

रोल नं.
Roll No.

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परीक्षार्थी प्रश्न-पत्र कोड को उत्तर-पुस्तिका के मुख-पृष्ठ पर अवश्य लिखें।

Candidates must write the Q.P. Code on the title page of the answer-book.

भौतिक विज्ञान (सैद्धान्तिक) PHYSICS (Theory)

निर्धारित समय : 3 घण्टे

अधिकतम अंक : 70

Time allowed : 3 hours

Maximum Marks : 70

नोट	NOTE
(I) कृपया जाँच कर लें कि इस प्रश्न-पत्र में मुद्रित पृष्ठ 27 हैं।	(I) Please check that this question paper contains 27 printed pages.
(II) कृपया जाँच कर लें कि इस प्रश्न-पत्र में 33 प्रश्न हैं।	(II) Please check that this question paper contains 33 questions.
(III) प्रश्न-पत्र में दाहिने हाथ की ओर दिए गए प्रश्न-पत्र कोड को परीक्षार्थी उत्तर-पुस्तिका के मुख-पृष्ठ पर लिखें।	(III) Q.P. Code given on the right hand side of the question paper should be written on the title page of the answer-book by the candidate.
(IV) कृपया प्रश्न का उत्तर लिखना शुरू करने से पहले, उत्तर-पुस्तिका में प्रश्न का क्रमांक अवश्य लिखें।	(IV) Please write down the serial number of the question in the answer-book before attempting it.
(V) इस प्रश्न-पत्र को पढ़ने के लिए 15 मिनट का समय दिया गया है। प्रश्न-पत्र का वितरण पूर्वाह्न में 10.15 बजे किया जाएगा। 10.15 बजे से 10.30 बजे तक छात्र केवल प्रश्न-पत्र को पढ़ेंगे और इस अवधि के दौरान वे उत्तर-पुस्तिका पर कोई उत्तर नहीं लिखेंगे।	(V) 15 minute time has been allotted to read this question paper. The question paper will be distributed at 10.15 a.m. From 10.15 a.m. to 10.30 a.m., the students will read the question paper only and will not write any answer on the answer-book during this period.

General Instructions :

Read the following instructions carefully and follow them :

- (i) *This question paper contains **33** questions. **All** questions are **compulsory**.*
- (ii) *This question paper is divided into **five** sections – **Sections A, B, C, D and E**.*
- (iii) *In **Section A** – Questions no. **1** to **16** are **Multiple Choice** type questions. Each question carries **1** mark.*
- (iv) *In **Section B** – Questions no. **17** to **21** are **Very Short Answer** type questions. Each question carries **2** marks.*
- (v) *In **Section C** – Questions no. **22** to **28** are **Short Answer** type questions. Each question carries **3** marks.*
- (vi) *In **Section D** – Questions no. **29** and **30** are **case study based** questions. Each question carries **4** marks.*
- (vii) *In **Section E** – Questions no. **31** to **33** are **Long Answer** type questions. 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 in all the Sections except Section A.*
- (ix) *Kindly note that there is a separate question paper for Visually Impaired candidates.*
- (x) *Use of calculators is **not** allowed.*

You may use the following values of physical constants wherever necessary :

$$c = 3 \times 10^8 \text{ m/s}$$

$$h = 6.63 \times 10^{-34} \text{ Js}$$

$$e = 1.6 \times 10^{-19} \text{ C}$$

$$\mu_0 = 4\pi \times 10^{-7} \text{ T m A}^{-1}$$

$$\epsilon_0 = 8.854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$$

$$\frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{ N m}^2 \text{ C}^{-2}$$

$$\text{Mass of electron (m}_e\text{)} = 9.1 \times 10^{-31} \text{ kg}$$

$$\text{Mass of neutron} = 1.675 \times 10^{-27} \text{ kg}$$

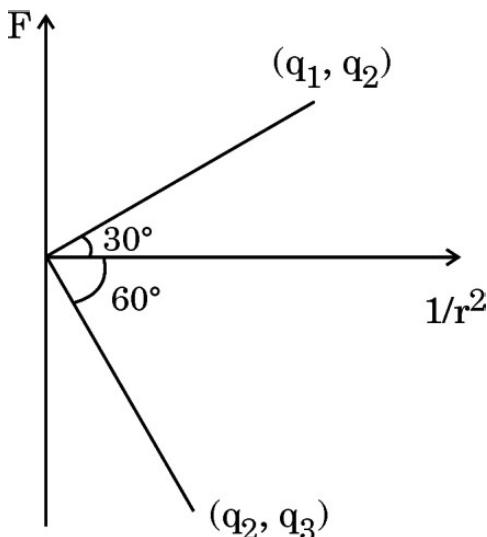
$$\text{Mass of proton} = 1.673 \times 10^{-27} \text{ kg}$$

$$\text{Avogadro's number} = 6.023 \times 10^{23} \text{ per gram mole}$$

$$\text{Boltzmann constant} = 1.38 \times 10^{-23} \text{ JK}^{-1}$$

SECTION A

1. Coulomb force F versus $\left(\frac{1}{r^2}\right)$ graphs for two pairs of point charges $(q_1 \text{ and } q_2)$ and $(q_2 \text{ and } q_3)$ are shown in the figure. The ratio of charges $\left(\frac{q_1}{q_3}\right)$ is :



