Roll No. ☐☐☐☐☐☐☐☐

Q.P. Code 55/1/1

PHYSICS (THEORY)

CBSE Class XII Board Examination 2026 — with answers

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

General Instructions:

1. The paper has 33 questions in five sections (A to E); all questions are compulsory.
2. Section A: Q1–16, multiple choice / Assertion-Reason, 1 mark each. Section B: Q17–21, very short answer, 2 marks each.
3. Section C: Q22–28, short answer, 3 marks each. Section D: Q29–30, case-study based, 4 marks each. Section E: Q31–33, long answer, 5 marks each.
4. There is no overall choice, but some questions in Sections B to E have an internal choice.
5. Calculators are not allowed.
6. Constants: $c = 3 \times 10^{8}$ 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, mass of neutron = 1.675×10^{-27} kg, mass of proton = 1.673×10^{-27} kg, Avogadro's number = 6.023×10^{23} per gram mole, Boltzmann's constant = 1.38×10^{-23} J K^{-1}.

SECTION A

Q1–16 carry 1 mark each (MCQ / Assertion-Reason).

1. The electric potential in a region is given by V = 10 − 50x (V in volt, x in metre). What is the electric field in this region? **1**

(A) 10 N/C along +x

(B) 10 N/C along −x

(C) 50 N/C along +x

(D) 50 N/C along −x

ANSWER

(C) 50 N/C along +x

Use $E_x = -\frac{dV}{dx}$.

$\frac{dV}{dx} = -50$ V/m, so $E_x = -(-50) = +50$ V/m = 50 N/C.

The positive sign means the field points along +x (towards decreasing potential).

Common mistake: forgetting the minus sign and choosing −x.

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2. Two charged metal spheres A and B, of radii r_1 and r_2, are far apart and joined by a conducting wire. Find the ratio E_A/E_B of the electric fields at their surfaces. **1**

(A) $\frac{r_1}{r_2}$

(B) $\frac{r_2}{r_1}$

(C) $\frac{r_1^2}{r_2^2}$

(D) $\frac{r_2^2}{r_1^2}$

ANSWER

(B) $E_A/E_B = r_2/r_1$

Joined by a wire, both spheres reach the same potential: $\frac{kQ_1}{r_1} = \frac{kQ_2}{r_2}$, so $Q_1/Q_2 = r_1/r_2$.

Surface field $E = \frac{kQ}{r^2}$, so $\frac{E_A}{E_B} = \frac{Q_1}{Q_2} \cdot \frac{r_2^2}{r_1^2} = \frac{r_1}{r_2} \cdot \frac{r_2^2}{r_1^2} = \frac{r_2}{r_1}$.

So the smaller sphere has the stronger surface field (this is why charge collects at sharp points).

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3. A long straight wire of circular cross-section of radius a carries a steady current I spread uniformly over its cross-section. What is the magnitude of the magnetic field at a distance a/2 from the axis? **1**

(A) Zero

(B) $\frac{\mu_0 I}{2\pi a}$

(C) $\frac{\mu_0 I}{4\pi a}$

(D) $\frac{\mu_0 I}{6\pi a}$

ANSWER

(C) $\mu_0 I/(4\pi a)$

Apply Ampere's circuital law on a circle of radius r = a/2 inside the wire.

Current enclosed: $I_{enc} = I\frac{\pi r^2}{\pi a^2} = \frac{I}{4}$.

$B(2\pi r) = \mu_0 I_{enc} \Rightarrow B = \frac{\mu_0 (I/4)}{2\pi (a/2)} = \frac{\mu_0 I}{4\pi a}$.

Check: inside the wire $B = \frac{\mu_0 I r}{2\pi a^2}$, which also gives $\mu_0 I/(4\pi a)$ at r = a/2.

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4. In Young's double-slit experiment the screen is very far from the slits compared with the slit separation. The interference fringes then have nearly which shape? **1**

(A) straight **(B)** parabolic

(C) circular **(D)** hyperbolic

ANSWER
(A) straight

Points of constant path difference $S_2P - S_1P$ lie on hyperbolas (in 3-D, hyperboloids).
When D ≫ d, the part of these hyperbolas that falls on the screen near the centre is almost straight, so the fringes look like straight lines parallel to the slits.

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5. An electromagnetic wave goes from vacuum into a medium having relative permittivity 3/2 and relative permeability 8/3. What happens to the wave? **1**

(A) wavelength is doubled and frequency remains unchanged

(B) wavelength is doubled and frequency is halved

(C) wavelength is halved and frequency remains unchanged

(D) wavelength and frequency both remain unchanged

ANSWER
(C) wavelength is halved, frequency unchanged

Speed in the medium: $v = \dfrac{c}{\sqrt{\varepsilon_r \mu_r}} = \dfrac{c}{\sqrt{(3/2)(8/3)}} = \dfrac{c}{\sqrt{4}} = \dfrac{c}{2}$.

Frequency is fixed by the source and does not change on entering a new medium.
$\lambda = v/\nu$, so the wavelength becomes half.

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6. In a series LCR circuit the voltages across R, C and L are each 10 V. If the capacitor is now short-circuited, what will be the voltage across the inductor? **1**

(A) 10 V **(B) 5√2 V**

(C) 5/√2 V **(D)** 10√2 V

ANSWER
(B) 5√2 V

V_R = V_L = V_C = 10 V ⇒ the circuit is at resonance, source voltage V = V_R = 10 V, and R = X_L (same current through both).

