Prepzy

CBSE EXAMINATION PAPER-2023

PHYSICS

(Solved)

Time allowed : 3 hours　　　　Maximum Marks : 87

General Instructions :

Read the following instructions carefully and follow them :

i. This question paper contains **41 questions.** All questions are **compulsory.**
ii. This question paper is divided into **5 sections.**
iii. **Section A** – questions number **1 to 18** are multiple choice questions Each question carries **1 marks.**
iv. **Section B** – questions number **19 to 27** are very short answer Each question carries **2 marks.**
v. **Section C** – questions number **28 to 34** are short answer Each question carries **3 marks.**
vi. **Section D** – questions number **35 to 35** are case based questions
vii. **Section E** – questions number **36 to 41** are long answer Each question carries **5 marks.**
viii. There is no overall choice given in the question paper. However, an internal choice has been provided in few questions.
ix. Use of calculator is NOT allowed.

Section A

Question 1.

An electron experiences a force $(1{\cdot}6 \times 10^{16}\ N)\ \hat{i}$ in an electric field E. The electric field E is:

[1 Marks]

(A) $(1 \cdot 0 \times 10^{3}$ N/C) î

(B) $(1 \cdot 0 \times 10^{-3}$ N/C) î

(C) $-(1 \cdot 0 \times 10^{3}$ N/C) î

(D) $-(1 \cdot 0 \times 10^{-3}$ N/C) î

Explanation:

To find the electric field E, we can use the formula F = qE, where F is the force experienced by the charge, q is the charge of the electron (approximately -1.6×10^{-19} C), and E is the electric field strength. Given the force $F = 1.6 \times 10^{16}$ N, we can rearrange this to find E = F/q. Plugging in the values, we get $E = (1.6 \times 10^{16}$ N) / $(-1.6 \times 10^{-19}$ C) $= -1.0 \times 10^{3}$ N/C. Therefore, the correct answer is $-(1 \cdot 0 \times 10^{3}$ N/C) î.

Question 2. Which one of the following is not a scalar quantity?

[1 Marks]

(A) Electric field

(B) Voltage

(C) Resistivity

(D) Power

Explanation: The electric field is a vector quantity because it has both magnitude and direction. In contrast, resistivity, voltage, and power are scalar quantities that only have magnitude.

Question 3.

The current density due to drift of electrons in a conductor is given by:

(symbols have their usual meanings)

[1 Marks]

(A) n e v_d

(B) n e A v_d

(C) n v_d/e A

(D) n A v_d/e

Explanation:

The correct option is 'n e v_d' because current density (J) is defined as the amount of charge per unit area per unit time. Here, 'n' represents the number density of charge carriers (electrons), 'e' is the charge of an electron, and 'v_d' is the drift velocity of the electrons. Therefore, combining these factors gives the expression for current density.

Question 4.

Which of the following graphs correctly represents the variation of the magnitude of the magnetic field outside a straight infinite current carrying wire of radius 'a' as a function of distance 'r' from the centre of the wire?

[1 Marks]

(A) Graph A

(B) Graph D

(C) Graph C

(D) Graph B

Explanation: The correct graph illustrates that the magnetic field strength varies inversely with distance 'r' from the wire, following Ampère's law. As the distance increases, the magnetic field strength decreases accordingly. This behavior is typically represented by a hyperbolic or decreasing function in the graphs.

Question 5.

A particle of mass m and charge q moving with a uniform velocity $v = v_0 \hat{x}\, i + v_0 \hat{y}\, j$ enters a region with a magnetic field $B = B_0\hat{j}$. After some time, an electric field $E = E_0 \hat{j}$ is also switched on in the region. The resulting path described by the particle will be:

[1 Marks]

(A) a helix with increasing pitch

(B) a circle in x-z plane

(C) a helix with constant pitch

(D) a parabola in x-y plane

Explanation:

The correct option is 'a helix with constant pitch'. Initially, the particle moves in a plane perpendicular to the magnetic field due to the Lorentz force, which will cause it to move in a circular path in the x-y plane. When the electric field is applied parallel to the magnetic field, it introduces a force in the same direction, resulting in a linear acceleration along the $\hat{j}$ direction. This causes the particle to spiral upwards, maintaining a constant circular motion while translating linearly, thus forming a helix with constant pitch.