(A) $\sqrt{3}$ (B) $\frac{1}{\sqrt{3}}$
 (C) 3 (D) $\frac{1}{3}$

2. Electrons drift with speed v_d in a conductor with potential difference V across its ends. If V is reduced to $\left(\frac{V}{2}\right)$, their drift speed will become :

(A) $\frac{v_d}{2}$ (B) v_d
 (C) $2 v_d$ (D) $4 v_d$

3. The emf induced in a coil rotating in a magnetic field does **not** depend upon the following :

(A) Area of the coil
 (B) Resistance of the coil
 (C) Number of turns in the coil
 (D) Angular speed of rotation of the coil

4. A circular coil of radius 10 cm is placed in a magnetic field $\vec{B} = (1.0 \hat{i} + 0.5 \hat{j}) \text{ mT}$ such that the outward unit vector normal to the surface of the coil is $(0.6 \hat{i} + 0.8 \hat{j})$. The magnetic flux linked with the coil is :

(A) $0.314 \mu\text{Wb}$ (B) $3.14 \mu\text{Wb}$
 (C) $31.4 \mu\text{Wb}$ (D) $1.256 \mu\text{Wb}$

5. Which of the following quantity/quantities remains same in primary and secondary coils of an ideal transformer ?
 Current, Voltage, Power, Magnetic flux

(A) Current only
 (B) Voltage only
 (C) Power only
 (D) Magnetic flux and Power both

6. In an ac circuit, the instantaneous values of current (in A) and voltage (in V) are $I = 5 \sin \omega t$ and $E = 200 \cos (\omega t + \frac{\pi}{3})$ respectively. The phase difference between voltage and current at any instant is :

(A) $\frac{5\pi}{6}$ (B) $\frac{5\pi}{4}$
 (C) $\frac{5\pi}{2}$ (D) $\frac{3\pi}{2}$

7. In four regions I, II, III and IV, the magnetic field is given by :
 I. $B_y = B_0 \sin kz$ II. $B_y = B_0 \cos kz$
 III. $B_y = B_0 \sin (kz - \omega t)$ IV. $B_y = B_0 \sin kz + B_0 \cos kz$
 The electromagnetic wave will exist in the region :
 (A) IV (B) I
 (C) III (D) II

8. The momentum (in SI units) associated with a photon of energy 1.5 eV is :

(A) 4×10^{-27} (B) 8×10^{-28}
 (C) 2×10^{-30} (D) 6×10^{-29}

9. An n-type semiconducting Si is obtained by doping intrinsic Si with :

(A) Al (B) B
 (C) P (D) In

10. Energy levels A, B and C of an atom correspond to increasing values of energy i.e. $E_A < E_B < E_C$. Let λ_1 , λ_2 and λ_3 be the wavelengths of radiation corresponding to the transitions C to B, B to A and C to A, respectively. The correct relation between λ_1 , λ_2 and λ_3 is :

(A) $\lambda_1^2 + \lambda_2^2 = \lambda_3^2$ (B) $\frac{1}{\lambda_1} + \frac{1}{\lambda_2} = \frac{1}{\lambda_3}$
 (C) $\lambda_1 + \lambda_2 + \lambda_3 = 0$ (D) $\lambda_1 + \lambda_2 = \lambda_3$

11. When a p-n junction diode is subjected to reverse biasing :

(A) the barrier height decreases and the depletion region widens.
 (B) the barrier height increases and the depletion region widens.
 (C) the barrier height decreases and the depletion region shrinks.
 (D) the barrier height increases and the depletion region shrinks.

12. An alpha particle approaches a gold nucleus in Geiger-Marsden experiment with kinetic energy K. It momentarily stops at a distance d from the nucleus and reverses its direction. Then d is proportional to :

(A) $\frac{1}{\sqrt{K}}$ (B) \sqrt{K}
 (C) $\frac{1}{K}$ (D) K

Questions number **13** to **16** are Assertion (A) and Reason (R) type questions. Two statements are given — one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer from the codes (A), (B), (C) and (D) as given below.

- (A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).
- (B) Both Assertion (A) and Reason (R) are true, but Reason (R) is **not** the correct explanation of the Assertion (A).
- (C) Assertion (A) is true, but Reason (R) is false.
- (D) Assertion (A) is false and Reason (R) is also false.

