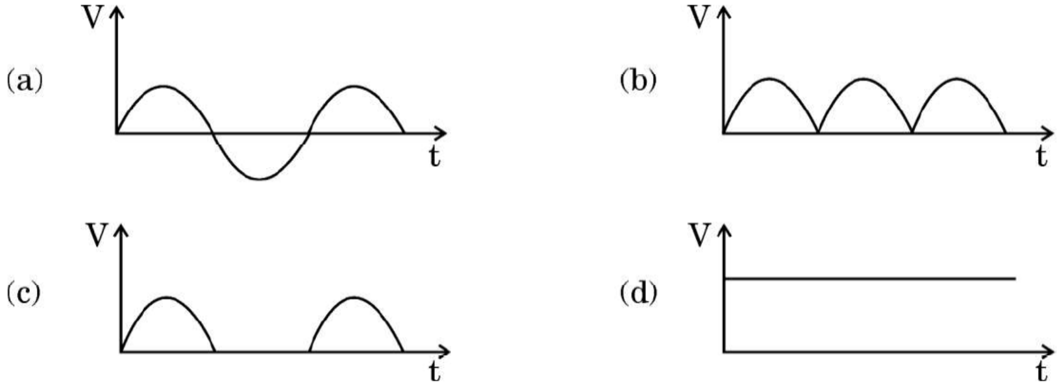
Ans: (d) independent of A

7. In the energy-band diagram of n-type Si, the gap between the bottom of the conduction band E_C and the donor energy level E_D is of the order of :

(a) 10 eV (b) 1 eV (c) 0 1 eV (d) 0 01 eV

Ans: (d) 0.01 eV

8. An ac source of voltage is connected in series with a p-n junction diode and a load resistor. The correct option for output voltage across load resistance will be :



Ans: (c)

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(a) repelled by both the poles.
(b) attracted by both the poles.
(c) repelled by the north pole and attracted by the south pole.
(d) attracted by the north pole and repelled by the south pole.
Ans: (a) Repelled by both the poles.

10. A circular coil of radius 8 0 cm and 40 turns is rotated about its vertical diameter with an angular speed of 25/π rad s-1 in a uniform horizontal magnetic field of magnitude 3.0 x 10-2 T. The maximum emf induced in the coil is:
(a) 0·12 V (b) 0·15 V (c) 0·19 V (d) 0·22 V
Ans: (c) 0·19 V

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The magnitude of flux passing through the square is:
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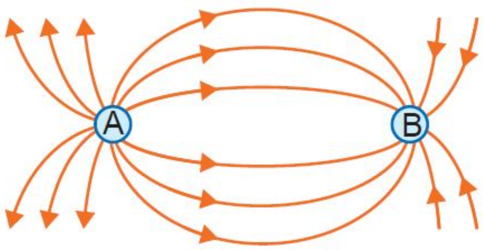
Ans: (c) $4B_0L^2Wb$

12. The spatial distribution of the electric field due to two charges (A, B) is shown in figure. Which one of the following statements is correct?



(a) A is + ve and B is – ve and |A|>|B|
(b) A is – ve and B is + ve, |A|=|B|
(c) Both are + ve but A>B
(d) Both are – ve but A>B
Ans: (a) A is + ve and B is – ve and |A|>|B|

ASSERTION-REASON BASED QUESTIONS

In the following questions, a statement of assertion (A) is followed by a statement of Reason (R). Choose the correct answer out of the following choices.

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

13. Assertion (A): The phase difference between any two points on a wavefront is zero.
Reason (R): All points on a wavefront are at the same distance from the source and thus oscillate in the same phase.
Ans: (a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).

14. Assertion (A): Photoelectric effect demonstrates the particle nature of light.
Reason (R): Photoelectric current is proportional to intensity of incident radiation for frequencies more than the threshold frequency.
Ans: (b) Both Assertion (A) and Reason (R) are true but reason (R) is the not correct explanation of the Assertion (A)

15. Assertion (A): Bohr's postulate states that the electrons in stationary orbits around the nucleus do not radiate.
Reason (R): According to classical physics, all moving electrons radiate.
Ans: (b) Both Assertion (A) and Reason (R) are true but reason (R) is the not correct explanation of the Assertion (A)
According to classical physics, all moving charged particle radiate electromagnetic radiation. So moving electrons will also radiate energy. If we see the atomic structure we find that electrons revolve around the nucleus in some particular orbits. Bohr termed these orbits as the stationary orbits as the electrons do not radiate energy as long as they are moving in these orbits. This is one of Bohr's postulates. This postulate is based on the fact that if the moving electrons radiate thereby losing energy, they have got a chance to finally fall back onto the nucleus and the atom will be collapsed.

16. Assertion (A): When a bar of copper is placed in an external magnetic field, the field lines get concentrated inside the bar.
Reason (R): Copper is a paramagnetic substance.
Ans: (d) Assertion (A) is false and Reason (R) is also false.

SECTION – B

Questions 17 to 21 carry 2 marks each.

17. Distinguish between a metal and an insulator on the basis of energy band diagrams.
Ans:

Metals	Insulators
(i) Conduction band and valence band overlap each other.	There is large energy gap between conduction band and valence band.
(ii) Conduction band is partially filled and valence band is partially empty.	Conduction band is empty. This is because no electrons can be excited to it from valence band.

OR

(a) Which charge carriers in intrinsic semiconductor will have conduction?
(b) How does the resistance of a semiconductor change when heated?
Ans: (a) Electrons and holes. These are the change carriers which are responsible for conduction. In p type of semiconductor holes are majority charge carriers while in n-type, electrons are majority charge carriers.

(b) Resistance decreases. As with rise in temperature, number of free charge carriers increases due to breaking of more and more covalent bonds and hence its resistivity decreases.