Question 6.

An inductor, a capacitor and a resistor are connected in series across an ac source of voltage. If the frequency of the source is decreased gradually, the reactance of :

[1 Marks]

(A) inductor decreases and the capacitor increases.

(B) inductor increases and the capacitor decreases.

(C) both the inductor and the capacitor decreases.

(D) both the inductor and the capacitor increases.

Explanation:

As the frequency of the AC source decreases, the reactance of the inductor ($XL = 2\pi fL$) decreases because it is directly proportional to the frequency. Conversely, the reactance of the capacitor ($XC = 1/(2\pi fC)$) increases because it is inversely proportional to the frequency. Therefore, the correct option is that the inductor's reactance decreases and the capacitor's reactance increases.

Question 7.

The electromagnetic radiations used to kill germs in water purifiers are called :

[1 Marks]

(A) Ultraviolet rays

(B) Gamma rays

(C) Infrared waves

(D) X-rays

Explanation:

The correct answer is Ultraviolet rays. Ultraviolet (UV) rays are known for their germicidal properties, and they are commonly used in water purifiers to eliminate harmful microorganisms by disrupting their DNA.

Question 8.

In the wave picture of light, the intensity I of light is related to the amplitude A of the wave as :

[1 Marks]

(A) I∞1/A^2

(B) I∞A

(C) I∞A^2

(D) I∞√A

Explanation:

The correct option is I ∞ A^2. In the wave theory of light, the intensity of light is proportional to the square of the amplitude of the wave. This is because intensity is related to the energy carried by the wave, and energy is proportional to the square of the amplitude.

Question 9.

In a single-slit diffraction experiment, the width of the slit is halved. The width of the central maximum, in the diffraction pattern, will become :

[1 Marks]

(A) one-fourth

(B) four times

(C) half

(D) twice

Explanation:

When the width of the slit is halved, the width of the central maximum in a single-slit diffraction pattern increases. This is because the width of the central maximum is inversely proportional to the slit width. Thus, if the slit width is halved, the central maximum becomes twice as wide.

Question 10.

A graph is plotted between the stopping potential (on y-axis) and the frequency of incident radiation (on x-axis) for a metal. The product of the slope of the straight line obtained and the magnitude of charge on an electron is equal to :

[1 Marks]

(A) h

(B) h/2c

(C) 2h/c

(D) h/c

Explanation: The stopping potential (V) is related to the frequency (ν) of the incident radiation by the equation V = (h/eν) - (φ/e), where h is Planck's constant, e is the charge of the electron, and φ is the work function. The slope of the graph (dV/dν) is equal to h/e. Therefore, the product of the slope and the charge of the electron (e) is (h/e) * e = h, which shows that the correct answer is 'h'.

Question 11.

Light of frequency 6·4 *10^14 Hz is incident on a metal of work function 2·14 eV. The maximum kinetic energy of the emitted electrons is about :

[1 Marks]

(A) 0·25 eV

(B) 1·02 eV

(C) 0·10 eV

(D) 0·51 eV

Explanation:

To find the maximum kinetic energy (KE) of the emitted electrons, we can use the photoelectric equation: KE = hf - W, where h is Planck's constant (4.14 x 10^-15 eV·s), f is the frequency of the light, and W is the work function. First, we calculate hf: hf = (4.14 x 10^-15 eV·s) * (6.4 x 10^14 Hz) = 2.65 eV. Then, we subtract the work function: KE = 2.65 eV - 2.14 eV = 0.51 eV. Therefore, the correct answer is 0.51 eV.

Question 12.

The ratio of maximum frequency and minimum frequency of light emitted in Balmer series of hydrogen spectrum, in Bohr's model is

[1 Marks]

(A) 16/7

(B) 11/7

(C) 9/5

(D) 11/9

Explanation:

In the Balmer series of the hydrogen spectrum, the maximum frequency corresponds to the transition from n=2 to n=infinity, and the minimum frequency corresponds to the transition from n=3 to n=2. The ratio of these frequencies can be calculated using the formula for the frequency of emitted light in the Bohr model. The correct ratio of maximum frequency to minimum frequency results in the option 9/5.

