Roll No. ☐☐☐☐☐☐☐☐

Q.P. Code 55/1/1

PHYSICS (THEORY)

CBSE Class XII Board Examination 2023

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

General Instructions:

1. The paper has 35 questions in five sections (A to E); all of them must be answered.
2. Section A: Q1–18, multiple choice (Q16–18 Assertion-Reason), 1 mark each.
3. Section B: Q19–25, very short answer, 2 marks each.
4. Section C: Q26–30, short answer, 3 marks each.
5. Section D: Q31–33, long answer, 5 marks each.
6. Section E: Q34–35, case-based, 4 marks each.
7. There is no overall choice, but internal choices (OR) are given in 2 questions of Section B, 2 of Section C, 3 of Section D and 2 of Section E. 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

Q1–18 carry 1 mark each (MCQ; Q16–18 are Assertion-Reason).

1. A point charge kept on the axis of a short electric dipole at distance r from it feels a force $\vec{F}$. If the charge is moved to distance 2r (still on the axis), the force on it becomes: **1**

(A) $\vec{F}/16$ **(B)** $\vec{F}/8$

(C) $\vec{F}/4$ **(D)** $\vec{F}/2$

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2. Which graph correctly shows how the resistance R of a metallic conductor varies with temperature T? **1**

(a) a straight rising line with a positive intercept on the R-axis

(b) a straight rising line passing through the origin

(c) a falling curve (R decreases as T increases)

(d) a rising curve that bends upward (R increases faster and faster with T, small at low T)

(A) Graph (a): straight rising line with an intercept on R-axis

(B) Graph (b): straight rising line through the origin

(C) Graph (c): R decreasing with T

(D) Graph (d): R rising non-linearly, curving upward

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3. A cell shows 8 V across its terminals on open circuit. When 4 A is drawn from it, the terminal voltage drops to 4 V. Its internal resistance is: **1**

(A) 4 Ω **(B)** 3 Ω

(C) 2 Ω **(D)** 1 Ω

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4. A steady current flows through a metal wire whose cross-sectional area A increases continuously from one end to the other. Which graph shows the drift speed v_d of the free electrons as a function of A? **1**

(a) a decreasing hyperbola-like curve

(b) a straight line decreasing to zero

(c) a horizontal line (constant)

(d) a straight line increasing with A

(A) (a) $\boldsymbol{v_d}$ falls as a hyperbola ($\propto$ 1/A)

(B) (b) $\boldsymbol{v_d}$ falls linearly

(C) (c) $\boldsymbol{v_d}$ constant

(D) (d) $\boldsymbol{v_d}$ rises linearly

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5. A diamagnetic sample is brought close to either the north pole or the south pole of a bar magnet. The sample will be: **1**

(A) repelled by both poles **(B)** attracted by both poles

(C) repelled by N and attracted by S **(D)** attracted by N and repelled by S

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6. A circular coil of 40 turns and radius 8.0 cm spins about its vertical diameter at $\frac{25}{\pi}$ rad s^{-1} in a uniform horizontal magnetic field of 3.0×10^{-2} T. The peak emf induced in it is: **1**

(A) 0.12 V **(B)** 0.15 V

(C) 0.19 V **(D)** 0.22 V

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7. A rectangular frame PSRQ lies in a uniform magnetic field directed into the page. Its sliding arm PQ (length l) has resistance r, while the rest of the frame has negligible resistance. PQ is moved with velocity $\vec{v}$. The size of the induced emf does NOT depend on: **1**

(A) magnetic field $\vec{B}$ **(B)** velocity $\vec{v}$

(C) resistance r **(D)** length of PQ

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8. While a capacitor is being charged, the current that exists in the gap between its plates is (symbols have usual meanings): **1**

(A) $\mu_0 \frac{d\phi_E}{dt}$

(B) $\frac{1}{\mu_0} \frac{d\phi_E}{dt}$

(C) $\varepsilon_0 \frac{d\phi_E}{dt}$

(D) $\frac{1}{\varepsilon_0} \frac{d\phi_E}{dt}$

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9. For a concave mirror of focal length f, what is the least possible distance between an object and its real image? **1**

(A) zero **(B)** f

(C) 2f **(D)** 4f

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10. In Bohr's model of the hydrogen atom, the radius of the nth orbit varies as: **1**

(A) $1/n^2$ **(B)** $1/n$

(C) n^2 **(D)** n

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11. A hydrogen atom in its ground state absorbs a photon and is raised to the n = 5 level. The photon's wavelength is: **1**