18. Consider an induced magnetic field due to changing electric field and an induced electric field due to changing magnetic field. Which one is more easily observed? Justify your answer.
Ans: Induced electric field due to changing magnetic field is easily observed. Induced electric field due to changing magnetic field can be easily produced by various ways like rotating/moving a coil in magnetic field, changing the shape of coil in magnetic field, bringing bar magnet near a coil etc.

19. Two coherent monochromatic light beams of intensities I and 4I superpose each other. Find the ratio of maximum and minimum intensities in the resulting beam.
Ans:

$$\frac{I_{max}}{I_{min}} = \frac{(\sqrt{I_1}+\sqrt{I_2})^2}{(\sqrt{I_1}-\sqrt{I_2})^2} = \frac{I_1+I_2+2\sqrt{I_1I_2}}{I_1+I_2-2\sqrt{I_1I_2}} = \frac{5I+4I}{5I-4I} = \frac{9}{1}$$

Alternatively

$$\frac{I_1}{I_2} = \frac{a^2}{b^2} = \frac{4I}{I} = \frac{4}{1} \Rightarrow \frac{a}{b} = \frac{2}{1}$$

$$\Rightarrow \frac{I_{max}}{I_{min}} = \frac{(a+b)^2}{(a-b)^2} \Rightarrow \frac{I_{max}}{I_{min}} = \frac{(2+1)^2}{(2-1)^2} = \frac{9}{1}$$

20. A charged particle enters perpendicularly a region having either (i) magnetic field or (ii) an electric field. How can the trajectory followed by the charged particle help us to know whether the region has an electric field or a magnetic field? Explain briefly.
Ans: The path of the charged particle will be circular in a magnetic field. This is due to the reason that the force acting on the particle will be at right angles to the field as well as direction of motion, resulting in a circular trajectory.
In the case of electric field, the trajectory of the particle will be determined by the equation

$$s = ut + \frac{1}{2}\left(\frac{qE}{m}\right)t^2 \qquad \left(\because s = ut + \frac{1}{2}at^2\right)$$

Where q and m are charge and mass of the particle, E is the electric field and s is the distance travelled by the particle in time t. Thus, the trajectory will be a parabolic path.

21. The ground state energy of hydrogen atom is -13.6 eV. What is the potential energy and kinetic energy of an electron in the third excited state?
Ans:

$$E_n = \frac{-13.6}{n^2}eV = \text{Total energy}$$

For third excited state n=4

$$E_4 = \frac{-13.6}{4^2} = \frac{-13.6}{16} = -0.85 \text{ eV}$$

Potential Energy = 2 x Total Energy = 2 x E4
= 2 x (-0.85) eV = - 1.70 eV
Kinetic energy = - (Total Energy) = -E4 = 0.85 eV

SECTION – C

Questions 22 to 28 carry 3 marks each.

22. In a plane electromagnetic wave, the electric field oscillates sinusoidally at a frequency of 2.0 x 10^{10} Hz and amplitude 48 V/m.

(i) What is the wavelength of a wave?

(ii) What is the amplitude of the oscillating magnetic field?

(iii) Show that the average energy density of the electric field equals the average energy density of the magnetic field. [c = 3 x 10^8 m/s]

Ans: (i) Wavelength, $\lambda = \frac{c}{v} = \frac{3\times10^8}{2\times10^{10}} = 1.5\times10^{-2} m$

(ii) $B_0 = \frac{E_0}{c} = \frac{48}{3\times10^8} = 1.6\times10^{-7} tesla$

(iii) Energy density of electric field is $U_E = \frac{1}{2}\varepsilon_0 E^2 \ldots$(i)

Energy density of Magnetic field is $U_B = \frac{1}{2\mu_0} B^2 \ldots$(ii)

where ε_0 is permittivity of free space and μ_0 is permeability of free space

We have, $E = cB$ ...(iii)

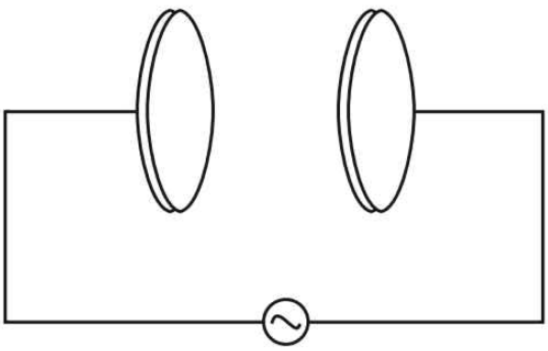
$\therefore U_E = \frac{1}{2}\varepsilon_0 (cB)^2 = c^2\left(\frac{1}{2}\varepsilon_0 B^2\right)$

But $c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$

$\therefore U_E = \frac{1}{\mu_0\varepsilon_0}\left(\frac{1}{2}\varepsilon_0 B^2\right) = \frac{1}{2\mu_0}B^2 \Rightarrow U_E = U_B$

OR

A parallel plate capacitor (fig.) made of circular plates each of radius R = 6.0 cm has a capacitance C = 100 pF. The capacitor is connected to a 230 V ac supply with an angular frequency of 300 rad/s.



(i) What is the rms value of the conduction current?

(ii) Is conduction current equal to the displacement current?

(iii) Determine the amplitude of magnetic field induction B at a point 3.0 cm from the axis between the plates.

Ans: Given R = 6.0 cm, C=100 pF = 1 × 10^{-10} F, w = 300 rad/s, V_{rms} = 230 V

(i) Impedance of circuit Z = capacitance reactance, $X_C = \frac{1}{\omega C}$

Root mean square current, $I_{rms} = \frac{V_{rms}}{Z} = V_{rms} \times \omega C$

= 230 × 300 × 10^{-10}

= 6.9 × 10^{-6} A = 6.9 μA

(ii) Yes, the conduction current is equal to the displacement current.

