Roll No. ☐☐☐☐☐☐☐☐

Q.P. Code 55/4/1

PHYSICS (THEORY)

CBSE Class XII Board Examination 2025 — with answers

Time allowed: 3 hours **Maximum Marks: 70**

General Instructions:

1. The paper has 33 questions in five sections (A to E); all of them must be answered.
2. Section A: Q1–16, multiple choice and Assertion-Reason, 1 mark each.
3. Section B: Q17–21, very short answer, 2 marks each.
4. Section C: Q22–28, short answer, 3 marks each.
5. Section D: Q29–30, case-study based, 4 marks each.
6. Section E: Q31–33, long answer, 5 marks each.
7. There is no overall choice, but some questions in Sections B to E offer an internal choice (OR). Calculators are not allowed.
8. Constants you may use: $c = 3 \times 10^{8}$ m/s, $h = 6.63 \times 10^{-34}$ J s, $e = 1.6 \times 10^{-19}$ C, $\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}, $\varepsilon_0 = 8.854 \times 10^{-12}$ C^2 N^{-1} m^{-2}, $1/(4\pi\varepsilon_0) = 9 \times 10^{9}$ N m^2 C^{-2}, $m_e = 9.1 \times 10^{-31}$ kg, $m_n = 1.675 \times 10^{-27}$ kg, $m_p = 1.673 \times 10^{-27}$ kg, Avogadro number = 6.023×10^{23} per gram mole, Boltzmann constant = 1.38×10^{-23} J K^{-1}.

SECTION A

Q1–16 carry 1 mark each (MCQ; Q13–16 are Assertion-Reason).

1. A body is given a charge of 8.0×10^{-12} C. What happens to its mass? **1**

(A) It increases by 4.5×10^{-7} kg

(B) It decreases by 1.0×10^{-6} kg

(C) It decreases by 4.55×10^{-23} kg

(D) It increases by 9.1×10^{-23} kg

ANSWER

(C) decreases by 4.55×10^{-23} kg

A positive charge means the body has LOST electrons, so its mass decreases.

Number of electrons removed: $n = q/e = 8.0 \times 10^{-12} / 1.6 \times 10^{-19} = 5 \times 10^{7}$.

Mass lost = $n\, m_e = 5 \times 10^{7} \times 9.1 \times 10^{-31}$ kg $= 4.55 \times 10^{-23}$ kg.

Common mistake: thinking a charged body gains mass – that happens only when it becomes negatively charged.

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2. Current flows along a cylindrical conductor of radius R. The current density at distance r from the axis is $j = \alpha r$ (directed along the axis), α being a constant. The current through the part of the cross-section from r = 0 to r = R/2 is proportional to: **1**

(A) R

(B) R^2

(C) R^3

(D) R^4

ANSWER

(C) R^3

Take a thin ring of radius r and width dr: area $dA = 2\pi r\, dr$.

$dI = j\, dA = \alpha r \cdot 2\pi r\, dr = 2\pi\alpha\, r^2\, dr$.

$$I = 2\pi\alpha \int_0^{R/2} r^2\, dr = \frac{2\pi\alpha}{3}\left(\frac{R}{2}\right)^3 = \frac{\pi\alpha R^3}{12}$$

So $I \propto R^3$.

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3. Figure: a uniform magnetic field B points into the page (−Z direction) and fills only the region above the X-axis (y > 0). A particle of charge +q, initially just below the X-axis on the positive x side, moves with velocity v along +Y and enters the field region. The particle will describe: **1**

(A) a circular path in the XZ plane

(B) a semicircular path in the XY plane

(C) a helical path with its axis parallel to the Y-axis

(D) a semicircular path in the YZ plane

ANSWER

(B) a semicircular path in the XY plane

v is perpendicular to B, so the magnetic force $F = q\, v \times B$ is always perpendicular to v and lies in the XY plane → circular motion in the XY plane.

Direction: $v = +\hat{y}$, $B = -\hat{z} \Rightarrow \hat{y} \times (-\hat{z}) = -\hat{x}$, so the particle curves towards −X.

Since the field exists only on one side (y > 0), the particle completes half a circle and leaves the field moving along −Y. Hence a semicircle in the XY plane.

No velocity component along B, so no helix.

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4. A bar magnet is placed perpendicular to a uniform magnetic field. It is then turned until the torque on it falls to half its starting value. Through what angle has it been turned? **1**

(A) 30° **(B)** 45°

(C) 60° **(D)** 75°

ANSWER

(C) 60°

$\tau = mB \sin\theta$, where θ is the angle between m and B.

Initially $\theta = 90°$, so $\tau_0 = mB$.

After turning through angle φ, $\theta = 90° - \varphi$ and $\tau = mB \cos\varphi$.

$mB \cos\varphi = mB/2 \Rightarrow \cos\varphi = 1/2 \Rightarrow \varphi = 60°$.

Common mistake: answering 30° – that is the final angle between m and B, not the angle turned.

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5. Which one of these materials is NOT paramagnetic? **1**

(A) Aluminium **(B) Sodium chloride**

(C) Calcium **(D)** Copper chloride

ANSWER

(B) Sodium chloride

Sodium chloride has no unpaired electrons (Na^+ and Cl^- have closed shells), so it is diamagnetic.