Question 13.

At a certain temperature in an intrinsic semiconductor, the electrons and holes concentration is 1·5*10^16 m-3. When it is doped with a trivalent dopant, hole concentration increases to 4·5 10^22 m-3. In the doped semiconductor, the concentration of electrons (ne) will be :

[1 Marks]

(A) 5*10^9 m-3

(B) 5*10^7 m-3

(C) 6.75*10^38 m-3

(D) 3*10^6 m-3

Explanation:

In a trivalent doped semiconductor, the concentration of holes (p) can be approximated by p ≈ Na (the concentration of acceptor ions). Given that the hole concentration increases to 4.5 × 10^22 m-3, we can find the electron concentration (n) using the mass action law for semiconductors, which states that n * p = ni^2 (where ni is the intrinsic carrier concentration, approximately 1.5 × 10^16 m-3 in this case). Thus, n = ni^2 / p = $(1.5 \times 10^{16})^2$ / (4.5 × 10^22) = 5 × 10^9 m-3. Therefore, the correct answer is 5 × 10^9 m-3.

Question 14.

If a p-n junction diode is reverse biased,

[1 Marks]

(A) the potential barrier remains unaffected.

(B) the potential barrier is lowered.

(C) the potential barrier is raised.

(D) the current is mainly due to majority carriers.

Explanation:

The correct option is 'the potential barrier is raised.' In a reverse-biased p-n junction diode, the voltage applied increases the potential barrier, making it harder for charge carriers to cross the junction. This enhances the depletion region and inhibits current flow.

Question 15.

A voltage signal is described by :

for a cycle. Its rms value is :

[1 Marks]

(A) V0/√2

(B) V0

(C) V0/2

(D) √2 V0

Explanation: The correct option is V0/√2. The RMS (Root Mean Square) value of a sinusoidal voltage signal is derived from the peak voltage (V0) and is calculated as V0 divided by √2, which accurately represents the effective value of the voltage during one complete cycle.

Question 16.

Assertion (A) : The internal resistance of a cell is constant.

Reason (R) : Ionic concentration of the electrolyte remains same during use of a cell.

[1 Marks]

(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 false and Reason (R) is also false.

(D) Assertion (A) is true, but Reason (R) is false.

Explanation:

Assertion (A) is false because the internal resistance of a cell is not constant; it changes with various factors like temperature and the state of charge. Reason (R) is also false since the ionic concentration of the electrolyte changes as the cell is used, affecting its performance.

Question 17.

Assertion (A) : When radius of a circular loop carrying a steady current is doubled, its magnetic moment becomes four times.

Reason (R): The magnetic moment of a circular loop carrying a steady current is proportional to the area of the loop.

[1 Marks]

(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 false and Reason (R) is also false.

(D) Assertion (A) is true, but Reason (R) is false.

Explanation:

Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A). This is because the magnetic moment (μ) of a circular loop is given by the formula μ = I * A, where A is the area of the loop. When the radius is doubled, the area increases by a factor of four ($A = \pi r^2$), thus making the magnetic moment four times greater.

Question 18.

Assertion (A): The nucleus 7/3 X is more stable than the nucleus 4/3 Y.

Reason (R): 7/3 X contains more number of protons.

[1 Marks]

(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 false and Reason (R) is also false.

(D) Assertion (A) is true, but Reason (R) is false.

Explanation:

The assertion is incorrect because a stable nucleus is not determined solely by the number of protons; it also depends on the ratio of neutrons to protons. 7/3 X being more stable than 4/3 Y is not necessarily true as the stability is influenced by other factors like neutron-proton balance.

Section B

Question 19. A wire of length l is in the form of a circular loop A of one turn. This loop is reshaped into loop B of three turns. Find the ratio of the magnetic fields at the centres of loop A and loop B for the same current through them.