After shorting C: $Z = \sqrt{R^2 + X_L^2} = \sqrt{2}\,R$, so $I = \dfrac{10}{\sqrt{2}R}$.

$V_L = IX_L = \dfrac{10}{\sqrt{2}R} \cdot R = \dfrac{10}{\sqrt{2}} = 5\sqrt{2}$ V ≈ 7.07 V.

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7. Electromagnetic waves used as a diagnostic tool in medicine lie in which wavelength range? **1**

(A) 1 nm to 10^{-3} nm **(B)** 400 nm to 1 nm

(C) 1 mm to 700 nm **(D)** 0.1 m to 1 mm

ANSWER

(A) 1 nm to 10^{-3} nm (X-rays)

The diagnostic tool is X-ray imaging. X-rays have wavelengths from about 1 nm down to 10^{-3} nm. 400 nm–1 nm is ultraviolet, 1 mm–700 nm is infrared and 0.1 m–1 mm is microwaves.

8. An alpha particle moving head-on towards a nucleus with speed v has distance of closest approach d. If its speed is made v/2, what is the new distance of closest approach? **1**

(A) d/2 **(B)** 2d

(C) d/4 **(D) 4d**

ANSWER

(D) 4d

At closest approach all KE becomes electrostatic PE: $\frac{1}{2}mv^2 = \frac{k(2e)(Ze)}{d}$, so $d \propto \frac{1}{v^2}$.

Halving v makes v^2 one-fourth, so d becomes 4 times: d' = 4d.

9. A concave lens of focal length 10 cm is cut into two identical plano-concave lenses. What is the focal length of each piece? **1**

(A) 20 cm **(B)** 30 cm

(C) 40 cm **(D)** 5 cm

ANSWER

(A) 20 cm

The original lens is like two identical plano-concave lenses in contact: $\frac{1}{F} = \frac{1}{f} + \frac{1}{f} = \frac{2}{f}$.

So f = 2F = 2 × 10 = 20 cm (each piece is diverging, f = −20 cm).

By lens maker's formula: one curved surface instead of two halves the power.

10. Four independent waves are: (i) $y_1 = A_1 \sin \omega t$, (ii) $y_2 = A_2 \sin 2\omega t$, (iii) $y_3 = A_3 \cos \omega t$, (iv) $y_4 = A_4 \sin(\omega t + \pi/3)$. Between which of these can interference be obtained? **1**

(A) (i) and (iii) only **(B)** (iii) and (iv) only

(C) (i), (iii) and (iv) only **(D)** All of them

ANSWER

(C) (i), (iii) and (iv) only

Sustained interference needs waves of the same frequency with a constant phase difference.

(i), (iii) and (iv) all have angular frequency ω: $\cos \omega t = \sin(\omega t + \pi/2)$, and (iv) has a fixed phase π/3.

(ii) has frequency 2ω, so it cannot interfere steadily with the others.

11. Two heaters rated (P_1, V) and (P_2, V) are joined in series and connected to a dc source of V/2 volt. What power does the combination consume? **1**

(A) ($P_1 + P_2$)

(B) $\dfrac{P_1 + P_2}{2}$

(C) $\dfrac{P_1 P_2}{2(P_1 + P_2)}$

(D) $\dfrac{P_1 P_2}{4(P_1 + P_2)}$

ANSWER

(D) $P_1P_2 / [4(P_1 + P_2)]$

Resistances: $R_1 = V^2/P_1, R_2 = V^2/P_2$.

Series: $R = V^2\left(\frac{1}{P_1} + \frac{1}{P_2}\right) = \frac{V^2(P_1 + P_2)}{P_1P_2}$.

Power at V/2: $P = \frac{(V/2)^2}{R} = \frac{V^2}{4} \cdot \frac{P_1P_2}{V^2(P_1 + P_2)} = \frac{P_1P_2}{4(P_1 + P_2)}$.

12. For an unbiased p-n junction in equilibrium, which statement is correct? **1**

(A) Diffusion current is zero but drift current exists.

(B) Diffusion current exists but drift current is zero.

(C) Diffusion and drift currents are equal and opposite.

(D) Both diffusion and drift currents exist but are unequal.

ANSWER

(C) Diffusion and drift currents are equal and opposite

Diffusion of majority carriers builds the depletion layer and barrier field; this field drives a drift current of minority carriers in the opposite direction.

Equilibrium is reached when the two currents are equal in size, so the net current is zero.

13. Assertion (A): Every atom has a net magnetic moment. **1**

Reason (R): A current loop does not always behave like a magnetic dipole.

(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

(D) Both A and R are false

A is false: in diamagnetic substances the magnetic moments of electrons cancel, so their atoms have zero net magnetic moment.

R is false: a current loop always behaves as a magnetic dipole with moment m = IA.

14. Assertion (A): A diffraction pattern is seen when accelerated electrons pass through a narrow slit. **1**

Reason (R): Electrons show both particle and wave nature.

(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

Moving electrons have a de Broglie wavelength $\lambda = h/p$. Diffraction is a wave effect, so it is observed only because electrons behave as waves too.

Both statements are true and R correctly explains A.