Aluminium, calcium and copper chloride (Cu^{2+} has an unpaired electron) are paramagnetic.

6. An ammeter in series in an AC circuit shows 10 A. The peak (maximum instantaneous) current in the circuit is: **1**

(A) $10\sqrt{2}$ A **(B)** $10/\sqrt{2}$ A

(C) $10/\pi$ A **(D)** $10/(\sqrt{2}\,\pi)$ A

ANSWER
(A) $10\sqrt{2}$ A

AC ammeters read the rms value: $I_{rms} = 10$ A.
$I_0 = \sqrt{2} \times I_{rms} = 10\sqrt{2}$ A ≈ 14.1 A.

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7. In free space, an electromagnetic wave has an electric-field amplitude of 1000 V m^{-1}. What is the amplitude of its magnetic field? **1**

(A) 3.0×10^{-3} T **(B)** 3.33×10^{-8} T

(C) 3.0×10^{11} T **(D) 3.33×10^{-6} T**

ANSWER
(D) 3.33×10^{-6} T

$B_0 = E_0/c = 1000 / (3 \times 10^8)$ T $= 3.33 \times 10^{-6}$ T.

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8. A spherical mirror gives a magnification of −2.0. Which mirror is it and what kind of image does it form? **1**

(A) Convex, virtual image **(B) Concave, real image**

(C) Concave, virtual image **(D)** Convex, real image

ANSWER
(B) Concave and real

Negative magnification ⇒ image is inverted ⇒ image is real.
Only a concave mirror forms real (and enlarged, $|m| = 2$) images; a convex mirror always gives virtual, erect, diminished images.

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9. Pick the correct statement: **1**

(A) Light photons show diffraction but electrons do not.

(B) Electrons possess momentum but photons do not.

(C) Both light photons and electrons show dual (wave–particle) nature.

(D) Not all electromagnetic radiations consist of photons.

ANSWER
(C) Photons and electrons both exhibit dual nature

Electrons show diffraction (Davisson–Germer), so (A) is wrong.
Photons carry momentum $p = h/\lambda$, so (B) is wrong.
All EM radiation is quantised into photons, so (D) is wrong.
Both light and matter show wave as well as particle behaviour → (C).

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10. A red light beam and a blue light beam have the same intensity. Which statement is correct? **1**

(A) The blue beam contains more photons than the red beam.

(B) The red beam contains more photons than the blue beam.

(C) Red light has a shorter wavelength than blue light.

(D) Each photon of blue light has less energy than a photon of red light.

ANSWER

(B) The red beam has more photons

Intensity I = (number of photons per second per unit area) × hν.
Red light has lower ν, so each red photon carries less energy (E = hν).
For the same intensity, the red beam must carry more photons.
(C) and (D) are wrong: red has the longer wavelength and lower photon energy.

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11. Which of these conducts electricity at room temperature? **1**

(A) Sn

(B) Mica

(C) Si

(D) C

ANSWER

(A) Sn

Tin (Sn) has essentially zero band gap and behaves as a metal (conductor).
Mica and carbon (diamond) are insulators; Si is a semiconductor with Eg ≈ 1.1 eV.

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12. A long straight vertical wire carries a steady current upwards. The magnetic field lines around it are: **1**

(A) horizontal straight lines pointing radially outward from the wire

(B) straight lines parallel to the wire

(C) concentric horizontal circles around the wire

(D) coaxial helices around the wire

ANSWER

(C) concentric horizontal circles

For a straight current, field lines are circles centred on the wire, in planes perpendicular to it. The wire is vertical, so the circles are horizontal; their sense is given by the right-hand thumb rule (anticlockwise seen from above for upward current).

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13. Assertion (A): An n-type semiconductor is electrically neutral, not negatively charged. **1**
Reason (R): A neutral pentavalent impurity atom added to the neutral intrinsic crystal gives its fifth electron to the lattice and itself becomes a positive donor ion.

(A) Both A and R are true and R is the correct explanation of A.

(B) Both A and R are true but R is not the correct explanation of A.

(C) A is true but R is false.

(D) Both A and R are false.

ANSWER

(A) Both true, R explains A

Each donor atom that releases a free electron becomes a fixed positive ion. Number of free electrons ≈ number of positive donor ions (+ equal numbers of thermally generated electrons and holes), so the total charge is zero.
Thus R directly explains why the n-type crystal stays neutral.

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14. Assertion (A): At resonance, a series LCR circuit acts like a purely resistive circuit. **1**
Reason (R): At resonance X_L = X_C, which gives $\omega = \frac{1}{\sqrt{LC}}$.

(A) Both A and R are true and R is the correct explanation of A.

(B) Both A and R are true but R is not the correct explanation of A.

(C) A is true but R is false.

(D) Both A and R are false.

ANSWER

(A) Both true, R explains A

$Z = \sqrt{(R^2 + (X_L - X_C)^2)}$. When $X_L = X_C$, $Z = R$ and the phase angle $\tan\varphi = (X_L - X_C)/R = 0$, so current and voltage are in phase – purely resistive behaviour.
$X_L = X_C \Rightarrow \omega L = 1/(\omega C) \Rightarrow \omega = 1/\sqrt{(LC)}$. R is the reason for A (as per the CBSE key).