(iii) The whole space between the plates occupies displacement current which is equal in magnitude to the conduction current.

Magnetic field, $B = \frac{\mu_0 I r}{2\pi R^2}$

Here r = 3 cm = 3×10^{-2} m, R = 6 cm = 6×10^{-2} m

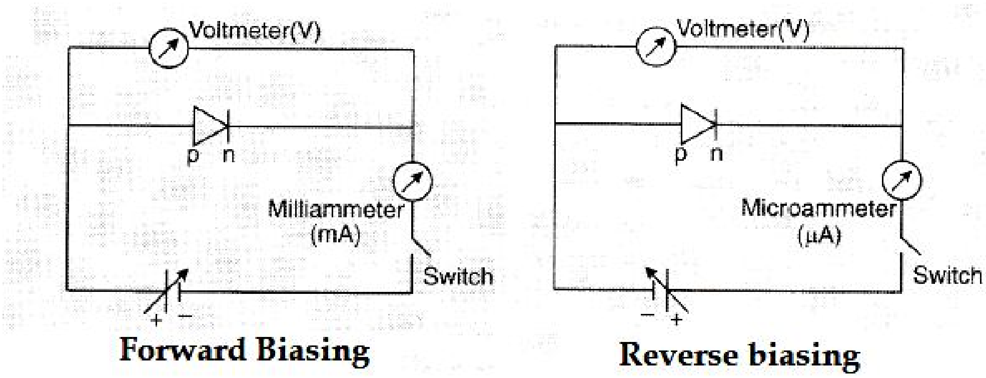
Amplitude of displacement current = Peak value of conduction current = $I_0 = I_{rms}\sqrt{2}$

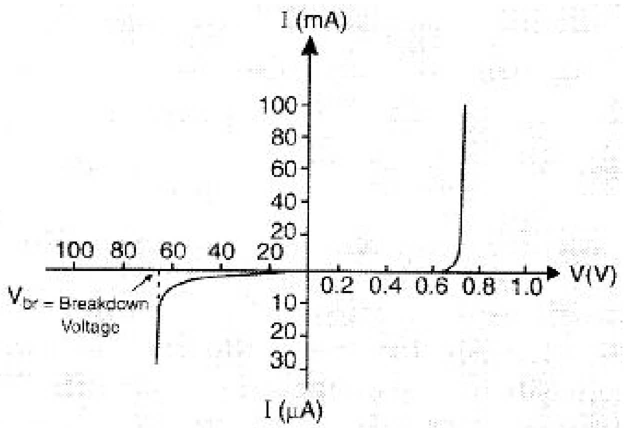
Amplitude of magnetic field, $B = \frac{\mu_0 I_0 r}{2\pi R^2} = \frac{\mu_0 I_{rms}\sqrt{2} r}{2\pi R^2}$

$= \frac{4\pi\times10^{-7}\times6.9\times10^{-6}\times1.41\times3\times10^{-2}}{2\pi\times(6\times10^{-2})^2} = 1.63\times10^{-11} T$

23. Draw the circuit arrangement for studying the V-I characteristics of a p-n junction diode in forward bias and reverse bias. Show the plot of V-I characteristic of a silicon diode.

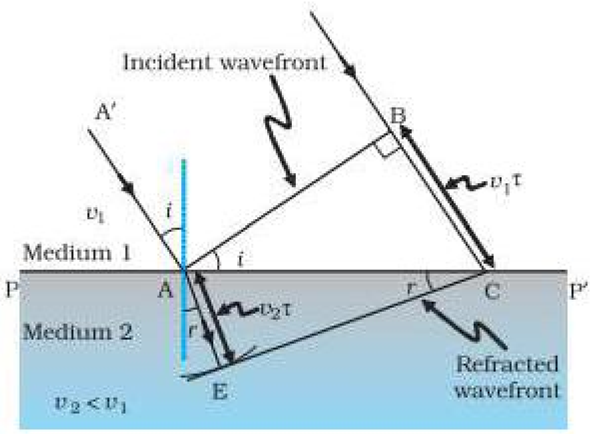
Ans:





24. Using Huygens' principle, draw a ray diagram showing ther propagation of a plane wave refracting at a plane surface separating two media. Also verify the Snell's law of refraction.

Ans:

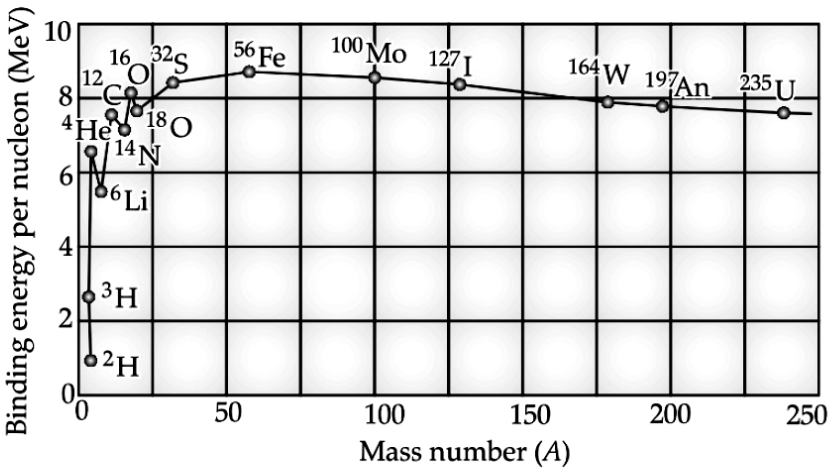


AB is incident wave front, incident at an angle i. Let τ be time taken by the wave front to travel distance BC.