15. Assertion (A): A nucleus has less mass than the total mass of its separate nucleons. **1**

Reason (R): Energy is absorbed when nucleons come together to form a nucleus.

(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 is true, R is false

A is true: this is the mass defect ΔM.

R is false: when nucleons bind, energy (binding energy = ΔMc^2) is released, not absorbed. That released energy is why the nucleus is lighter.

16. Assertion (A): In the Bohr model of the hydrogen atom, energy levels are discrete (quantised). **1**

Reason (R): In a hydrogen atom the electrostatic attraction on the electron supplies the centripetal force for its revolution about the nucleus.

(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

Both statements are true.

But quantisation of energy comes from Bohr's postulate that angular momentum is quantised ($mvr = nh/2\pi$), not from the electrostatic force providing centripetal force (which holds even in a classical orbit). So R is not the explanation.

SECTION B

Q17–21 are very short answer questions, 2 marks each.

17. Light of wavelength 200 nm falls on the emitter plate in a photoelectric experiment. The photocurrent just becomes zero when the collector potential is −0.80 V. Find the work function of the emitter in eV. **2**

ANSWER

$\varphi_0 \approx 5.4$ eV

Einstein's equation: $\frac{hc}{\lambda} = \phi_0 + eV_0$, with stopping potential $V_0 = 0.80$ V.

Photon energy: $\frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{200 \times 10^{-9}} = 9.945 \times 10^{-19}$ J $= \frac{9.945 \times 10^{-19}}{1.6 \times 10^{-19}} \approx 6.2$ eV.

$\phi_0 = 6.2 - 0.80 = 5.4$ eV.

18. A single slit of width 1 mm is lit by light containing two wavelengths, 400 nm and 600 nm. The screen is 1.5 m from the slit. Find the smallest distance from the central maximum at which dark fringes of both wavelengths fall at the same place. **2**

ANSWER

y = 1.8 mm

Minima of a single slit: $a \sin\theta = n\lambda$, position $y = \frac{n\lambda D}{a}$.

For coincidence: $n_1(400) = n_2(600)$. Smallest integers: $n_1 = 3$, $n_2 = 2$ (both give 1200 nm).

$y = \frac{2 \times 600 \times 10^{-9} \times 1.5}{1 \times 10^{-3}} = 1.8 \times 10^{-3}$ m = 1.8 mm.

Check: $3 \times 400 \times 10^{-9} \times 1.5 / 10^{-3}$ = 1.8 mm as well.

OR

In a Young's double-slit set-up the slits are 0.6 mm apart and the screen is 1.5 m away. Light having two wavelengths, 440 nm and 660 nm, is used. Find the least distance from the central maximum where bright fringes of the two wavelengths coincide.

ANSWER

y = 3.3 mm

Bright fringe: $y = \frac{n\lambda D}{d}$.

Coincidence: $n_1(440) = n_2(660) \Rightarrow$ smallest $n_1 = 3$, $n_2 = 2$ (both 1320 nm).

$y = \frac{2 \times 660 \times 10^{-9} \times 1.5}{0.6 \times 10^{-3}} = 3.3 \times 10^{-3}$ m = 3.3 mm.

19. A wire of length L is wound into (i) a square coil of N turns and (ii) a circular coil of N turns. Each coil carries the same current and can rotate about a vertical axis lying in its plane, in the same uniform horizontal magnetic field. Find the ratio of the maximum torque on the square coil to that on the circular coil. **2**

ANSWER

$\tau_{square} : \tau_{circle} = \pi : 4$

Maximum torque $\tau = NIAB$, so with N, I, B equal, $\tau \propto A$.

Square: perimeter of one turn = L/N ⇒ side a = L/(4N), area $A_1 = \frac{L^2}{16N^2}$.

Circle: $2\pi r = L/N \Rightarrow$ r = L/(2πN), area $A_2 = \pi r^2 = \frac{L^2}{4\pi N^2}$.

$\frac{\tau_1}{\tau_2} = \frac{A_1}{A_2} = \frac{L^2/16N^2}{L^2/4\pi N^2} = \frac{\pi}{4}$.

20. State the order of magnitude of the drift velocity of electrons in a conductor. Derive the relation between the current in a conductor and the drift velocity of its electrons. **2**

ANSWER

$v_d \sim 10^{-4}$ m/s (a fraction of a mm/s to a few mm/s); $I = neAv_d$

Order: drift speeds are tiny, about 10^{-4} m/s (of the order of mm per second or less).

Derivation: let n = free electrons per unit volume, A = cross-section, v_d = drift speed.

In time Δt electrons move a distance $v_d\Delta t$, so the electrons in volume $A\,v_d\Delta t$ cross a section.

Charge crossing: $Q = neAv_d\,\Delta t$ (electrons move opposite to E, so current is along E).

$I = \frac{Q}{\Delta t} = neAv_d$.

21. Sketch the potential energy of a pair of nucleons against their separation. State two important conclusions from this graph. **2**

ANSWER

PE is minimum at $r_0 \approx 0.8$ fm; force attractive for r > 0.8 fm, strongly repulsive for r < 0.8 fm, and negligible beyond a few fm.

Graph: x-axis r (fm), y-axis potential energy (MeV). The curve is very high (positive) at small r, falls steeply, crosses zero, reaches a negative minimum (about −100 MeV) at $r_0 \approx 0.8$ fm, then rises and approaches zero by about 2–3 fm.