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15. Assertion (A): In a double-slit experiment, if one slit is covered, the single-slit diffraction pattern of the other slit is seen on the screen. **1**
Reason (R): Interference needs at least two separate waves.

(A) Both A and R are true and R is the correct explanation of A.

(B) Both A and R are true but R is not the correct explanation of A.

(C) A is true but R is false.

(D) Both A and R are false.

ANSWER
(C) A true, R false

A is true: with one slit open, the light from that single slit spreads and gives a single-slit diffraction pattern (wide central maximum with weaker side maxima).
R is taken as false (CBSE key): a diffraction pattern is itself produced by superposition (interference) of secondary wavelets coming from different parts of a single wavefront – it does not need two separate sources/waves.

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16. Assertion (A): With monochromatic light falling on a given metal, the photoelectrons come out with speeds ranging from zero up to a certain maximum. **1**
Reason (R): Every metal has a definite work function.

(A) Both A and R are true and R is the correct explanation of A.

(B) Both A and R are true but R is not the correct explanation of A.

(C) A is true but R is false.

(D) Both A and R are false.

ANSWER
(B) Both true, R does not explain A

A is true: electrons at the surface leave with $K_{max} = h\nu - \varphi_0$, but electrons from deeper inside lose extra energy in collisions, so they emerge with less KE – down to zero.
R is true (φ_0 is a property of the metal), but it only fixes the maximum KE; it does not explain why there is a spread of speeds. Hence (B).

SECTION B

Q17–21 carry 2 marks each.

17. Three identical bulbs P, Q and S are connected to a battery. Bulb S is in series with the battery; the other end of S goes to a junction from which two parallel branches lead back to the battery: one branch has bulb Q, the other has a key K in series with bulb P. **2**

(i) With K closed, compare the brightness of P and Q with that of S.

(ii) With K open, compare the brightness of S and Q.

Give reasons in both cases.

ANSWER

(i) S is brighter than P and Q (P and Q equal); (ii) S and Q equally bright

Let each bulb have resistance R and current through S be I.

(i) K closed: P and Q are in parallel, so each carries I/2 (identical bulbs). Power in S = I^2R; in P or Q = $(I/2)^2R = I^2R/4$. S glows brighter (four times the power); P and Q glow equally. (Equivalently, the p.d. across S is twice that across P or Q.)

(ii) K open: P's branch is broken, so S and Q are simply in series and carry the same current ⇒ same power ⇒ equal brightness.

Key point for marks: brightness ∝ power = I^2R, so compare currents.

OR

Two cells of emf 10 V each (negligible internal resistance) are stacked one above the other on the left side of a circuit, joined in series in the same sense. A bulb B of resistance 10 Ω connects the junction between the two cells to a junction on the right side. On the right, a 20 Ω resistor goes up from this junction to the top wire, and a 10 Ω resistor goes down from it to the bottom wire; the top wire connects to the free end of the upper cell and the bottom wire to the free end of the lower cell. Find the current through the bulb.

ANSWER

I_{bulb} = 0.2 A (1/5 A)

Take the potential of the left middle junction (between the cells) as 0 and the right junction as x.

Top of upper cell = +10 V, bottom of lower cell = −10 V (cells aiding).

KCL at the right junction (currents in = currents out):

from 20 Ω: (10 − x)/20, from bulb: (0 − x)/10, out through 10 Ω: (x − (−10))/10.

(10 − x)/20 − x/10 = (x + 10)/10

⇒ 10 − x − 2x = 2x + 20 ⇒ x = −2 V.

Current through bulb = (0 − (−2))/10 = 0.2 A (from the cells' junction towards the right junction).

Check with loop rule (Kirchhoff): the same result I = 1/5 A is obtained by writing loop equations for the upper and lower meshes.

18. In single-slit diffraction with slit width 0.55 mm and light of wavelength 550 nm, find the angle of diffraction (in degrees) of the first secondary maximum. **2**

ANSWER

$\theta = 1.5 \times 10^{-3}$ rad $\approx 0.086°$

Secondary maxima: $a \sin\theta \approx a\theta = (n + \tfrac{1}{2})\lambda$; first secondary maximum $n = 1 \Rightarrow \theta = 3\lambda/(2a)$.

$\theta = 3 \times 550 \times 10^{-9} / (2 \times 0.55 \times 10^{-3}) = 1.5 \times 10^{-3}$ rad.

In degrees: $1.5 \times 10^{-3} \times (180/\pi) \approx 0.086°$.

Common mistake: using $\theta = \lambda/a$ – that gives the first minimum, not the first secondary maximum.

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19. An equiconvex glass lens (refractive index 1.55) has a focal length of 15.0 cm. Find the radius of curvature of each surface. **2**

ANSWER

R = 16.5 cm

Lens maker's formula: $\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$.

Equiconvex: $R_1 = +R$, $R_2 = -R \Rightarrow 1/f = (n-1)(2/R)$.

$R = 2(n-1)f = 2 \times 0.55 \times 15.0 = 16.5$ cm.

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20. Find the mass of an α-particle in atomic mass units, given: mass of a neutral helium atom = 4.002603 u, mass of a carbon-12 atom = 1.9926×10^{-26} kg (take $m_e = 9.1 \times 10^{-31}$ kg). **2**

ANSWER

m_α ≈ 4.001507 u

1 u = (mass of C-12 atom)/12 = $1.9926 \times 10^{-26} / 12 = 1.66 \times 10^{-27}$ kg.