BC= $v_1 \tau$ where v_1 is speed of wave in medium 1.
To determine shape of refracted wave front, we draw a sphere of radius $v_2 \tau$, where v_2 is speed of wave in medium 2.
CE represents a tangent drawn from point C on sphere, CE is the refracted wave front.

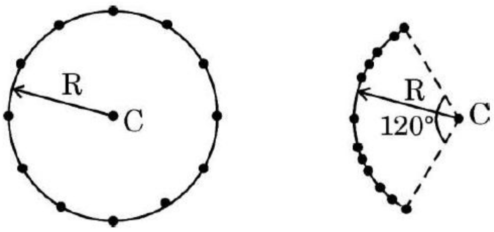
$$\sin i = \frac{BC}{AC} = \frac{v_1\tau}{AC} \qquad \sin r = \frac{AE}{AC} = \frac{v_2\tau}{AC} \qquad \frac{\sin i}{\sin r} = \frac{v_1}{v_2} = n_{21}$$

25. Draw the curve showing the variation of binding energy per nucleon with the mass number of nuclei. Using it explain the fusion of nuclei lying on ascending part and fission of nuclei lying on descending part of this curve.
Ans: From the graph, it is clear that it has a peak near A = 60. Nuclei around this are most stable. (Example: Iron)



The shape of this curve suggests two possibilities for converting significant amounts of mass into energy :
(i) **Fission reactions:** From the curve, the heaviest nuclei are less stable than the nuclei near A = 60. This suggests that energy can be released if heavy nuclei split apart into smaller nuclei. This process is called fission.
(ii) **Fusion reactions:** The curve also suggests energy can be released from the lighter elements (like hydrogen and helium) as they are less stable than heavier elements up to A~60. Thus, sticking two light nuclei together to form a heavier nucleus can also release energy. This process is called fusion. In both fission and fusion reactions, the total masses after the reaction are less than those before. Thus "missing mass" appears as energy.

26. (a) Twelve negative charges of same magnitude are equally spaced and fixed on the circumference of a circle of radius R as shown in Fig. (i). Relative to potential being zero at infinity, find the electric potential and electric field at the centre C of the circle.
(b) If the charges are unequally spaced and fixed on an arc of 120 of radius R as shown in Fig. (ii), find electric potential at the centre C.



(i) (ii)

Ans: (a) Electric potential due to point charge, $V = \frac{kq}{R}$

Value of each charge = - q , Total charge = -12q

Total potential, $V = \frac{k(-12q)}{R} = \frac{-12kq}{R} = \frac{-12q}{4\pi\varepsilon_0 R}$

By symmetry the resultant of all electric field vectors becomes zero.
So electric field is zero.
(b) Electric potential is a scalar quantity and does not depend on placement of charges

Therefore, $V = \frac{-12kq}{R} = \frac{-12q}{4\pi\varepsilon_0 R}$

27. A long solenoid of radius r consists of n turns per unit length. A current $I = I_0 \sin \omega t$ flows in the solenoid. A coil of N turns is wound tightly around it near its centre. What is :
(a) the induced emf in the coil?
(b) the mutual inductance between the solenoid and the coil?
Ans: (a) magnetic field produced in the solenoid near the center
$B = \mu_o n I$
Flux linked with the coil wound over solenoid
$\phi = NBA = N\pi r^2 B$
$= N\pi r^2 \mu_o n I$

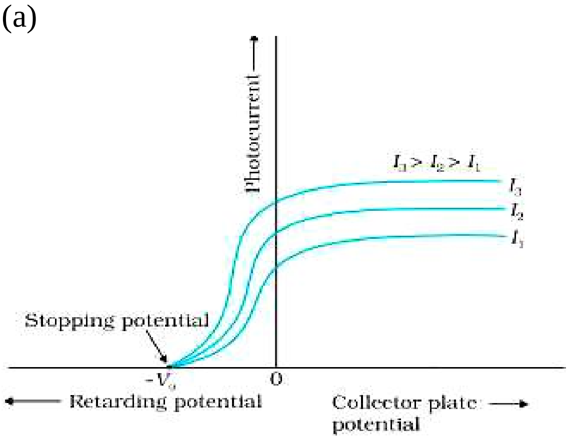
Induced emf $e = \frac{-d\phi}{dt} = -\pi r^2 N n \mu_o \frac{dI}{dt}$ (i)

$= -\mu_o \pi r^2 n N I_o \omega \cos \omega t$

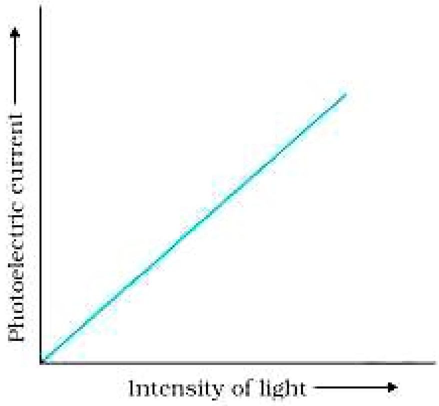
b) comparing Eq (i) with $e = -M\frac{dI}{dt}$

$M = \mu_o \pi r^2 n N$

28. How does Einstein's photoelectric equation explain the emission of electrons from a metal surface? Explain briefly.
Plot the variation of photocurrent with :
(a) collector plate potential for different intensity of incident radiation, and
(b) intensity of incident radiation.
Ans: According to Einstein's photoelectric equation, An electron absorbs a quantum of energy 'hυ' of incident radiation. If the energy of absorbed quantum exceeds the minimum energy needed by the electron to escape from the metal surface (work function φo), the electron is emitted.
$K_{max} = h\upsilon - \varphi o$
(a)



(b)



SECTION – D (Case Study Based Questions)

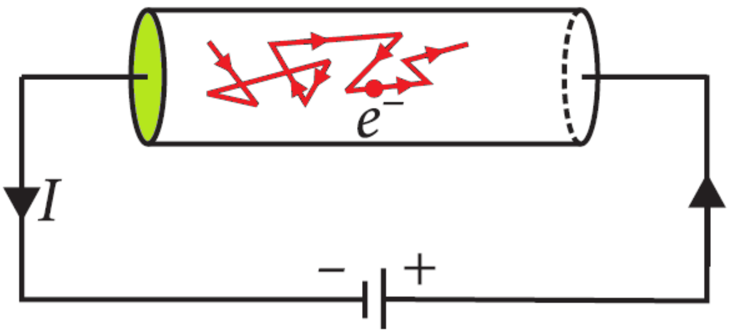
Questions 29 to 30 carry 4 marks each.