Conclusions (any two):

1. PE is minimum at about $r_0 = 0.8$ fm, the stable separation of nucleons.
2. For $r > r_0$ the slope is positive, so the nuclear force is attractive.
3. For $r < r_0$ the force is strongly repulsive, which keeps nucleons from collapsing.
4. The force is short-range: it becomes negligible beyond a few fermi.

SECTION C

Q22–28 are short answer questions, 3 marks each.

22. (a) Using Gauss's law, find the electric field at a point near a uniformly charged, infinite, thin plane sheet. **3**

(b) Two large thin parallel sheets, each with surface charge density σ, are held close to each other in air. What is the net field (i) between the sheets and (ii) outside them?

ANSWER

(a) E = σ/(2ε₀), normal to the sheet; (b) (i) 0 inside, (ii) σ/ε₀ outside

(a) Take a cylindrical Gaussian surface of end-cap area A that pierces the sheet, with caps on both sides at equal distance.

By symmetry E is normal to the sheet, so the curved surface gives zero flux; each cap gives EA.

Total flux = 2EA. Charge enclosed = σA.

Gauss's law: $2EA = \frac{\sigma A}{\varepsilon_0} \Rightarrow E = \frac{\sigma}{2\varepsilon_0}$, directed away from the sheet if σ > 0. It does not depend on distance.

(b) Each sheet gives σ/(2ε₀).

(i) Between the sheets the two fields point in opposite directions: E = σ/2ε₀ − σ/2ε₀ = 0.

(ii) Outside, they point the same way: E = σ/2ε₀ + σ/2ε₀ = σ/ε₀, directed away from the sheets.

OR

(a) Derive the balance condition of a Wheatstone bridge.

(b) Find the equivalent resistance between A and B of this network: A to M is 2R. From M, one resistor R goes to point O and another R goes (over the top) to point P. Between O and P there is R. From O, a resistor R goes (along the bottom) to point N, and between P and N there is R. Finally N to B is 3R.

ANSWER

(b) R_AB = 6R

(a) Bridge ABCD: P in AB, Q in BC, R in AD, S in DC; galvanometer G between B and D; cell between A and C. Let I_1 flow in P, I_2 in R.

At balance I_g = 0, so P and Q carry the same current I_1; R and S carry I_2, and V_B = V_D.

Loop ABDA: $-I_1P + I_2R = 0 \Rightarrow I_1P = I_2R$.

Loop BCDB: $-I_1Q + I_2S = 0 \Rightarrow I_1Q = I_2S$.

Dividing: $\frac{P}{Q} = \frac{R}{S}$.

(b) Between M and N: arms M–O (R), O–N (R), M–P (R), P–N (R), with O–P (R) as the bridge.

R/R = R/R, so the bridge is balanced and O–P carries no current.

R_MN = (R + R) ∥ (R + R) = 2R ∥ 2R = R.

R_AB = 2R + R + 3R = 6R.

23. A parallel-plate capacitor of capacitance C has a dielectric slab between its plates. It is charged to potential difference V by a battery, and then the battery is removed. Now the slab is pulled out. How do (a) the capacitance, (b) the stored energy and (c) the potential difference between the plates change? Justify each. **3**

ANSWER

(a) C falls to C/K; (b) energy rises K times; (c) V rises to KV

After disconnecting, charge Q stays constant.

(a) With slab C = Kε₀A/d; without slab C' = ε₀A/d = C/K, so capacitance decreases K times.

(b) $U = \frac{Q^2}{2C}$; with C' = C/K, $U' = \frac{Q^2}{2C/K} = KU$. Energy increases (the extra energy comes from the work done in pulling the slab out against attraction).

(c) V = Q/C ⇒ V' = Q/C' = KV, so the potential difference increases K times.

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24. A narrow electron beam with speed 3×10^7 m/s enters midway between two horizontal parallel plates P_1P_1' (upper) and P_2P_2' (lower) that are 2 cm apart. Each plate is 3 cm long. Find the potential difference V between the plates needed so that the beam just hits the far end P_2' of the lower plate. **3**

ANSWER

V ≈ 2275 V

Field between plates E = V/d with d = 2 cm; acceleration $a = \frac{eE}{m} = \frac{eV}{md}$ (vertical).

Time in plates: $t = \frac{x}{u}$, x = 3 cm.

The beam starts midway, so it must deflect y = 1 cm: $y = \frac{1}{2}at^2 = \frac{1}{2}\frac{eV}{md}\frac{x^2}{u^2}$.

$V = \frac{2ymdu^2}{ex^2} = \frac{2(0.01)(9.1 \times 10^{-31})(0.02)(3 \times 10^7)^2}{(1.6 \times 10^{-19})(0.03)^2}$.

Numerator = 3.276×10^{-19}, denominator = 1.44×10^{-22}, V ≈ 2275 V.

Common mistake: using y = 2 cm (the full gap) instead of half the gap.

25. An ac voltage Vi = 12 sin(100πt) V is applied between points A (top) and B (bottom) of a diamond-shaped network. Ideal diode D_1 joins A to P (cathode at A, anode at P) and ideal diode D_2 joins A to R (anode at A, cathode at R). A 1 kΩ resistor joins P and R, 2 kΩ joins P and B, and 3 kΩ joins R and B. Consider the positive half-cycle (A positive). **3**

(a) Which diode conducts, and why?