Mass of 2 electrons in u = $2 \times 9.1 \times 10^{-31} / 1.66 \times 10^{-27} \approx 0.001096$ u.

An α-particle is a helium nucleus = helium atom minus its 2 electrons:

m_α = 4.002603 − 0.001096 ≈ 4.001507 u.

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21. An intrinsic semiconductor has carrier concentration 5×10^8 m^{-3}. After doping, the hole concentration becomes 8×10^{12} m^{-3}. **2**

(a) Name (i) the kind of dopant used and (ii) the type of extrinsic semiconductor obtained.

(b) Find the electron concentration in the doped semiconductor.

ANSWER

(a) trivalent (acceptor) dopant, p-type; (b) $n_e = 3.125 \times 10^4$ m^{-3}

(a) Holes increased far above $n_i \Rightarrow$ acceptor (trivalent, e.g. B, Al, In) impurity ⇒ p-type semiconductor.

(b) Mass-action law: $n_e n_h = n_i^2$.

$n_e = (5 \times 10^8)^2 / (8 \times 10^{12}) = 25 \times 10^{16} / 8 \times 10^{12} = 3.125 \times 10^4$ m^{-3}.

SECTION C

Q22–28 carry 3 marks each.

22. (i) Derive an expression for the resistivity of a conductor in terms of the number density of free electrons and their relaxation time. **3**

(ii) A current–time graph for a wire shows: a constant current of 2.0 A from t = 1 s to t = 2 s (charge Q_1), and a current rising linearly from 0 at t = 4 s to 1.5 A at t = 6 s, then dropping to zero (charge Q_2). Compare Q_1 and Q_2.

ANSWER

(i) $\rho = m/(n e^2 \tau)$; (ii) $Q_1 = 2$ C, $Q_2 = 1.5$ C, $Q_1 : Q_2 = 4 : 3$

(i) In field E, each electron accelerates $a = -eE/m$; average over relaxation time τ gives drift speed $v_d = eE\tau/m$.

Current $I = n e A v_d = n e A (eE\tau/m) \Rightarrow$ current density $j = I/A = (n e^2 \tau/m) E$.

Comparing with Ohm's law $j = \sigma E = E/\rho$:

$\rho = \frac{m}{ne^2\tau}$

(ii) Charge = area under the I–t graph.

$Q_1 = 2.0\ A \times 1\ s = 2$ C (rectangle).

$Q_2 = \frac{1}{2} \times 2\ s \times 1.5\ A = 1.5$ C (triangle).

$Q_1/Q_2 = 2/1.5 = 4/3$.

OR

(i) A battery of emf E and internal resistance r is connected to a variable external resistance R.

(I) Find the current I in the circuit and the largest current the battery can give.

(II) Find the terminal voltage V and its largest possible value.

(ii) The same battery gives current I_1 when $R = R_1$ and current I_2 when $R = R_2$. Express r in terms of I_1, I_2, R_1 and R_2.

ANSWER

$I = E/(R + r)$, $I_{max} = E/r$; $V = E - Ir$, $V_{max} = E$; $r = (I_2R_2 - I_1R_1)/(I_1 - I_2)$

(i)(I) Total resistance $R + r \Rightarrow I = E/(R + r)$. I is largest when R = 0 (short circuit): $I_{max} = E/r$.

(II) $V = E - Ir = ER/(R + r)$. V is largest when I = 0 ($R \to \infty$, open circuit): $V_{max} = E$.

(ii) $E = I_1(R_1 + r) = I_2(R_2 + r)$

$\Rightarrow I_1R_1 + I_1r = I_2R_2 + I_2r$

$\Rightarrow r(I_1 - I_2) = I_2R_2 - I_1R_1$

$\Rightarrow r = (I_2R_2 - I_1R_1)/(I_1 - I_2)$.

23. (a) State the Biot–Savart law in vector form. **3**

(b) Two long, insulated straight wires each carry 2.0 A: one lies along the x-axis (current towards +x) and the other along the y-axis (current towards +y). Find the magnitude and direction of the net magnetic field at P (4 m, 5 m).

ANSWER

B = 2×10^{-8} T along −z (into the xy-plane)

(a) $d\vec{B} = \frac{\mu_0}{4\pi} \frac{I\,d\vec{l} \times \vec{r}}{r^3}$

(b) Field of a long wire: B = $\mu_0 I/(2\pi d) = 2 \times 10^{-7}\ I/d$.

Wire along x: distance of P = 5 m ⇒ $B_1 = 2 \times 10^{-7} \times 2/5 = 8 \times 10^{-8}$ T; direction $\hat{x} \times \hat{y} = +\hat{z}$.

Wire along y: distance = 4 m ⇒ $B_2 = 2 \times 10^{-7} \times 2/4 = 1 \times 10^{-7}$ T; direction $\hat{y} \times \hat{x} = -\hat{z}$.

Net: B = $(8 - 10) \times 10^{-8}\ \hat{z} = -2 \times 10^{-8}\ \hat{z}$ T.

Magnitude 2×10^{-8} T, directed along −z.