29. Case-Study 1:

Read the following paragraph and answer the questions

Mechanism of Current Flow in a Conductor

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 m s^{-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 again 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.



(i) Magnitude of drift velocity per unit electric field is

(a) current density (b) current (c) resistivity (d) mobility

(ii) 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)

(iii) 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 speeds 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.

(iv) Drift speed of electrons in a conductor is very small *i.e.*, $i = 10^{-4}$ m s^{-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.

OR

(v) 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. (i) (d) : Mobility is defined as the magnitude of drift velocity per unit electric field.

Mobility, $\mu = \dfrac{|v_d|}{E}$

(ii) (c) : Drift velocity, $v_d = \dfrac{I}{neA}$

where the symbols have their usual meanings.
(iii) (b) : $I = neAv_d$
v_d is of order of few m s^{-1}, e = 1.6×10^{-19} C,
A is of the order of mm^2, so a large I is due to a large value of n in conductors.
(iv) (c) : 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.
(v) (b) : Here,
Number density of free electrons, n = 8.5×10^{28} m^{-3}
Area of cross-section of a wire, A = 2.0×10^{-6} m^2
Length of the wire, l = 3.0 m
Current, I = 3.0 A

The drift velocity of an electron is $v_d = \dfrac{I}{neA}$

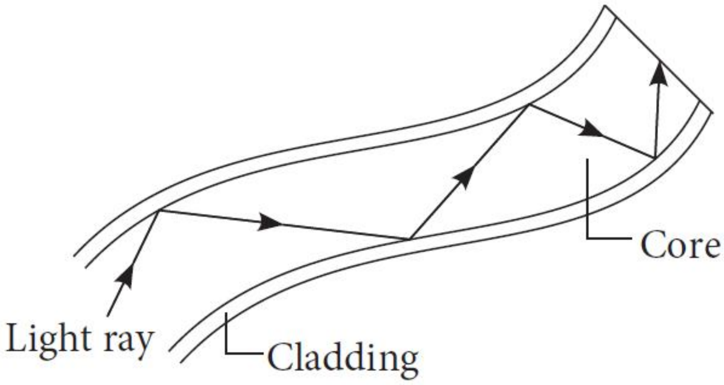
The time taken by the electron to drift from one end to other end of the wire is

$$t = \frac{l}{v_d} = \frac{l\,neA}{I} = \frac{3.0 \times 8.5 \times 10^{28} \times 1.6 \times 10^{-19} \times 2.0 \times 10^{-6}}{3.0} = 2.7 \times 10^4 s$$

30. Case-Study 2:

Read the following paragraph and answer the questions.

An optical fibre is a thin tube of transparent material that allows light to pass through, without being refracted into the air or another external medium. It make use of total internal reflection. These fibres are fabricated in such a way that light reflected at one side of the inner surface strikes the other at an angle larger than critical angle. Even, if fibre is bent, light can easily travel along the length.

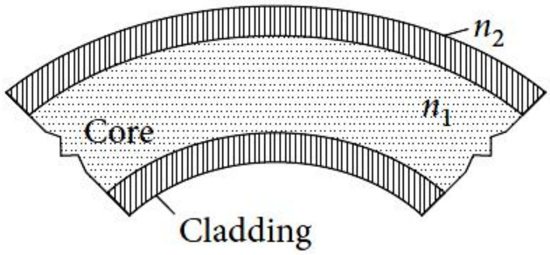


(i) Which of the following is based on the phenomenon of total internal reflection of light?
(a) Sparkling of diamond
(b) Optical fibre communication
(c) Instrument used by doctors for endoscopy
(d) All of these

(ii) A ray of light will undergo total internal reflection inside the optical fibre, if it
(a) goes from rarer medium to denser medium
(b) is incident at an angle less than the critical angle
(c) strikes the interface normally
(d) is incident at an angle greater than the critical angle

(iii) If in core, angle of incidence is equal to critical angle, then angle of refraction will be
(a) 0°
(b) 45°
(c) 90°
(d) 180°

(iv) In an optical fibre (shown), correct relation for refractive indices of core and cladding is



(a) $n_1 = n_2$
(b) $n_1 > n_2$
(c) $n_1 < n_2$
(d) $n_1 + n_2 = 2$

OR

(v) If the value of critical angle is 30° for total internal reflection from given optical fibre, then speed of light in that fibre is
(a) 3×10^8 m s^{-1}
(b) 1.5×10^8 m s^{-1}
(c) 6×10^8 m s^{-1}
(d) 4.5×10^8 m s^{-1}

Ans. (i) (d) : Total internal reflection is the basis for following phenomenon:
(a) Sparkling of diamond.
(b) Optical fibre communication.
(c) Instrument used by doctors for endoscopy.
(ii) (d) : Total internal reflection (TIR) is the phenomenon that involves the reflection of all the incident light off the boundary. TIR only takes place when both of the following two conditions are met:
The light is in the more denser medium and approaching the less denser medium.
The angle of incidence is greater than the critical angle.
(iii) (c) : If incidence of angle, i = critical angle C, then angle of refraction, $r = 90°$
(iv) (b) : In optical fibres, core is surrounded by cladding, where the refractive index of the material of the core is higher than that of cladding to bound the light rays inside the core.