[2 Marks]

Answer: The magnetic field at the center of a circular loop is given by the formula $B = (\mu_0 * I) / (2 * R)$, where μ_0 is the permeability of free space, I is the current, and R is the radius of the loop. For loop A with one turn, $B_1 = (\mu_0 * I) / (2 * R_1)$. For loop B with three turns, $B_2 = (3 * \mu_0 * I) / (2 * R_2)$. Since the length of wire is constant, $2\pi R_1 = 3 * 2\pi R_2$, which leads to $R_2 = (R_1/3)$. Hence, $B_2 = (3 * \mu_0 * I) / (2 * R_1/3)$, resulting in $B_2 = (9 * \mu_0 * I) / (2 * R_1)$. The ratio $B_1/B_2 = 1/9$.

Question 20.

What is meant by the term 'displacement current' ? Briefly explain how this current is different from a conduction current.

[2 Marks]

Answer: Displacement current is a term used in electromagnetism to describe a kind of current that arises in dielectric materials when there is a changing electric field. It is not a flow of charges but rather a change in the electric field that creates an effect similar to current. Unlike conduction current, which is a flow of free charges through a conductor, displacement current accounts for the time-varying electric field in capacitors or non-conductive materials.

Question 21.

(a) State Huygens principle. How did Huygens' explain the absence of the backwave?

[2 Marks]

Answer: Huygens' principle states that every point on a wavefront serves as a source of secondary wavelets, which combine to form the new wavefront. Huygens explained the absence of the backwave by suggesting that the secondary waves produced by these points have maximum amplitude in the forward direction, while they have zero amplitude in the backward direction. This assumption helps to account for the observed forward propagation of waves and the non-existence of backwave.

Question 22.

The refractive indices of two media A and B are 2 and √2 respectively. What is the critical angle for their interface?

[2 Marks]

Answer: To calculate the critical angle for the interface between two media with given refractive indices, we can use Snell's law. The critical angle (C) can be found using the formula: $C = \sin^{-1}(n_2/n_1)$, where n_1 is the refractive index of the denser medium (A) and n_2 is for the less dense medium (B). Here, $n_1 = 2$ and $n_2 = \sqrt{2}$. Thus, $C = \sin^{-1}(\sqrt{2}/2) = 45$ degrees.

Question 23.

(a) Draw a graph showing the variation of binding energy per nucleon as a function of mass number A. The binding energy per nucleon for heavy nuclei (A > 170) decreases with the increase in mass number. Explain.

[2 Marks]

Answer: The graph of binding energy per nucleon (Ebn) versus mass number (A) shows initial constancy in Ebn for A between 30 and 170, peaking at about 8.75 MeV. For larger nuclei (A > 170), Ebn decreases as mass number increases. This decline is due to the diminishing effect of the nuclear force, which is short-ranged, leading to lower stability in heavier nuclei as nucleons experience reduced binding energy per nucleon.

Question 24. Explain the roles of diffusion current and drift current in the formation of the depletion layer in a p-n junction diode.

[2 Marks]

Answer: In a p-n junction diode, the diffusion current occurs when holes from the p-side move toward the n-side due to concentration gradients. This movement causes electrons to flow from the n-side to the p-side, leading to charge carrier recombination. The drift current, on the other hand, arises from the electric field created in the depletion region as charge carriers recombine. This field directs the flow of remaining carriers, reinforcing the depletion layer. Together, these currents establish an equilibrium in the depletion layer.

Question 25. Explain the property of a p-n junction which makes it suitable for rectifying alternating voltages. Differentiate between a half-wave and a full-wave rectifier.

[2 Marks]

Answer: A p-n junction exhibits the property of rectification, allowing current to flow only in one direction. This is due to the formation of a depletion region at the junction, which creates a barrier for charge carriers. When an alternating voltage is applied, the p-n junction allows current flow during the positive cycle (forward bias) but blocks it during the negative cycle (reverse bias). A half-wave rectifier utilizes only one half of the AC wave, while a full-wave rectifier utilizes both, providing more efficient conversion.

Question 26.

(b) Use Huygens' principle to show reflection/ refraction of a plane wave by (i) concave mirror, and (ii) a convex lens.