(b) Draw the equivalent circuit showing the current path.

(c) Find the voltage drops across the three resistors when Vi is at its peak.

ANSWER

(a) D_2 conducts; (c) V_RP = 4 V, V_PB = 8 V, V_RB = 12 V

(a) With A positive, D_2 (anode at A) is forward biased and conducts; D_1 (cathode at A) is reverse biased and acts as an open switch.

(b) Equivalent circuit: A is joined directly to R (ideal D_2 = a plain wire); D_1 is removed. From R, current divides: one path R → 3 kΩ → B; the other path R → 1 kΩ → P → 2 kΩ → B.

(c) Peak: V_R − V_B = 12 V.

The 3 kΩ resistor is directly across 12 V: V_RB = 12 V.

The 1 kΩ and 2 kΩ in series (3 kΩ) are also across 12 V: current = 12/3000 = 4 mA, so V_RP = 4 mA × 1 kΩ = 4 V and V_PB = 4 mA × 2 kΩ = 8 V.

26. Briefly describe the two important processes that take place while a p-n junction is being formed. **3**

ANSWER

Diffusion and drift

1. Diffusion: there are many holes in the p-side and many electrons in the n-side. Due to this concentration difference, holes diffuse p → n and electrons diffuse n → p, giving a diffusion current from p to n. They leave behind immobile ions: positive donor ions on the n-side and negative acceptor ions on the p-side, forming the depletion region.

2. Drift: the ion layers set up an electric field from the n-side to the p-side (barrier potential). This field pushes minority carriers across the junction (electrons p → n, holes n → p), giving a drift current opposite to the diffusion current.

Diffusion current falls and drift current rises until they become equal; then equilibrium is reached and net current is zero.

27. (a) Draw a ray diagram for image formation by a refracting telescope and write its angular magnification in normal adjustment. **3**

(b) Give two reasons why a reflecting telescope is preferred to a refracting one.

ANSWER

(a) m = f_o/f_e (normal adjustment); (b) e.g. no chromatic aberration, less spherical aberration with a parabolic mirror, lighter and cheaper to support, brighter image

(a) Diagram: parallel rays from a distant object fall on the objective (large f_o) and form a real, inverted image A′B′ at its focus. This point is also the focus of the eyepiece (small f_e), so rays leave the eyepiece parallel and the final image is at infinity. Tube length = $f_o + f_e$.

Angular magnification $m = \dfrac{\beta}{\alpha} = \dfrac{f_0}{f_e}$.

(b) Any two:

1. A mirror has no chromatic aberration.
2. A parabolic mirror removes spherical aberration.
3. A mirror can be supported over its whole back, so a large aperture is lighter and easier to mount than a large lens.
4. A large mirror is cheaper to make and gives a brighter image (more light gathered).

28. (a) Write the two conditions needed for total internal reflection. **3**

(b) A transparent container holds three immiscible liquid layers: A at the bottom (refractive index n), B in the middle (3n/4) and C on top (2n/3). A laser beam inside A strikes the A–B interface at angle θ. Show that the beam does not enter C at all if sin θ ≥ 2/3.

ANSWER

(a) light goes denser → rarer, and i > critical angle; (b) at sin θ = 2/3 the ray grazes the B–C interface, so it cannot enter C for sin θ ≥ 2/3

(a) 1. Light must travel from an optically denser to a rarer medium.

2. Angle of incidence must be greater than the critical angle.

(b) A → B (Snell): $n \sin\theta = \dfrac{3n}{4} \sin\theta_1 \Rightarrow \sin\theta_1 = \dfrac{4}{3}\sin\theta$.

Interfaces are parallel, so θ_1 is the angle of incidence at B → C:

$\dfrac{3n}{4}\sin\theta_1 = \dfrac{2n}{3}\sin r \Rightarrow \sin r = \dfrac{9}{8}\sin\theta_1 = \dfrac{9}{8}\cdot\dfrac{4}{3}\sin\theta = \dfrac{3}{2}\sin\theta$.

(Shortcut: $n\sin\theta = \dfrac{2n}{3}\sin r$ directly.)

For sin θ = 2/3: sin r = 1, r = 90°, the ray just grazes the B–C surface.

For sin θ > 2/3, sin r would exceed 1, so the ray is totally reflected at B–C. Hence it never enters C for sin θ ≥ 2/3.

SECTION D

Q29–30 are case-study based questions, 4 marks each.

29. *A moving-coil galvanometer detects and measures small currents: the current-carrying coil feels a deflecting torque in a magnetic field, a hair spring supplies the restoring torque, and with suitable resistances the galvanometer can be turned into an ammeter or a voltmeter of any desired range.* **4**

(a) (I) The torque on the coil stays the same whatever the coil's orientation during rotation. This is because of:

(A) the soft iron core, which increases the magnetic field

(B) the radial magnetic field

(C) the hair spring, which provides the counter torque

(D) eddy currents in the iron core, which cause damping

ANSWER

(B) radial magnetic field

Torque $\tau = NIAB \sin\theta$, where θ is the angle between the field and the coil's normal.
With concave pole pieces and a soft iron core the field is radial, so the plane of the coil is always parallel to B ($\theta = 90°$) and $\tau = NIAB$ for every position.