(v) (b) : From Snell's law, $\sin C = {}_1n_2 = \dfrac{v_1}{v_2}$

where, C = critical angle = 30° and v_1 and v_2 are speed of light in medium and vacuum, respectively. We know that, $v_2 = 3 \times 10^8$ m s^{-1}

$\therefore \sin 30^0 = \dfrac{v_1}{3\times10^8} \Rightarrow v_1 = 3\times10^8 \times \dfrac{1}{2} = 1.5\times10^8 m/s$

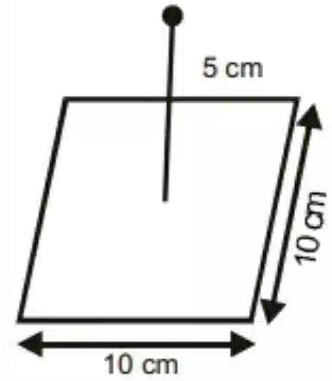
SECTION – E

Questions 31 to 33 carry 5 marks each.

31. (i) Define electric flux. Write its SI unit.

(ii) "Gauss's law in electrostatics is true for any closed surface, no matter what its shape or size is." Justify this statement with the help of a suitable example.

(iii) A point charge + 10 μC is at a distance 5 cm directly above the centre of a square of side 10 cm as shown in figure. What is the magnitude of the electric flux through the square?



Ans: (i) Total number of electric field lines crossing a surface normally is called electric flux. Its SI unit is Nm^2C^{-1} or Vm.

(ii) According to Gauss theorem, the electric flux through a closed surface depends only on the net charge enclosed by the surface and not upon the shape or size of the surface.

For any closed arbitrary shape of the surface enclosing a charge the outward flux is the same as that due to a spherical Gaussian surface enclosing the same charge.

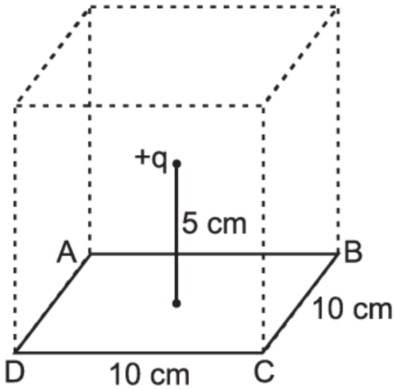
Justification: This is due to the fact that

(a) electric field is radial and

(b) the electric field $E \propto \frac{1}{R^2}$

Thus, electric field at each point inside a charged thin spherical shell is zero.

(iii) Obviously the given square ABCD of side 10 cm is one face of a cube of side 10 cm. At the centre of this cube a charge + q =10 μC is placed.



According to Gauss's theorem, the total electric flux through the six faces of cube $= \frac{q}{\varepsilon_0}$

$\therefore$ Total electric flux through square $= \frac{1}{6}\frac{q}{\varepsilon_0} = \frac{1}{6} \times \frac{10\times10^{-6}}{8.85\times10^{-12}} = 1.88\times10^5\, Nm^2C^{-1}$

OR

(i) Consider a system of n charges $q_1, q_2, \ldots q_n$, with position vectors relative $\vec{r_1}, \vec{r_2}, \vec{r_3}, \ldots\ldots \vec{r_n}$ to some origin 'O'. Deduce the expression for the net electric field $\vec{E}$ at a point P with position vector $\vec{r_p}$, due to this system of charges.

(ii) Two charges of value 2 μC and -50 μC are placed 80 cm apart. Calculate the distance of the point from the smaller charge where the intensity is zero.

Ans: **Electric field due to a system of point charges.**

Consider a system of n charges q_1, q_2, ... q_n, with position vectors relative $\vec{r_1}, \vec{r_2}, \vec{r_3}, ...\vec{r_n}$ to some origin 'O'. We wish to determine the electric field at point P whose position vector is $\vec{r}$. According to Coulomb's law, the force on charge q_0 due to charge q_1 is

$$\vec{F_1} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_0}{r_{1p}^2}\hat{r}_{1p}$$

where $\hat{r}_{1p}$ is a unit vector in the direction from q_1 to P and r_{1P} is the distance between q_1 and P.

Hence the electric field at point P due to charge q_1 is $\vec{E_1} = \frac{\vec{F_1}}{q_0} = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_{1p}^2}\hat{r}_{1p}$

Similarly, electric field at P due to charge q_2, $\vec{E_2} = \frac{1}{4\pi\varepsilon_0}\frac{q_2}{r_{2p}^2}\hat{r}_{2p}$

According to the principle of superposition of electric fields, the electric field at any point due to a group of point charges is equal to the vector sum of the electric fields produced by each charge individually at that point, when all other charges are assumed to be absent. Hence, the electric field at point P due to the system of n charges is

$$\vec{E} = \vec{E_1} + \vec{E_2} + ... + \vec{E_n}$$

$$\Rightarrow \vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_{1p}^2}\hat{r}_{1p} + \frac{1}{4\pi\varepsilon_0}\frac{q_2}{r_{2p}^2}\hat{r}_{2p} + ... + \frac{1}{4\pi\varepsilon_0}\frac{q_n}{r_{np}^2}\hat{r}_{np}$$

$$\Rightarrow \vec{E} = \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{n}\frac{q_i}{r_{ip}^2}\hat{r}_{ip}$$

(ii) The electric field cannot be zero at a point between the charges because the two charges are of opposite signs. The electric field cannot be zero at a point to the right of B because magnitude of charge at B is of opposite sign and is greater in magnitude than the charge at A.