24. Two coils are placed side by side. Coil 2 is joined in series with a battery and a rheostat R_2 (ends M, N); coil 1 is joined to a resistor R_1 (ends O, P). The current in coil 2 is such that its face towards coil 1 acts as a south pole. Find the direction of the induced current in coil 1 (as seen from the side of coil 2) and justify, when: **3**

(a) coil 2 is moved towards coil 1;

(b) coil 2 is moved away from coil 1;

(c) both coils are kept fixed and the resistance R_2 is increased.

ANSWER

(a) clockwise; (b) anticlockwise; (c) anticlockwise (momentarily)

Lenz's law: the induced current opposes the change of flux.

(a) A south pole approaches coil 1 ⇒ coil 1's near face becomes a south pole to repel it ⇒ current appears clockwise when viewed from coil 2's side.

(b) The south pole moves away ⇒ coil 1's near face becomes a north pole to attract it ⇒ anticlockwise as seen from coil 2.

(c) Increasing R_2 lowers the current in coil 2, so the flux through coil 1 decreases ⇒ coil 1 tries to keep the flux, making its near face a north pole ⇒ anticlockwise current, only while R_2 is changing; it stops once R_2 is steady.

25. (a) Give any three properties of electromagnetic waves. **3**

(b) Briefly explain how and where a displacement current exists while a capacitor is being charged.

ANSWER

(a) e.g. transverse, travel at c in vacuum without medium, carry energy & momentum; (b) between the plates, due to changing electric flux: $i_d = \varepsilon_0 d\Phi_E/dt$

(a) Any three:

• They are transverse; E, B and direction of propagation are mutually perpendicular.

• They need no material medium and travel in vacuum at $c = 1/\sqrt{(\mu_0\varepsilon_0)} = 3 \times 10^8$ m/s.

• They carry energy and momentum (and exert radiation pressure).

• They consist of oscillating E and B fields in phase, with $E_0/B_0 = c$.

(b) While charging, the charge on the plates and hence the electric field/flux between them changes with time. This changing flux acts as a current, the displacement current $i_d = \varepsilon_0 d\Phi_E/dt$, which exists in the gap between the plates, where no conduction current flows. It equals the conduction current in the wires, keeping current continuous.

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26. A double-slit set-up kept inside a tank of water gives an interference pattern with laser light. The water is then replaced by a transparent liquid of refractive index n greater than that of water. What happens to: **3**

(a) the speed, frequency and wavelength of the laser light;

(b) the fringe width, the shape of the fringes and the position of the central maximum?

ANSWER

(a) speed ↓, frequency unchanged, wavelength ↓; (b) fringe width ↓, shape unchanged, central maximum does not shift

(a) $v = c/n$: larger n ⇒ speed decreases.

Frequency is set by the source ⇒ unchanged.

$\lambda' = \lambda_0/n$ ⇒ wavelength decreases.

(b) $\beta = \lambda' D/d$ ⇒ fringe width decreases.

The fringes remain straight bright and dark bands (shape unchanged).

The whole set-up is in the same medium, so the central maximum stays at the centre (no shift).

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27. Using Einstein's photoelectric equation, explain: **3**

(a) why no photoemission occurs when the incident frequency is below a certain minimum value;

(b) why the maximum kinetic energy of photoelectrons depends on the frequency and not on the intensity of the light;

(c) why the graph of cut-off voltage V_0 against frequency ν is a straight line of slope h/e.

ANSWER

From $K_{max} = h\nu - h\nu_0 = eV_0$: (a) $\nu < \nu_0$ gives negative K_{max}; (b) K_{max} depends only on ν; (c) $V_0 = (h/e)\nu - h\nu_0/e$

Einstein's equation: $h\nu = \varphi_0 + K_{max}$, with $\varphi_0 = h\nu_0 \Rightarrow K_{max} = h(\nu - \nu_0)$.

(a) If $\nu < \nu_0$, K_{max} would be negative, which is impossible; one photon cannot give an electron enough energy to escape. So no emission below threshold frequency, however intense the light.

(b) $K_{max} = h(\nu - \nu_0)$ contains only ν (and the metal's ν_0). Greater intensity means more photons, so more electrons (larger current), but each photon still has energy $h\nu$, so K_{max} is unchanged.

(c) $K_{max} = eV_0 \Rightarrow V_0 = (h/e)\nu - (h/e)\nu_0$. This is of the form $y = mx + c$, so V_0 vs ν is a straight line of slope h/e (same for all metals) and intercept depending on ν_0.

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28. (a) Name the majority and minority charge carriers in p-type and in n-type semiconductors. **3**

(b) Briefly explain how diffusion current and drift current arise in a p-n junction.

ANSWER

(a) p-type: holes majority, electrons minority; n-type: electrons majority, holes minority; (b) diffusion due to concentration gradient, drift due to junction field

(a) p-type: majority = holes, minority = electrons.
n-type: majority = electrons, minority = holes.

(b) Diffusion current: when the junction forms, holes are far more concentrated on the p-side and electrons on the n-side. Because of this concentration difference, holes diffuse p → n and electrons diffuse n → p, giving the diffusion current. This leaves charged ions behind, forming the depletion layer and a junction electric field (n → p).

Drift current: this field sweeps minority carriers across – electrons from the p-side to the n-side and holes from the n-side to the p-side. This field-driven motion is the drift current, opposite to the diffusion current; in equilibrium the two are equal.