(b) (II) The best way to increase the current sensitivity of a galvanometer is by:

(A) increasing the number of turns of the coil

(B) increasing the area of the coil and the magnetic field strength

(C) decreasing the area of the coil and the magnetic field strength

(D) increasing the torsional constant of the hair spring

ANSWER

(A) increasing the number of turns

Current sensitivity $\frac{\phi}{I} = \frac{NAB}{k}$.

Raising N is the practical way: B cannot be raised much beyond what strong magnets give, and a larger area makes the coil bulky and heavy. Increasing k would reduce sensitivity, and option (C) reduces it too.

(c) (III) A galvanometer coil of cross-sectional area 4.0×10^{-3} m² and 50 turns is in a magnetic field of 0.25 T. What torque acts on it when a current of 5 A flows?

(A) 1.0 N m **(B)** 2.0 N m

(C) 0.50 N m **(D) 0.25 N m**

ANSWER

(D) 0.25 N m

$\tau = NIAB = 50 \times 5 \times 4.0 \times 10^{-3} \times 0.25$.

$50 \times 5 = 250$; $250 \times 4 \times 10^{-3} = 1.0$; $1.0 \times 0.25 = 0.25$ N m.

OR

(c) (III) A galvanometer of coil resistance 15 Ω gives full-scale deflection at 3 mA. What resistance is needed to make it a voltmeter of range 0–12 V?

(A) 4015 Ω **(B) 3985 Ω**

(C) 415 Ω **(D)** 385 Ω

ANSWER

(B) 3985 Ω (in series)

For a voltmeter, a high resistance R is put in series: $V = I_g(G + R)$.

$R = \dfrac{V}{I_g} - G = \dfrac{12}{3 \times 10^{-3}} - 15 = 4000 - 15 = 3985\ \Omega.$

(d) (IV) A galvanometer of coil resistance 20 Ω gives full-scale deflection at 5 mA. To convert it into an ammeter of range 0–10 A, one should connect:

(A) 0.05 Ω in series with it **(B)** 0.05 Ω in parallel with it

(C) 0.01 Ω in parallel with it **(D)** 0.01 Ω in series with it

ANSWER

(C) 0.01 Ω in parallel

An ammeter needs a small shunt S in parallel: $I_g G = (I - I_g)S$.

$S = \dfrac{5 \times 10^{-3} \times 20}{10 - 0.005} = \dfrac{0.1}{9.995} \approx 0.01\ \Omega$, in parallel.

30. *A researcher shines monochromatic light of different frequencies on two metals A and B and records the stopping potential Vs. The graph of Vs against frequency ν gives two parallel straight lines: line A cuts the ν-axis at ν_1 and line B at ν_2 ($\nu_2 > \nu_1$); extended backwards, they meet the Vs-axis below the origin at $-V_1$ (A) and $-V_2$ (B).* **4**

(a) (I) From the graph, the work functions of A and B are (h = Planck's constant, e = electronic charge):

(A) ν_1 and ν_2 **(B)** V_1 and V_2

(C) $h\nu_1$ and $h\nu_2$ **(D)** $h\nu_1/e$ and $h\nu_2/e$

ANSWER
(C) $h\nu_1$ and $h\nu_2$

The ν-intercept is the threshold frequency, and the work function is $\varphi_0 = h\nu_0$.
So $\varphi_A = h\nu_1$ and $\varphi_B = h\nu_2$. (Equivalently $\varphi_0 = eV_1$ and eV_2 from the Vs-intercepts, but that is not an option; hν/e and V are potentials, not energies.)

(b) (II) For light of frequency $\nu > \nu_2$ falling on both A and B, the maximum kinetic energy of the emitted electrons is:

(A) greater for metal A because it has a smaller work function

(B) greater for metal B because it has a larger work function

(C) greater for metal B because it has a higher threshold frequency

(D) the same for both, as it does not depend on the work function

ANSWER
(A) greater for A (smaller work function)

$K_{max} = h\nu - \varphi_0$. For the same ν, the metal with the smaller work function gives the larger K_{max}.
$\varphi_A = h\nu_1 < \varphi_B = h\nu_2$, so electrons from A are faster.

(c) (III) If the intensity of the light falling on A and B is doubled without changing its frequency, then:

(A) the slope of the parallel lines will increase

(B) the slope of the parallel lines will decrease

(C) the threshold frequencies of both A and B will decrease

(D) the slope will not change, but more electrons will be emitted per second

ANSWER
(D) slope unchanged; more electrons per second

Slope of Vs–ν graph = h/e, a universal constant, and the threshold is a property of the metal; neither depends on intensity.
Greater intensity means more photons per second, so more photoelectrons are emitted per second (larger photocurrent).

(d) (IV) A metal has threshold frequency ν_0. With light of frequency $3\nu_0$ the maximum KE of the photoelectrons is E_1; with frequency $6\nu_0$ it is E_2. Find E_1/E_2.

(A) 1/3 **(B)** 1/2

(C) 2/5 **(D)** 3/4

ANSWER

(C) 2/5

$E_1 = h(3\nu_0) - h\nu_0 = 2h\nu_0$.

$E_2 = h(6\nu_0) - h\nu_0 = 5h\nu_0$.

$E_1/E_2 = 2/5$.