Let the resultant electric field be zero at P located at a distance x metre to the left of point A.

∴ AP = x metre and BP = (x + 0.8) m

$E_A = E_B$

$$\Rightarrow k\frac{2\times10^{-6}}{x^2} = k\frac{50\times10^{-6}}{(x+0.8)^2} \Rightarrow x^2 = \frac{(x+0.8)^2}{25}$$

$$\Rightarrow x = \pm\frac{(x+0.8)}{5} \Rightarrow 5x = \pm(x+0.8)g$$

$\Rightarrow 5x = x + 0.8$ or $5x = -x - 0.8 \Rightarrow 4x = 0.8$ or $6x = -0.8$

$\Rightarrow x = 0.2$ m or $x = -0.8/6 \Rightarrow x = 0.2$ m = 20 cm

The negative answer is not possible because in that case P will lie between the charges.

Therefore, x = 20 cm.

32. (a) (i) (1) Write two points of difference between an interference pattern and a diffraction pattern.

(2) Name any two factors on which the fringe width in a Young's double-slit experiment depends.

(ii) In Young's double-slit experiment, the two slits are separated by a distance equal to 100 times the wavelength of light that passes through the slits. Calculate:

(1) the angular separation in radians between the central maximum and the adjacent maximum.

(2) the distance between these two maxima on a screen 50 cm from the slits.

Ans: (i) (1) (a) The interference pattern has a number of equally spaced bright and dark bands while diffraction pattern has a central bright maximum which is twice as wide as the other maxima.

(b) Interference pattern is obtained by superposing two waves originating from two narrow slits, while diffraction pattern is a superposition of a continuous family of waves originating from each point on a single slit.
(c) The maxima in interference pattern is obtained at angle λ *l* a , while the first minima is obtained at same angle λ *l* a for diffraction pattern.
(d) In interference pattern the intensity of bright fringes remain same while in diffraction the intensity falls as we go to successive maxima away from the center on either side.
(2) Factors affecting fringes width
Wave length (λ) / distance of screen from slits (D) / separation between slits (d).

(ii) (1) $d \sin\theta = n\lambda$

$n=1$

$$\sin\theta = \frac{\lambda}{d}$$

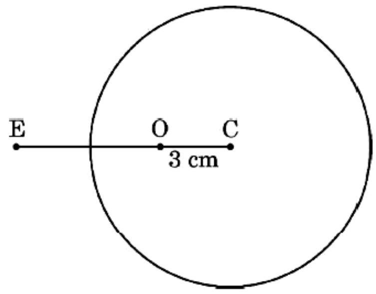
For small angle $\sin\theta \approx \theta = \frac{\lambda}{100\lambda} = \frac{1}{100}$ radian.

(2) $\beta = \frac{\lambda D}{d} = \theta D = \frac{1}{100} \times 50 \times 10^{-2} = 50 \times 10^{-4} m$

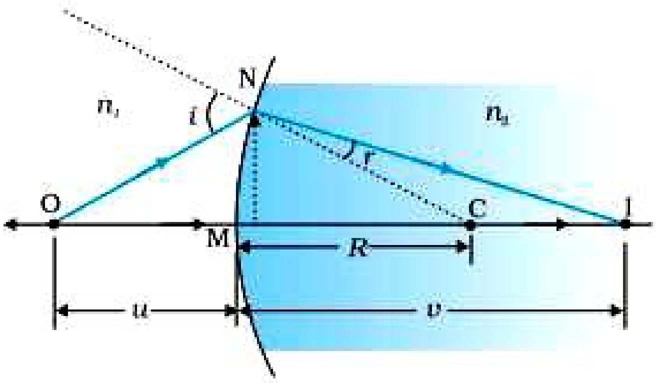
$= 5$ mm

OR

(b) (i) A spherical surface of radius of curvature R separates two media of refractive indices n_1 and n_2. A point object is placed in front of the surface at distance u in medium of refractive index n_1 and its image is formed by the surface at distance v, in the medium of refractive index n_2. Derive a relation between u and v.
(ii) A solid glass sphere of radius 6.0 cm has a small air bubble trapped at a distance 3.0 cm from its centre C as shown in the figure. The refractive index of the material of the sphere is 1.5. Find the apparent position of this bubble when seen through the surface of the sphere from an outside point E in air.



Ans: (i) Assume that the aperture of the surface is small as compared to other distance involved, so that small angle approximation can be made.



For small angles, for ΔNOC, i is the exterior angle

$\therefore$ i = $\angle NOM + \angle NCM$

i= $\dfrac{MN}{OM} + \dfrac{MN}{MC}$ (i)

Similarly r = $\angle NCM - \angle NIM$

$= \dfrac{MN}{MC} - \dfrac{MN}{MI}$ (ii)

By Snell's law, $n_1 \sin i = n_2 \sin r \Rightarrow$ for small angles, $n_2\, i = n_2\, r$
substituting i and r from (i) and (ii) we get

$$\frac{n_1}{OM} + \frac{n_2}{MI} = \frac{n_2 - n_1}{MC}$$

Applying Cartesian coordinates

OM= -u, MI= + v , MC= +R

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$$

(ii) $\dfrac{n_2}{v} - \dfrac{n_1}{u} = \dfrac{n_2 - n_1}{R}$

R= - 6 cm, u = - 3cm , n_1 =1.5 n_2 = 1

$$\frac{1}{v} + \frac{1.5}{3} = \frac{1-1.5}{-6} \Rightarrow \frac{1}{v} = \frac{0.5}{6} - \frac{1.5}{3}$$

$$\Rightarrow \frac{1}{v} = \frac{0.5-3}{6} \Rightarrow \frac{1}{v} = \frac{-2.5}{6} \Rightarrow v = -2.4 \text{ cm}$$

from the left surface inside the sphere

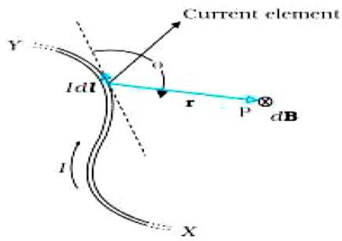
33. (a) (i) State Biot-Savart's law for the magnetic field due to a current carrying element. Use this law to obtain an expression for the magnetic field at the centre of a circular loop of radius 'a' and carrying a current 'I'. Draw the magnetic field lines for a current loop indicating the direction of magnetic field.