SECTION D

Q29–30 are case-study based, 4 marks each (four 1-mark MCQs; choice in part (iv)).

29. three large, equally spaced, parallel square metal plates P_1, P_2, P_3 (side L, gap d between neighbours) have both gaps fully filled with mica of dielectric constant K. The middle plate P_2 is joined to point A; the outer plates P_1 and P_3 are joined to point B. A is at potential V above B. **4**

(i) Capacitance between A and B: (A) $\varepsilon_0 KL^2/d$ (B) $\varepsilon_0 KL^2/(2d)$ (C) $2\varepsilon_0 KL^2/d$ (D) $2\varepsilon_0 Kd/L^2$

(ii) Magnitude of charge on plate P_1: (A) $\varepsilon_0 VKL^2/(2d)$ (B) $\varepsilon_0 VKL^2/d$ (C) $2\varepsilon_0 VKL^2/d$ (D) $\varepsilon_0 VKL^2/(4d)$

(iii) Electric field between P_1 and P_2: (A) V/d (B) 2V/d (C) V/(2d) (D) d/V

(iv) Separation of an air-filled parallel-plate capacitor with the same plate area L^2 and the same capacitance as this system: (A) d/K (B) 2d/K (C) d/(2K) (D) d/(4K)

ANSWER

(i) C; (ii) B; (iii) A; (iv) C

P_2 forms one capacitor with P_1 and another with P_3; both share the p.d. V (A to B), so they are in parallel.

Each: $C_1 = K\varepsilon_0 L^2/d$.

(i) $C = 2K\varepsilon_0 L^2/d \rightarrow$ (C).

(ii) P_1 belongs to one capacitor: $|Q_1| = C_1 V = \varepsilon_0 KVL^2/d$ (it is negative, since B is at lower potential) → (B).

(iii) Uniform field $E = V/d$ (p.d. V across gap d) → (A).

(iv) $\varepsilon_0 L^2/x = 2K\varepsilon_0 L^2/d \Rightarrow x = d/(2K) \rightarrow$ (C).

OR

(iv) (b) The supply connected between A and B is removed, and A and B are then joined by a conducting wire. The net charge on the whole system becomes:

(A) $\varepsilon_0 VKL^2/(4d)$ **(B)** $\varepsilon_0 VKL^2/(2d)$

(C) $\varepsilon_0 VKL^2/d$ **(D) Zero**

ANSWER

(D) Zero

Even while charged, the system as a whole is neutral: P_2 carries +Q and P_1, P_3 together carry −Q. Joining A and B lets the charges neutralise each other (the capacitor discharges), and the net charge of the system is zero in any case.

30. in Bohr's model of hydrogen, an electron (mass m, charge −e) revolves round the proton in a circular orbit of radius r with speed v; the Coulomb attraction provides the centripetal force, angular momentum is quantised in units of $h/2\pi$, and a photon is emitted when the electron drops to a lower level. Take $K = 1/(4\pi\varepsilon_0)$. **4**

(i) The speed v in terms of r and K: (A) $Ke^2/(mr)$ (B) $Ke^2/(mr^2)$ (C) $\sqrt{(Ke^2/(mr))}$ (D) $\sqrt{(Ke^2/(mr^2))}$

(ii) Total energy of the atom: (A) Ke^2/r (B) $-Ke^2/(2r)$ (C) $Ke^2/(2r)$ (D) $(3/2)Ke^2/r$

(iii) A 500 nm photon is emitted in a transition. The change in total energy and the change in kinetic energy of the electron (in eV) are, respectively: (A) 2.48, −2.48 (B) −1.24, 1.24 (C) −2.48, 2.48 (D) 1.24, −1.24

(iv) The frequency of revolution of the electron in the nth orbit is proportional to: (A) n (B) 1/n (C) $1/n^2$ (D) $1/n^3$

ANSWER

(i) C; (ii) B; (iii) C; (iv) D

(i) $mv^2/r = Ke^2/r^2 \Rightarrow v = \sqrt{(Ke^2/(mr))} \rightarrow$ (C).

(ii) $KE = \tfrac{1}{2}mv^2 = Ke^2/(2r)$; $PE = -Ke^2/r$; total $E = -Ke^2/(2r) \rightarrow$ (B).

(iii) Photon energy = 1240 eV·nm / 500 nm = 2.48 eV. Emission ⇒ total energy decreases: $\Delta E = -2.48$ eV. Since $KE = -E$, $\Delta KE = +2.48$ eV → (C).

(iv) $v \propto 1/n$ and $r \propto n^2 \Rightarrow f = v/(2\pi r) \propto 1/n^3 \rightarrow$ (D).

OR

(iv) (b) An electron in a hydrogen atom jumps from the −3.4 eV level to the ground state. By how much does its orbit radius change? (Ground-state radius = 0.53 Å)

(A) 0.53 Å **(B)** 1.06 Å

(C) 1.59 Å **(D)** 2.12 Å

ANSWER

(C) 1.59 Å

$E_n = -13.6/n^2$ eV; −3.4 eV ⇒ n = 2.

$r_n = n^2 r_1 \Rightarrow r_2 = 4 \times 0.53 = 2.12$ Å.

Change = 2.12 − 0.53 = 1.59 Å.