(A) 975 nm **(B)** 740 nm

(C) 523 nm **(D)** 95 nm

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12. For a nucleus of mass number A, the nuclear mass density is: **1**

(A) proportional to $A^{1/3}$ **(B)** proportional to $A^{2/3}$

(C) proportional to A^3 **(D)** independent of A

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13. An ac voltage source is joined in series with a p-n junction diode and a load resistor. Which output voltage waveform appears across the load? **1**

(a) the full sine wave (positive and negative halves)

(b) positive humps with no gaps (every half-cycle positive)

(c) positive humps separated by flat zero gaps (alternate half-cycles only)

(d) a steady constant voltage

(A) (a) full sine wave

(B) (b) continuous positive humps

(C) (c) positive humps with zero gaps between them

(D) (d) constant dc

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14. An intrinsic semiconductor is doped with a small quantity of a trivalent impurity. Then: **1**

(A) its resistance increases

(B) it becomes a p-type semiconductor

(C) it has more free electrons than holes

(D) the dopant atoms act as donors

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15. In the energy-band diagram of n-type silicon, the separation between the bottom of the conduction band E_C and the donor level E_D is of the order of: **1**

(A) 10 eV

(B) 1 eV

(C) 0.1 eV

(D) 0.01 eV

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16. Assertion (A): A copper bar placed in an external magnetic field draws the field lines into itself (lines crowd inside the bar). **1**

Reason (R): Copper is a paramagnetic material.

(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) A is false and R is also false.

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17. Assertion (A): Any two points on a wavefront have zero phase difference. **1**

Reason (R): Every point of a wavefront is equally far from the source, so all of them oscillate in the same phase.

(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) A is false and R is also false.

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18. Assertion (A): The photoelectric effect shows that light behaves as particles. **1**
Reason (R): Above the threshold frequency, the photoelectric current is proportional to the intensity of the incident radiation.

(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) A is false and R is also false.

SECTION B

Q19–25 carry 2 marks each.

19. An alpha particle enters, with velocity $\vec{v} = (3.0 \times 10^5\ \text{m/s})\,\hat{i}$, a region having magnetic field $\vec{B} = (0.4\ \text{T})\hat{i} + (0.3\ \text{T})\hat{j}$. The charge-to-mass ratio of the alpha particle is 4.8×10^7 C/kg. Find its acceleration in this region. **2**

20. Compare (i) a magnetic field induced by a changing electric field and (ii) an electric field induced by a changing magnetic field. Which of the two is easier to observe? Give a reason. **2**

21. Using Huygens' principle, draw a diagram showing a plane wavefront being refracted at a plane boundary between two media, and use it to prove Snell's law of refraction. **2**

OR

Why is a reflecting telescope preferred to a refracting telescope? Give two reasons.

22. Two coherent monochromatic light beams with intensities I and 4I overlap. Find the ratio of the maximum to the minimum intensity in the resultant pattern. **2**

23. The energy of the hydrogen atom in its ground state is −13.6 eV. Find the kinetic energy and the potential energy of the electron in the third excited state. **2**

24. Distinguish between intrinsic and extrinsic semiconductors. **2**

OR

Draw the circuit used to study the V–I characteristics of a p-n junction diode in forward bias and in reverse bias. Sketch the V–I characteristic of a silicon diode.

25. Explain briefly how diffusion current and drift current together lead to the formation of the potential barrier in a p-n junction. **2**

SECTION C

Q26–30 carry 3 marks each.

26. (a) Twelve equal negative charges (each −q) are fixed at equal spacing around a circle of radius R. Taking potential at infinity as zero, find the electric potential and electric field at the centre C. **3**

(b) If the same twelve charges are instead fixed, unequally spaced, along a 120° arc of radius R centred at C, find the potential at C.

27. How is impedance different from resistance? Using a suitable phasor diagram, derive the impedance of a series LCR circuit connected to a source $v = v_m \sin \omega t$. **3**

OR

A series LCR circuit is driven by $v = v_m \sin \omega t$ with adjustable ω. Find the condition for resonance. On what factors does the resonant frequency depend? Sketch how the current varies with frequency.