(ii) An electron is revolving around the nucleus in a circular orbit with a speed of 10^{-7} m s^{-1}. If the radius of the orbit is 10^{-10} m, find the current constituted by the revolving electron in the orbit.

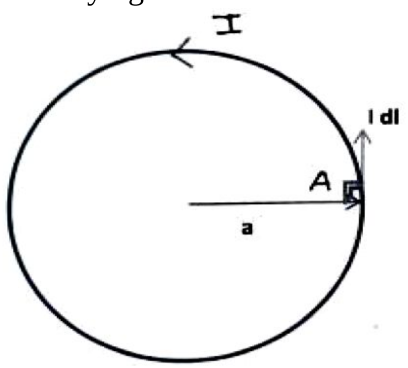
Ans: (i) The magnetic field at a point due to a current carrying element is proportional to magnitude of current, element length and inversely proportional to the square of the distance from the element.

$$\vec{dB} = \frac{\mu_o}{4\pi} I \frac{\vec{dl} \times \vec{r}}{r^3}$$

$$|dB| = \frac{\mu_o}{4\pi} \frac{Idl \sin\theta}{r^2}$$



Consider a circular coil of radius a carrying current I.



According to Biot-Savart's law

$$\left|\vec{dB}\right| = \frac{\mu_o}{4\pi}\frac{Idl\sin\theta}{r^2}$$

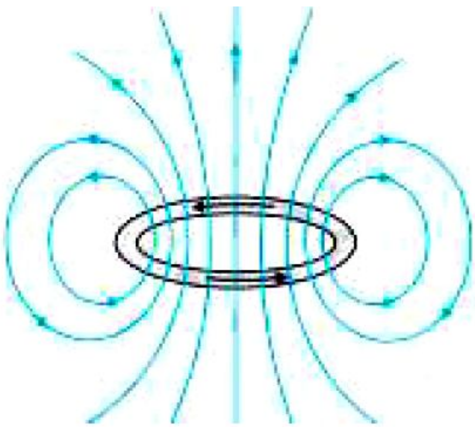
At point A $\quad I\,\vec{dl} \perp \vec{a}$

$\therefore \theta = 90^o, \sin 90^o = 1$

Hence dB= $\frac{\mu_o}{4\pi}\frac{Idl}{a^2}$

Magnetic field at centre

$$B = \int_o^{2\pi a} dB = \int_0^{2\pi a} \frac{\mu_o}{4\pi}\frac{Idl}{a^2} \Rightarrow B = \frac{\mu_o}{4\pi}\times\frac{I}{a^2}\times 2\pi a \Rightarrow B = \frac{\mu_o I}{2a}$$



ii) $\quad q=e, \quad v=10^7 ms^{-1}, r=10^{-10} m$

$$i = \frac{q}{T} = \frac{qv}{2\pi r} = \frac{ev}{2\pi r} = \frac{1.6\times10^{-19}\times10^7}{2\times\pi\times10^{-10}}$$

$$= \frac{0.8}{\pi}\times10^{-2} A = 0.255\times10^{-2} A \quad = 2.55 \text{ mA}$$

OR

(b) (i) Derive an expression for the force acting on a current carrying straight conductor kept in a magnetic field. State the rule which is used to find the direction of this force. Give the condition under which this force is (1) maximum, and (2) minimum.

(ii) Two long parallel straight wires A and B are 2.5 cm apart in air. They carry 5.0 A and 2.5 A currents respectively in opposite directions. Calculate the magnitude of the force exerted by wire A on a 10 cm length of wire B.

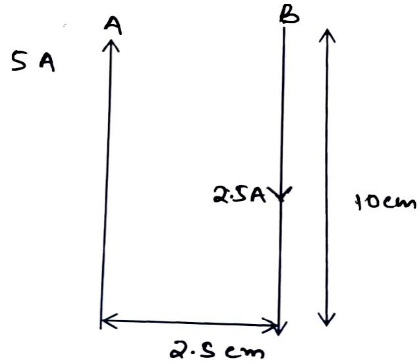
Ans: (i) Consider a rod of uniform cross sectional area A and length l. Let the number density of mobile charge carriers in it be n. Thus the total number of mobile charge carriers in it is n lA. For steady current I, drift velocity of electrons $\vec{v_d}$, in the presence of external magnetic field $\vec{B}$, the force on these carriers is

$$\vec{F} = n\,l\,Aq(\vec{v_d}\times\vec{B}) = \left[\vec{j}Al\right]\times\vec{B} = I(\vec{l}\times\vec{B})$$

Where $nq\vec{v_d}$ is current density ($\vec{j}$) and $\left|\vec{j}A\right|$ is current (I)

Fleming's left hand Rule: If forefinger, middle finger and thumb are stretched in mutually perpendicular directions, such that forefinger indicates the direction of magnetic field, middle finger indicates the direction of current in the conductor, then thumb indicates the direction of force on the conductor.

(ii)



F= $\frac{\mu_o}{4\pi}\frac{2I_1I_2}{d}l = \frac{10^{-7}\times 2\times 5\times 2.5}{2.5\times 10^{-2}}\times 10\times 10^{-2}N$ = 10^{-5} N