Common mistake: taking 3/6 = 1/2 by forgetting to subtract the work function.

OR

(d) (IV) If the slope of the line for metal B is m and e is the electronic charge, Planck's constant h equals:

(A) me **(B)** 1/(me)

(C) m/e **(D)** e/m

ANSWER

(A) h = me

From $eV_s = h\nu - \varphi_0$: $V_s = \frac{h}{e}\nu - \frac{\phi_0}{e}$.

Slope m = h/e ⇒ h = me.

SECTION E

Q31–33 are long answer questions, 5 marks each.

31. (a) An electric dipole is made of charges q and −q separated by 2a. Derive the electric field at a point at distance r from its centre on the equatorial plane. Write the result for a far point (r ≫ a). **5**

(b) A dipole lies in the x-y plane with charge q at x = a and −q at x = b on the x-axis. A uniform field $\vec{E} = 2\hat{i}$ N/C exists in the region. Find the force and the torque on the dipole.

ANSWER

(a) E = (1/4πε₀)·2qa/(r² + a²)^{3/2}, opposite to p; far: E = −p/(4πε₀r³); (b) F = 0, τ = 0

(a) Let the dipole lie along the axis with p = q(2a) from −q to +q, and P be on the perpendicular bisector at distance r.

Distance of P from each charge = $\sqrt{r^2 + a^2}$, so $E_{+q} = E_{-q} = \dfrac{1}{4\pi\varepsilon_0}\dfrac{q}{r^2 + a^2}$.

Components perpendicular to the dipole axis cancel; components parallel to the axis add, both pointing from +q towards −q (opposite to p).

With $\cos\theta = \dfrac{a}{\sqrt{r^2 + a^2}}$: $E = 2E_{+q}\cos\theta = \dfrac{1}{4\pi\varepsilon_0}\dfrac{2qa}{(r^2 + a^2)^{3/2}}$.

Vector form: $\vec{E} = -\dfrac{\vec{p}}{4\pi\varepsilon_0(r^2 + a^2)^{3/2}}$.

For r ≫ a: $\vec{E} = -\dfrac{\vec{p}}{4\pi\varepsilon_0 r^3}$.

(b) Force: $\vec{F} = q\vec{E} + (-q)\vec{E} = q(2\hat{i}) - q(2\hat{i}) = 0$ (uniform field).

Torque: p points from −q to +q, i.e. along the x-axis (parallel or antiparallel to E). $\vec{\tau} = \vec{p} \times \vec{E} = 0$ since the angle is 0 or π.

So both force and torque are zero.

OR

(a) Two cells of emfs E₁ and E₂ and internal resistances r₁ and r₂ are joined in parallel (positive to positive, negative to negative). Derive the equivalent emf and equivalent internal resistance.

(b) Two such cells, of emfs E and 3E and internal resistance R each, are joined in parallel as in (a) and connected across a resistance 2R. Find the current through 2R.

ANSWER

(a) E_eq = (E₁r₂ + E₂r₁)/(r₁ + r₂), r_eq = r₁r₂/(r₁ + r₂); (b) I = 4E/(5R)

(a) Let the common terminal voltage be V and currents I₁, I₂ leave the positive terminals; external current I = I₁ + I₂.

$V = E_1 - I_1 r_1 \Rightarrow I_1 = \dfrac{E_1 - V}{r_1}$; similarly $I_2 = \dfrac{E_2 - V}{r_2}$.

$I = \left(\dfrac{E_1}{r_1} + \dfrac{E_2}{r_2}\right) - V\left(\dfrac{1}{r_1} + \dfrac{1}{r_2}\right)$.

Rearranging: $V = \dfrac{E_1 r_2 + E_2 r_1}{r_1 + r_2} - I\dfrac{r_1 r_2}{r_1 + r_2}$.

Compare with V = E_eq − I r_eq: $E_{eq} = \dfrac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$, $r_{eq} = \dfrac{r_1 r_2}{r_1 + r_2}$.

(b) $E_{eq} = \dfrac{E \cdot R + 3E \cdot R}{2R} = 2E$; $r_{eq} = \dfrac{R \cdot R}{2R} = \dfrac{R}{2}$.

$I = \dfrac{E_{eq}}{2R + r_{eq}} = \dfrac{2E}{2R + R/2} = \dfrac{4E}{5R}$.

32. (a) Starting from the formula for refraction at a spherical surface, derive the lens maker's formula. **5**

(b) Three convex lenses L_1, L_2, L_3, each of focal length 40 cm, are placed coaxially. L_1 to L_2 is 120 cm and L_2 to L_3 is 20 cm. An object is 80 cm to the left of L_1. How far is the final image from the object?

ANSWER

(a) $1/f = (n_{21} - 1)(1/R_1 - 1/R_2)$; (b) final image is 40 cm beyond L_3, i.e. 260 cm from the object

(a) Thin lens of index n_2 in a medium n_1, surfaces of radii R_1 and R_2.

First surface (object O at distance u, image I_1 at v_1): $\frac{n_2}{v_1} - \frac{n_1}{u} = \frac{n_2 - n_1}{R_1}$.

I_1 acts as the object for the second surface (lens is thin): $\frac{n_1}{v} - \frac{n_2}{v_1} = \frac{n_1 - n_2}{R_2}$.