Common mistake: answering 2.12 Å (the radius itself, not the change).

SECTION E

Q31–33 carry 5 marks each.

31. (i) Charges +q and −q are placed at (a, 0) and (−a, 0) in the x-y plane. Find the net electric field at the point (0, y). Hence find the field at a distant point (y ≫ a). **5**

(ii) Charges −2 nC, −1 nC and +5 nC sit at the corners A, B and C of an equilateral triangle of side 0.2 m. They are moved: A to A_1, B to B_1 and C to C_1, where A_1, B_1 and C_1 are the midpoints of AB, BC and CA. Find the total work done.

ANSWER

(i) $E = -2qa/[4\pi\varepsilon_0(y^2 + a^2)^{\{3/2\}}]\ \hat{x}$, far: $E = -2qa/(4\pi\varepsilon_0 y^3)\ \hat{x}$; (ii) $W = -5.85 \times 10^{-7}$ J

(i) Distance of (0, y) from each charge = $\sqrt{(y^2 + a^2)}$.

Magnitude due to each: $E_+ = E_- = q/[4\pi\varepsilon_0(y^2 + a^2)]$.

The y-components cancel; the x-components add, both pointing towards −x (away from +q, towards −q).

Each x-component = E cos θ with cos θ = $a/\sqrt{(y^2 + a^2)}$.

$\vec{E} = -\frac{2qa}{4\pi\varepsilon_0(y^2+a^2)^{3/2}}\hat{i}$, i.e. opposite to the dipole moment p = 2qa x̂.

For y ≫ a: $\vec{E} = -\frac{2qa}{4\pi\varepsilon_0 y^3}\hat{i} = -\frac{\vec{p}}{4\pi\varepsilon_0 y^3}$.

(ii) $U = k\,\Sigma\, q_i q_j / r_{ij}$.

Initial (side 0.2 m): $\Sigma q_i q_j = (-2)(-1) + (-2)(5) + (-1)(5) = 2 - 10 - 5 = -13$ (nC)².

$U_1 = 9 \times 10^9 \times (-13 \times 10^{-18})/0.2 = -5.85 \times 10^{-7}$ J.

The midpoints form an equilateral triangle of side 0.1 m, and the same three charges sit at its corners:

$U_2 = 9 \times 10^9 \times (-13 \times 10^{-18})/0.1 = -11.7 \times 10^{-7}$ J.

Work done (by external agent) $W = U_2 - U_1 = -5.85 \times 10^{-7}$ J.

OR

(i) Show that Gauss's theorem agrees with Coulomb's law. Using Gauss's theorem, find the electric field of a uniformly charged thin spherical shell of radius r at a point at distance y from its centre when (I) y > r and (II) y < r.

(ii) A charge of +2 nC is at the origin. What charge (sign and size) must be placed at (0, 0, −6 m) so that the potential at (0, 0, 2 m) is zero?

ANSWER

(i) $E = q/(4\pi\varepsilon_0 y^2)$ outside, E = 0 inside; (ii) −8 nC

(i) Consistency: take a sphere of radius r around a point charge q. By symmetry E is radial and the same everywhere on it: $\oint E \cdot dS = E(4\pi r^2) = q/\varepsilon_0 \Rightarrow E = q/(4\pi\varepsilon_0 r^2)$. Force on $q_0 = q\, q_0/(4\pi\varepsilon_0 r^2)$, which is Coulomb's law. (Gauss's law relies on the inverse-square dependence.)

Shell of charge q ($\sigma = q/4\pi r^2$):

(I) y > r: Gaussian sphere of radius y encloses q. $E(4\pi y^2) = q/\varepsilon_0 \Rightarrow E = \frac{q}{4\pi\varepsilon_0 y^2}$, radially outward – as if all charge were at the centre.

(II) y < r: Gaussian sphere encloses no charge ⇒ $E(4\pi y^2) = 0 \Rightarrow E = 0$ inside.

(ii) Distance of (0, 0, 2) from origin = 2 m; from (0, 0, −6) = 8 m.

$V = k[2 \times 10^{-9}/2 + Q/8] = 0 \Rightarrow Q = -8 \times 10^{-9}$ C.

A negative charge of 8 nC.

32. (i) State Lenz's law and explain why it follows from conservation of energy. **5**

(ii) A square loop of side l/2 lies outside a region of uniform magnetic field B (directed into the page). The field region is a strip of width l, and the loop's front edge is initially a distance l from the strip. The loop is moved to the right with constant velocity v until it has completely left the field.

(I) What is the direction of the induced current as the loop enters the field and as it leaves?

(II) Sketch the magnetic flux φ through the loop versus time t and the induced emf E versus t, marking the important values.

ANSWER

(I) entering: anticlockwise, leaving: clockwise; (II) φ rises 0 → $Bl^2/4$, stays, falls to 0; $|E| = Blv/2$ during entry and exit, zero otherwise

(i) Lenz's law: the induced emf has a polarity that drives a current opposing the change in flux that causes it.

Energy: e.g. pushing a magnet towards a coil makes the near face of the coil the same pole, which repels the magnet; we must do mechanical work against this, and that work appears as electrical energy (heat) in the circuit. If the induced current aided the change, energy would be created from nothing – impossible.