[2 Marks]

Answer: Huygens' principle states that every point on a wavefront acts as a source of secondary wavelets. For a concave mirror, when a plane wavefront hits it, each point of the wavefront produces wavelets that converge at the focal point, demonstrating reflection. In the case of a convex lens, the plane wavefronts enter the lens, and the wavelets produced bend and converge towards a focal point on the opposite side, showing refraction.

Question 27.

(b) Using Bohr's postulates, obtain the expression for radius of nth stable orbit in a hydrogen atom.

[2 Marks]

Answer: According to Bohr's first postulate, electrons can only exist in stable orbits without emitting energy. The second postulate states that the angular momentum is quantized, given by $L = nh/2\pi$, where n is a positive integer. For a hydrogen atom, the centripetal force equals the electrostatic force between the electron and proton. This leads to the derivation of the radius of the nth orbit: $r_n = n^2h^2/(4\pi^2me^2)$, where m is the electron mass and e is the charge of the electron.

Section C

Question 28. A potential difference V is applied across a conductor of length l and uniform cross-section area A. How will the (i) electric field E, (ii) drift velocity v_d, and (iii) current density j be affected when (a) V is doubled and (b) l is halved (keeping other factors constant)?

[3 Marks]

Answer: When the potential difference V is doubled, the electric field E across the conductor, described by $E = V/l$, will also double since l remains constant. Thus, E becomes 2E. The drift velocity v_d, which is proportional to the electric field ($v_d = \mu E$, where μ is the mobility), will also double, leading to v_d becoming $2v_d$. The current density j, defined by $j = \sigma E$ (where σ is the conductivity), will double as well, resulting in j becoming 2j. When the length l is halved with V constant, the electric field E doubles ($E = V/l$). This increased E leads to a doubling of the drift velocity v_d and the current density j, even with V unchanged. Therefore, in both scenarios, E, v_d, and j are directly or indirectly proportional to each other, leading to a consistent doubling effect.

Question 29.

What is meant by the term 'mutual inductance' of a pair of coils? Obtain an expression for the mutual inductance of two long coaxial solenoids, each of length l but having different number of turns N_1 and N_2 and radii r_1 and r_2 ($r_2 > r_1$).

[3 Marks]

Answer: Mutual inductance is the property of a pair of coils whereby a change in current in one coil induces an electromotive force (EMF) in the second coil. It quantifies how effectively the magnetic field produced by one coil links with the other. For two long coaxial solenoids, the mutual inductance M can be derived from the relationship of their geometry and turns. The expression for mutual inductance M is given by $M = (\mu_0 N_1 N_2 A) / l$, where A is the cross-sectional area of the smaller solenoid, μ_0 is the permeability of free space, and l is the length of the solenoids.

Question 30.

An ac source $v = v_m \sin(\omega t)$ is connected across an ideal capacitor. Derive the expression for the (i) current flowing in the circuit, and (ii) reactance of the capacitor. Plot a graph of current i versus ωt.

[3 Marks]

Answer: When an AC source $v = v_m \sin(\omega t)$ is connected to an ideal capacitor, the current flowing in the circuit can be derived using Kirchhoff's laws. The voltage across the capacitor is $V = q/C$, where q is the charge. By differentiating the charge q with respect to time, we find the current $i = dq/dt = \omega C v_m \cos(\omega t)$. This can be expressed as $i = i_m \sin(\omega t + \pi/2)$, indicating that the current leads the voltage by π/2 radians. The capacitive reactance is given by $X_c = 1/(\omega C)$. In a plot of current i versus ωt, the graph demonstrates that the current reaches its peak 90 degrees ahead of the voltage waveform.

Question 31.

Calculate the wavelength of de Broglie waves associated with a proton having (500/1.673) eV energy. How will the wavelength be affected for an alpha particle having the same energy?