Adding: $n_1\left(\frac{1}{v} - \frac{1}{u}\right) = (n_2 - n_1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$.

For u = ∞, v = f: $\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$, and $1/v - 1/u = 1/f$.

(b) L_1: u = −80, f = 40: $\frac{1}{v} = \frac{1}{40} - \frac{1}{80} = \frac{1}{80} \Rightarrow v_1 = 80$ cm right of L_1.

L_2 is 120 cm away, so this image is 40 cm in front of L_2 (u = −40) = at its focus ⇒ rays leave L_2 parallel ($v_2 = \infty$).

L_3 receives parallel rays ⇒ image at its focus, 40 cm right of L_3.

Distance from object = 80 + 120 + 20 + 40 = 260 cm.

OR

(a) Draw a ray diagram for a concave mirror with the object between F and C. Use it to derive the mirror formula.

(b) A concave mirror gives a virtual image twice the size of an object placed 10 cm in front of it. Find its focal length.

ANSWER

(a) $1/f = 1/v + 1/u$; (b) f = −20 cm (focal length 20 cm)

(a) Diagram: object AB between F and C. A ray from B parallel to the axis reflects through F; a ray from B through F reflects parallel to the axis (or a ray to the pole P reflects symmetrically). They meet at B′, giving a real, inverted, magnified image A′B′ beyond C.

Triangles A′B′P and ABP are similar: $\frac{A'B'}{AB} = \frac{PA'}{PA}$.

Ray from B parallel to the axis hits the mirror at M (near P, so MP ≈ AB); triangles A′B′F and PMF are similar: $\frac{A'B'}{AB} = \frac{FA'}{FP} = \frac{PA' - PF}{PF}$.

So $\frac{PA'}{PA} = \frac{PA' - PF}{PF}$. Sign convention: PA = −u, PA′ = −v, PF = −f:

$\frac{-v}{-u} = \frac{-v + f}{-f} \Rightarrow vf = uv - uf \Rightarrow$ dividing by uvf: $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$.

(b) Virtual, erect image: m = +2 = −v/u, u = −10 cm ⇒ v = +20 cm (behind the mirror).

$\frac{1}{f} = \frac{1}{20} + \frac{1}{-10} = -\frac{1}{20} \Rightarrow$ f = −20 cm. Focal length is 20 cm.

33. (a) State Faraday's law of electromagnetic induction. **5**

(b) Derive the self-inductance of a long air-cored solenoid of length l, cross-sectional area A and N turns.

(c) A 50 cm conducting rod, pivoted at one end, rotates at 60 rpm in a uniform 4.0 mT magnetic field perpendicular to its plane of rotation. Find the emf induced in the rod.

ANSWER

(b) $L = \mu_0 N^2 A/l$; (c) $\varepsilon = \pi \times 10^{-3}$ V ≈ 3.14 mV

(a) The induced emf in a circuit equals the negative rate of change of magnetic flux through it: $\varepsilon = -\frac{d\Phi_B}{dt}$ (for N turns, $-N\frac{d\Phi}{dt}$).

(b) Field inside: $B = \mu_0 n I = \frac{\mu_0 N I}{l}$.

Flux linkage: $N\Phi = N(BA) = \frac{\mu_0 N^2 A I}{l}$.

Since $N\Phi = LI$: $L = \frac{\mu_0 N^2 A}{l}$.

(c) $\omega = 2\pi \times \frac{60}{60} = 2\pi$ rad/s.

$\varepsilon = \frac{1}{2} B\omega l^2 = \frac{1}{2}(4.0 \times 10^{-3})(2\pi)(0.5)^2 = \pi \times 10^{-3}$ V ≈ 3.14 mV.

OR

(a) Draw a labelled diagram of a step-up transformer. State its working principle and obtain the ratio of secondary to primary voltage in terms of the numbers of turns and the currents in the two coils.

(b) An ideal transformer has primary-to-secondary turns ratio 1 : 5. If 5 kW at 200 V is fed to the primary, find (i) the primary current and (ii) the output voltage.

ANSWER

(a) $V_s/V_p = N_s/N_p = I_p/I_s$; (b) (i) $I_p = 25$ A, (ii) $V_s = 1000$ V

(a) Diagram: laminated soft-iron core; primary coil with few turns on one limb, secondary with many more turns ($N_s > N_p$) on the other limb (or wound over the primary).

Principle: mutual induction – an alternating current in the primary produces changing flux in the core, which links the secondary and induces an emf in it.

If Φ is the flux per turn: $\varepsilon_s = -N_s\frac{d\Phi}{dt}$, back emf $\varepsilon_p = -N_p\frac{d\Phi}{dt}$.

For an ideal transformer (zero resistance, no flux leakage) $v_p = \varepsilon_p$ and $v_s = \varepsilon_s$, so $\frac{V_s}{V_p} = \frac{N_s}{N_p}$.

No losses: $V_p I_p = V_s I_s \Rightarrow \frac{V_s}{V_p} = \frac{I_p}{I_s}$.

(b) (i) $I_p = \frac{P}{V_p} = \frac{5000}{200} = 25$ A.

(ii) $V_s = V_p\frac{N_s}{N_p} = 200 \times 5 = 1000$ V.

— END —

Questions restated from the CBSE Class XII Board Examination 2026 (set 55/1/1) for practice. Reading passages and map items are described, not reproduced.