13. *Assertion (A) :* An electron and a proton enter with the same momentum \vec{p} in a magnetic field \vec{B} such that $\vec{p} \perp \vec{B}$. Then both describe a circular path of the same radius.

Reason (R) : The radius of the circular path described by the charged particle (charge q , mass m) moving in the magnetic field \vec{B} is given by $r = \frac{mv}{qB}$.

14. *Assertion (A) :* The magnifying power of a compound microscope is negative.

Reason (R) : The final image formed is erect with respect to the object.

15. *Assertion (A) :* Lenz's law is a consequence of the law of conservation of energy.

Reason (R) : There is no power loss in an ideal inductor.

16. *Assertion (A) :* Photoelectric current increases with an increase in intensity of incident radiation, for a given frequency of incident radiation and the accelerating potential.

Reason (R) : Increase in the intensity of incident radiation results in an increase in the number of photoelectrons emitted per second and hence an increase in the photocurrent.

SECTION B

17. An electric field E is maintained in a wire of length ' l ' and area of cross-section 'a'. Derive the relation between the current density 'σ' in the wire and the electric field E . 2

18. How does the energy gap of an intrinsic semiconductor effectively change when doped with a (a) trivalent impurity, and (b) pentavalent impurity ? Justify your answer in each case. 2

19. (a) Two waves, each of amplitude 'a' and frequency 'ω' emanating from two coherent sources of light superpose at a point. If the phase difference between the two waves is $ϕ$, obtain an expression for the resultant intensity at that point. 2

OR

(b) What is the effect on the interference pattern in Young's double-slit experiment when (i) the source slit is moved closer to the plane of the slits, and (ii) the separation between the two slits is increased ? Justify your answers. 2

20. In Bohr model of hydrogen atom, find the ratio of period of revolution of the electron in the orbit $n = 2$ to that in the orbit $n = 1$. 2

21. A convex lens ($n = 1.52$) has a focal length of 15.0 cm in air. Find its focal length when it is immersed in liquid of refractive index 1.65. What will be the nature of the lens ? 2

SECTION C

22. (a) Two long, straight, parallel conductors carry steady currents in opposite directions. Explain the nature of the force of interaction between them. Obtain an expression for the magnitude of the force between the two conductors. Hence define one ampere. 3

OR

(b) Obtain an expression for the torque $\vec{\tau}$ acting on a current carrying loop in a uniform magnetic field \vec{B} . Draw the necessary diagram. 3

23. (a) On what factors does the speed of an electromagnetic wave in a medium depend ?
 (b) How is an electromagnetic wave produced ?
 (c) Sketch a schematic diagram depicting the electric and magnetic fields for an electromagnetic wave propagating along z-axis. 3

24. An ac voltage $v_i = 140 \sin (100 \pi t)$ V is applied to the primary coil having 200 turns, of an ideal transformer and it supplies a power of 5 kW. If the secondary coil has 1000 turns, find :
 (a) the output voltage,
 (b) the instantaneous voltage across the secondary coil, and
 (c) the current in the secondary coil. (Take $\sqrt{2} = 1.4$) 3

25. The figure shows a circuit with three ideal batteries. Find the magnitude and direction of currents in the branches AG, BF and CD. 3

26. (a) Briefly discuss three characteristics of the forces between nucleons.
 (b) Which out of ${}^8_4 X$ and ${}^5_3 Y$ nuclei is more stable and why ? 3

27. Draw a schematic arrangement of Geiger-Marsden experiment. Briefly explain the conclusions drawn from the observations about the structure of an atom. Define 'distance of closest approach' in this case. 3

28. With the help of a circuit diagram, explain the working of a p-n junction diode as a full wave rectifier. Draw its input and output waveforms. 3

SECTION D

Case Study Based Questions

Questions number 29 and 30 are case study based questions. Read the following paragraphs and answer the questions that follow.

29. When a ray of light propagates from a denser medium to a rarer medium, it bends away from the normal. When the incident angle is increased, the refracted ray deviates more from the normal. For a particular angle of incidence in the denser medium, the refracted ray just grazes the interface of the two surfaces. This angle of incidence is called the critical angle for the pair of media involved.