[3 Marks]

Answer: To calculate the wavelength of de Broglie waves associated with a proton, we use the de Broglie wavelength formula, λ = h/p, where h is Planck's constant (6.626 x 10^-34 J·s) and p is the momentum. First, we convert the proton's energy from eV to joules: 500 eV = 500 x 1.6 x 10^-19 J = 8 x 10^-14 J. For a proton with mass approximately 1.673 x 10^-27 kg, we find the momentum, p = √(2*m*E) = √(2*1.673 x 10^-27 kg * 8 x 10^-14 J). This results in p = 1.0 x 10^-20 kg·m/s. Thus, the wavelength, λ = 6.626 x 10^-34 J·s / 1.0 x 10^-20 kg·m/s ≈ 6.63 x 10^-14 m. For an alpha particle (2 protons and 2 neutrons) with the same energy, its mass is roughly four times that of the proton, thus it will have a smaller momentum and consequently a shorter wavelength, suggesting that the de Broglie wavelength decreases for particles with larger mass.

Question 32.

(a) (i) Prove that the nuclear density is the same for all nuclei.

(ii) Draw a plot of potential energy of a pair of nucleons as a function of their separation. Draw two inferences from this plot.

[3 Marks]

Answer: The nuclear density being the same for all nuclei can be explained by noting that the size of the nucleus increases proportionally with the number of nucleons (A). Since density is mass divided by volume, and volume increases with the cube of the radius, the mass (which is proportional to A) and volume also increase proportionally, leading to a constant density of approximately 2.3 × 10^17 kg/m³. For part (ii), the plot of potential energy (in MeV) versus separation (in fm) reveals that the potential energy is minimized at about 0.8 fm where the force between nucleons is attractive, indicative of strong nuclear forces. Additionally, the potential energy becomes repulsive at distances below 0.8 fm, showing that nucleons cannot exist too close to one another. Thus, the interactions between nucleons are governed by a balance of attractive and repulsive forces.

Question 33.

A series combination of an inductor L, a capacitor C and a resistor R is connected across an ac source of voltage in a circuit. Obtain an expression for the average power consumed by the circuit. Find power factor for (i) purely inductive circuit, and (ii) purely resistive circuit.

[3 Marks]

Answer: In a series RLC circuit, the average power (P) consumed can be expressed as P = VI cos Φ, where V is the peak voltage, I is the peak current, and cos Φ is the power factor. For a purely resistive circuit (R), the power factor is 1, as the current and voltage are in phase. In contrast, in a purely inductive circuit (L), the power factor is 0 since the current lags the voltage by 90 degrees. Thus, no power is consumed in an ideal inductive circuit.

Question 34.

(i) Draw a graph to show the variation of the number of scattered particles detected (N) in Geiger-Marsden experiment as a function of scattering angle (θ).

(ii) Discuss briefly two conclusions that can be drawn from this graph and how they lead to the discovery of the nucleus in an atom.

[3 Marks]

Answer: In the Geiger-Marsden experiment, a graph plotting the number of scattered alpha particles (N) against the scattering angle (θ) shows that most particles scatter at small angles, with very few scattering at large angles. This indicates that atoms are mostly empty space, with a small, dense nucleus at the center. The conclusions drawn include that the large-angle scattering suggests a concentrated positive charge, revealing the existence of the nucleus, while the small angle scattering supports the notion of atomic structure as proposed by Rutherford by demonstrating the distribution of mass and charge within the atom.

Section D

Question 35.

Diffraction of light is bending of light around the corners of an object whose size is comparable with the wavelength of light. Diffraction actually defines the limits of ray optics. This limit for optical instruments is set by the wavelength of light. An experimental arrangement is set up to observe the diffraction pattern due to a single slit.

Answer the following questions based on the above :

> **(1) How will the width of central maximum be affected if the wavelength of light is increased?**
>
> [1 Marks]
>
> **Answer:** If the wavelength of light is increased, the width of the central maximum in the diffraction pattern will also increase, leading to a broader central bright fringe.

Key Points: increased wavelength results in wider central maximum

(2) Under what condition is the first minimum obtained?

[1 Marks]

Answer: The first minimum in the diffraction pattern is obtained when the angle θ satisfies the condition a sin θ = λ, where 'a' is the width of the slit and 'λ' is the wavelength of light.

Key Points: First minimum condition: a sin **θ** = **λ**; Angle **θ**; Width of slit; Wavelength of light

(3)

Write two points of difference between interference and diffraction patterns.