(ii)(I) Entering: inward flux increases ⇒ induced current tries to create outward field ⇒ anticlockwise.

Leaving: inward flux decreases ⇒ current makes inward field ⇒ clockwise.

(II) Time to start entering: $t_1 = l/v$. Fully inside at $t_2 = (l + l/2)/v = 3l/(2v)$. Front edge reaches far side at $t_3 = 2l/v$. Fully out at $t_4 = 5l/(2v)$.

φ–t: 0 for $t < l/v$; rises linearly to $B(l/2)^2 = Bl^2/4$ at $3l/(2v)$; constant $Bl^2/4$ till $2l/v$; falls linearly to 0 at $5l/(2v)$; zero after.

E–t: $E = -d\varphi/dt$. Magnitude $= B(l/2)v = Blv/2$ during entry (one sign, e.g. $-Blv/2$) and during exit (opposite sign, $+Blv/2$); zero when the loop is fully outside or fully inside.

OR

(i) Distinguish between the peak value and the rms value of an alternating current and give the relation between them.

(ii) An element X is connected to an AC source $V = V_0 \sin 2\pi\nu t$ and the voltage is found to lead the current by $\pi/2$. When X is replaced by element Y, the voltage lags the current by $\pi/2$.

(I) Identify X and Y with the help of phasor diagrams.

(II) If X and Y are connected in series to the source, find the resonance condition and the resonant frequency. What is the impedance then?

ANSWER

$I_{rms} = I_0/\sqrt{2}$; X = inductor, Y = capacitor; resonance $X_L = X_C$, $\nu_0 = 1/(2\pi\sqrt{(LC)})$, Z = 0

(i) Peak value I_0: the maximum instantaneous value of the current in a cycle.

rms value: the steady (dc) current that would produce the same heating in the same resistor in the same time.

$I_{rms} = I_0/\sqrt{2} \approx 0.707\, I_0$.

(ii)(I) Phasor for X: the V phasor is 90° ahead (anticlockwise) of the I phasor ⇒ X is a pure inductor L.

For Y: the V phasor is 90° behind the I phasor ⇒ Y is a pure capacitor C.

(II) Series LC: Z = |X_L − X_C| = |ωL − 1/(ωC)|.
Resonance: X_L = X_C ⇒ ωL = 1/(ωC) ⇒ ω₀ = 1/√(LC), i.e. $\nu_0 = \frac{1}{2\pi\sqrt{LC}}$.
At resonance Z = 0 (ideal L and C with no resistance), so the current would be very large in theory.

33. (i) An object is 30 cm from a thin convex lens of focal length 10 cm, and a sharp image is formed on a screen. A thin concave lens is now put in contact with the convex lens, and the screen must be moved 45 cm further to get a sharp image again. Find the focal length of the concave lens. **5**

(ii) An equilateral prism has refractive index √3. Find its angle of minimum deviation and the angle of incidence in this position.

ANSWER

(i) f = −20 cm; (ii) $\delta_m = 60°$, i = 60°

(i) Convex lens alone: 1/v − 1/u = 1/f ⇒ 1/v = 1/10 − 1/30 = 2/30 ⇒ v = 15 cm.
With the concave lens the image moves to 15 + 45 = 60 cm.
Combination: 1/F = 1/60 + 1/30 = 3/60 ⇒ F = 20 cm.
1/F = 1/f₁ + 1/f₂ ⇒ 1/20 = 1/10 + 1/f₂ ⇒ 1/f₂ = −1/20 ⇒ f₂ = −20 cm.
(ii) $n = \frac{\sin\frac{A+\delta_m}{2}}{\sin\frac{A}{2}}$, A = 60°.
√3 = sin((60° + δ_m)/2)/sin 30° ⇒ sin((60° + δ_m)/2) = √3/2 ⇒ (60° + δ_m)/2 = 60° ⇒ δ_m = 60°.
At minimum deviation i = (A + δ_m)/2 = 60°.

OR

(i) A teacher demonstrates Young's double-slit interference using a 633 nm laser. The pattern is formed on a wall 5.0 m from the slits, and a fringe width of 5 mm is wanted for comfortable viewing.

(I) What slit separation is needed?

(II) How far from the central maximum is the first minimum?

(ii) Parallel light of wavelength 650 nm falls on a slit 0.6 mm wide, and the diffraction pattern is seen on a screen 60 cm away. Find the distance between the first minima on the two sides of the central maximum.

ANSWER

(i) d = 633 μm (0.633 mm); first minimum at 2.5 mm; (ii) 1.3 mm

(i)(I) β = λD/d ⇒ d = λD/β = 633 × 10⁻⁹ × 5.0 / (5 × 10⁻³) = 6.33 × 10⁻⁴ m = 633 μm.
(II) Dark fringe n: x_n = (2n − 1)λD/(2d); n = 1 ⇒ x_1 = λD/(2d) = β/2 = 2.5 mm.
(ii) Width of central maximum = 2λD/a = 2 × 650 × 10⁻⁹ × 0.60 / (0.6 × 10⁻³) = 1.3 × 10⁻³ m = 1.3 mm.
Common mistake: forgetting the factor 2 – each first minimum is λD/a from the centre.

— END —

Questions restated from the CBSE Class XII Board Examination 2025 (set 55/4/1) for practice. Reading passages and map items are described, not reproduced.