28. A long solenoid of radius r has n turns per unit length and carries current $I = I_0 \sin \omega t$. A coil of N turns is wound tightly around its middle. Find: **3**

(a) the emf induced in the coil;

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

29. How did Einstein's photoelectric equation explain the emission of electrons from a metal surface? Explain briefly. Also plot how the photocurrent varies with: **3**

(a) the collector plate potential, for different intensities of incident light;

(b) the intensity of incident light.

30. Draw the energy level diagram of the hydrogen atom and mark the transitions that give the spectral series in the ultraviolet, visible and infrared regions. **3**

OR

Sketch the variation of binding energy per nucleon with mass number for different nuclei and state two of its features. Why do light nuclei usually undergo fusion?

SECTION D

Q31–33 carry 5 marks each.

31. (i) State Coulomb's law of electrostatics and write it in vector form for two charges. **5**

(ii) Explain the statement: 'Gauss's law rests on the inverse-square dependence on distance present in Coulomb's law.'

(iii) Charge A (q) is at (0, 0) and charge B (2q) is at (a, a). With $\hat{i}$ and $\hat{j}$ the unit vectors along x and y, find the force exerted by A on B in terms of $\hat{i}$ and $\hat{j}$.

OR

(i) Derive the expression for the electric field at a point on the equatorial plane of a dipole made of charges +q and −q separated by 2a.

(ii) If the distance of a far-off point on the equatorial plane is halved, how does the dipole's field there change?

(iii) Two identical dipoles lie along the diagonals of a square ABCD of side $\sqrt{2}$ m: +q at A and −q at C, +q at D and −q at B (A top-left, B top-right, C bottom-right, D bottom-left). Find the magnitude and direction of the net electric field at the centre O.

32. (i) State the Biot–Savart law for the magnetic field of a current element. Using it, derive the magnetic field at the centre of a circular loop of radius R carrying current I. Sketch the field lines of a current loop showing the field direction. **5**

(ii) An electron moves round the nucleus in a circular orbit of radius 10^{-10} m at a speed of 10^{7} m s^{-1}. Find the current due to this revolving electron.

OR

(i) Derive the force on a straight current-carrying conductor placed in a magnetic field. Name the rule that gives the direction of this force, and state when the force is (1) maximum and (2) minimum.

(ii) Two long straight parallel wires A and B, 2.5 cm apart in air, carry 5.0 A and 2.5 A in opposite directions. Find the magnitude of the force that wire A exerts on a 10 cm length of B.

33. (i) (1) Give two differences between an interference pattern and a diffraction pattern. **5**

(2) Name any two factors that affect the fringe width in Young's double-slit experiment.

(ii) In a Young's double-slit experiment the slit separation is 100 times the wavelength of the light used. Find:

(1) the angular separation (in radians) between the central maximum and the next maximum;

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

OR

(i) A spherical surface of radius of curvature R separates media of refractive indices n_1 and n_2. A point object in medium n_1 is at distance u from the surface and its image forms in medium n_2 at distance v. Derive the relation between u and v.

(ii) A solid glass sphere (radius 6.0 cm, n = 1.5) has a tiny air bubble at point O, 3.0 cm from its centre C. An observer at point E outside, on the line through C and O on the bubble's side, looks at the bubble through the nearest surface. Find where the bubble appears to be.

SECTION E

Q34–35 are case-based questions carrying 4 marks each.

34. A cell of emf E = 6.0 V and internal resistance r = 1.0 Ω (branch a–h) feeds two parallel branches: branch b–g has R_1 = 10 Ω (points i and j on either side of it), and branch c–f has R_2 = 5.0 Ω and R_3 = 5.0 Ω in series (points d and e between them). The top wire is a–b–c and the bottom wire is h–g–f. Kirchhoff's rules can give the currents and voltages. **4**

(a) Which points of the circuit are at the same potential?

(b) What is the current in arm bg?

(c) Find the potential difference across R_3.

OR

(c) Find the power dissipated in R_2.

35. Strontium titanate, a rare natural oxide, is used as a diamond substitute because its refractive index (2.41) and critical angle (24.5°) are almost the same as diamond's, so even experts find it hard to tell them apart. A ray falls normally on face AB of an equilateral prism ABC (angle A = 60°) made of this material. **4**

(a) Trace the path of the ray through the prism.

(b) Find the speed of light in the prism.

(c) Briefly explain two applications of total internal reflection.

OR

(c) Define total internal reflection of light and state two conditions necessary for it.

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Questions restated from the CBSE Class XII Board Examination 2023 (set 55/1/1) for practice. Reading passages and map items are described, not reproduced.