[2 Marks]

Answer: 1. Interference patterns result from the superposition of two or more coherent light waves, leading to a series of alternating bright and dark fringes that are evenly spaced. In contrast, diffraction patterns arise from the bending of light waves around obstacles or through openings, producing a different distribution of light intensity, which often includes a central maximum followed by gradually diminishing side maxima. 2. The interference pattern is generally stable in time if the sources maintain a consistent phase relationship, while diffraction patterns can show variations influenced by the geometry of the slit or obstacle and the wavelength of light used.

Key Points: 1. Interference involves two or more coherent sources; diffraction involves a single source or obstacle. 2. Interference patterns are uniform; diffraction patterns vary in intensity.

(4)

Two students are separated by a 7 m partition wall in a room 10 m high. If both light and sound waves can bend around obstacles, how is it that the students are unable to see each other even though they can converse easily?

[2 Marks]

Answer: The students are unable to see each other due to the diffraction of light, which is limited by the wavelength of light. Since the wavelength of light is much smaller than the 7 m partition wall separating them, the light does not bend sufficiently to allow them to see around it. In contrast, sound waves have a much longer wavelength and can easily diffract around the wall, allowing the students to hear each other despite the obstacle.

Key Points: Diffraction of light, Partition wall obstructs light, Sound waves diffract more easily

Section E

Question 36.

(a) (i) Define electric flux and write its SI unit.

(ii) Use Gauss' law to obtain the expression for electric field due to a uniformly charged infinite plane sheet.

(iii) A cube of side L is kept in space, as shown in the figure. An electric field E = (Ax + B) i N/C exists in the region. Find the net charge enclosed by the cube.

[5 Marks]

Answer: (i) Electric flux (Φ_E) is defined as the amount of electric field (E) passing through a given surface area (A) and is given by the integral $\Phi_E = \int E \cdot dA$. Its SI unit is volt-meter (V·m) or equivalently the newton-meter squared per coulomb ($N \cdot m^2/C$). (ii) For a uniformly charged infinite plane sheet with surface charge density σ, using Gauss's law, the electric field (E) at a distance from the sheet is $E = \sigma/(2\varepsilon_0)$ directed away from the sheet. (iii) To find the net charge enclosed in the cube by the given electric field E = (Ax + B) i N/C, we first calculate the electric flux through one face of the cube and then apply Gauss's law; using symmetry and the dimensions of the cube, we determine the charge contained.

Question 37.

(a) (i) Write the principle and explain the working of a moving coil galvanometer. A galvanometer as such cannot be used to measure the current in a circuit.

(ii) Why is the magnetic field made radial in a moving coil galvanometer? How is it achieved?

[5 Marks]

Answer: A moving coil galvanometer operates on the principle that a current-carrying coil placed in a magnetic field experiences a torque due to the interaction between the magnetic field and the magnetic field created by the current in the coil. The galvanometer consists of a coil mounted on a pivot, positioned in a uniform radial magnetic field produced by a cylindrical soft iron core. As current flows through the coil, it generates a magnetic field that interacts with the radial magnetic field, causing the coil to rotate. The angle of rotation, indicated by a pointer on a calibrated scale, is proportional to the current flowing through the coil. The magnetic field is kept radial to ensure uniform torque, thus achieving accurate deflections regardless of the coil's position. This radial field is formed by the cylindrical soft iron core that concentrates the magnetic lines of force, maintaining a constant field strength across the area of the coil. Since a galvanometer is sensitive to small currents, it cannot measure high currents directly; however, it can be adapted into an ammeter or voltmeter using shunt or series resistances, respectively.

Question 38.

(a) (i) Draw a ray diagram showing the formation of a real image of an object placed at a distance 'u' in front of a concave mirror of radius of curvature 'R'. Hence, obtain the relation for the image distance 'v' in terms of u and R.

(ii) A 1.8 m tall person stands in front of a convex lens of focal length 1 m, at a distance of 5 m. Find the position and height of the image formed.

[5 Marks]

Answer: To form a ray diagram for a concave mirror, begin by placing the object beyond the center of curvature (C). Draw a ray from the top of the object that goes parallel to the principal axis and reflects through the focus (F). Another ray goes through the center of curvature (C) and reflects back on itself. The intersection of these rays gives the position of the real image, which is inverted and smaller than the object. The mirror formula is given by 1/f = 1/v + 1/u. Since the focal length f is R/2 for a concave mirror, substituting f gives the relation v = (R*u)/(u + R). For the convex lens, using the lens formula 1/f = 1/v - 1/u, substituting u = 5m and f = 1m leads to v = 1.25m. The height of the image can be calculated using the magnification formula m = h'/h = v/u, where h = 1.8m resulting in an image height of approximately 0.54m.

Question 39.

(b) (i) Define electric potential at a point and write its SI unit.

(ii) Two capacitors are connected in series. Derive an expression of the equivalent capacitance of the combination.

(iii) Two point charges +q and -q are located at points (3a, 0) and (0, 4a) respectively in x-y plane. A third charge Q is kept at the origin. Find the value of Q, in terms of q and a, so that the electrostatic potential energy of the system is zero.

[5 Marks]

Answer: Electric potential (V) at a point is defined as the amount of work done by an external force in bringing a unit positive charge from infinity to that point against the electric field, without any acceleration. Its SI unit is volts (V), which is equivalent to joules per coulomb (J/C). When two capacitors, C1 and C2, are connected in series, the total voltage across the capacitors adds up while the charge across each capacitor remains the same. The equivalent capacitance (C_eq) for capacitors in series is expressed as 1/C_eq = 1/C1 + 1/C2. For the third charge at the origin to result in zero potential energy, considering the configuration of +q at (3a, 0) and -q at (0, 4a), we can derive the potential at the origin due to these point charges and set the total potential energy to zero, leading to the value of Q in terms of q and a.

Question 40.

(b) (i) Derive an expression for magnetic field on the axis of a current carrying circular loop.

(ii) Write any two points of difference between a diamagnetic and a paramagnetic substance.

[5 Marks]

Answer: To derive the magnetic field (B) on the axis of a circular current loop of radius R carrying current I, consider a point P at a distance x from the center of the loop along its axis. The magnetic field due to an infinitesimal current element (Idl) can be computed using Biot-Savart law, which gives $dB = (\mu_0/4\pi)(Idl \times r^\wedge)/r^2$, where r is the distance from the current element to point P. Integrating around the loop results in: $B = (\mu_0 I)/(2R)\ [1/(1 + (x^2/R^2))^\wedge(3/2)]$, showing that the field depends on both the current and the geometrical arrangement of the loop. Additionally, diamagnetic substances exhibit weak negative susceptibility, meaning they are repelled by external magnetic fields but do not retain magnetism when the field is removed. In contrast, paramagnetic substances have positive susceptibility, which leads them to be attracted to external magnetic fields and retain some magnetism even once the external field is removed.

Question 41.

(b) (i) Draw a ray diagram showing refraction of a ray of light through a triangular glass prism. Hence, obtain the relation for the refractive index (μ) in terms of angle of prism (A) and angle of minimum deviation (δm).

(ii) The radii of curvature of the two surfaces of a concave lens are 20 cm each. Find the refractive index of the material of the lens if its power is -5·0 D.

[5 Marks]

Answer: To analyze the refraction of light through a triangular prism, consider a ray of light entering the prism at point A, refracting at interface AB, and emerging at AC. The angle of incidence at AB is 'i' and the angle of refraction is 'r1'. At AC, the angle of incidence is 'r2' and the emergent angle is 'e'. For minimum deviation (δm), the relation between angle of prism (A) and deviation can be expressed as $\mu = \sin[(A + \delta m)/2] / \sin[A/2]$. This equation allows for the determination of the refractive index given the angles. In a concave lens, the power (P) is given by $P = 1/f$, where f is the focal length. The lens formula for a concave lens can be applied: $1/f = (n - 1)(1/R1 - 1/R2)$. Given the power is -5.0 D ($f = -0.2$ m), we substitute and rearrange to find the refractive index.