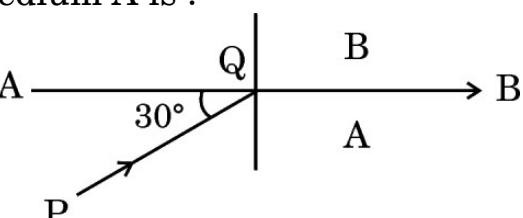
(i) For a ray incident at the critical angle, the angle of reflection is : 1

(A) 0° (B) $< 90^\circ$
 (C) $> 90^\circ$ (D) 90°

(ii) A ray of light of wavelength 600 nm is incident in water $\left(n = \frac{4}{3}\right)$ on the water-air interface at an angle less than the critical angle. The wavelength associated with the refracted ray is : 1

(A) 400 nm (B) 450 nm
 (C) 600 nm (D) 800 nm

(iii) (a) The interface AB between the two media A and B is shown in the figure. In the denser medium A, the incident ray PQ makes an angle of 30° with the horizontal. The refracted ray is parallel to the interface. The refractive index of medium B w.r.t. medium A is : 1



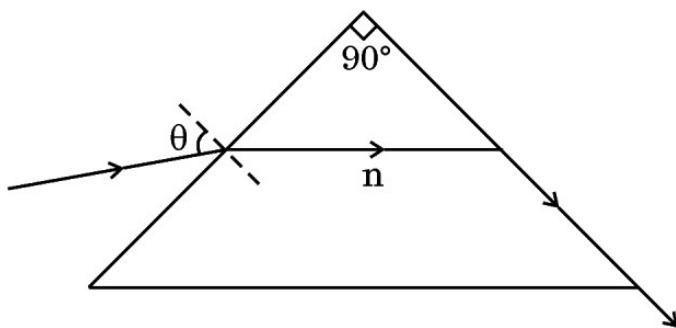
(A) $\frac{\sqrt{3}}{2}$ (B) $\frac{\sqrt{5}}{2}$
 (C) $\frac{4}{\sqrt{3}}$ (D) $\frac{2}{\sqrt{3}}$

OR

(b) Two media A and B are separated by a plane boundary. The speed of light in medium A and B is $2 \times 10^8 \text{ ms}^{-1}$ and $2.5 \times 10^8 \text{ ms}^{-1}$ respectively. The critical angle for a ray of light going from medium A to medium B is : 1

(A) $\sin^{-1} \frac{1}{2}$ (B) $\sin^{-1} \frac{4}{5}$
 (C) $\sin^{-1} \frac{3}{5}$ (D) $\sin^{-1} \frac{2}{5}$

The figure shows the path of a light ray through a triangular prism. In this phenomenon, the angle θ is given by : 1



(A) $\sin^{-1} \sqrt{n^2 - 1}$ (B) $\sin^{-1} (n^2 - 1)$
 (C) $\sin^{-1} \left[\frac{1}{\sqrt{n^2 - 1}} \right]$ (D) $\sin^{-1} \left[\frac{1}{(n^2 - 1)} \right]$

30. When the terminals of a cell are connected to a conductor of resistance R , an electric current flows through the circuit. The electrolyte of the cell also offers some resistance in the path of the current, like the conductor. This resistance offered by the electrolyte is called internal resistance of the cell (r). It depends upon the nature of the electrolyte, the area of the electrodes immersed in the electrolyte and the temperature. Due to internal resistance, a part of the energy supplied by the cell is wasted in the form of heat.

When no current is drawn from the cell, the potential difference between the two electrodes is known as emf of the cell (ε). With a current drawn from the cell, the potential difference between the two electrodes is termed as terminal potential difference (V).

(i) Choose the **incorrect** statement : 1

(A) The potential difference (V) between the two terminals of a cell in a closed circuit is always less than its emf (ε), during discharge of the cell.

(B) The internal resistance of a cell decreases with the decrease in temperature of the electrolyte.

(C) When current is drawn from the cell then $V = \varepsilon - Ir$.

(D) The graph between potential difference between the two terminals of the cell (V) and the current (I) through it is a straight line with a negative slope.

(ii) Two cells of emfs 2.0 V and 6.0 V and internal resistances 0.1 Ω and 0.4 Ω respectively, are connected in parallel. The equivalent emf of the combination will be : 1

(A) 2.0 V (B) 2.8 V

(C) 6.0 V (D) 8.0 V

(iii) Dipped in the solution, the electrode exchanges charges with the electrolyte. The positive electrode develops a potential V_+ ($V_+ > 0$), and the negative electrode develops a potential $-V_-$ ($V_- \geq 0$), relative to the electrolyte adjacent to it. When no current is drawn from the cell then : 1

(A) $\varepsilon = V_+ + V_- > 0$ (B) $\varepsilon = V_+ - V_- > 0$

(C) $\varepsilon = V_+ + V_- < 0$ (D) $\varepsilon = V_+ + V_- = 0$

(iv) (a) Five identical cells, each of emf 2 V and internal resistance 0.1 Ω are connected in parallel. This combination in turn is connected to an external resistor of 9.98 Ω . The current flowing through the resistor is : 1

(A) 0.05 A (B) 0.1 A

(C) 0.15 A (D) 0.2 A

OR

(b) Potential difference across a cell in the open circuit is 6 V. It becomes 4 V when a current of 2 A is drawn from it. The internal resistance of the cell is : 1

(A) 1.0 Ω (B) 1.5 Ω

(C) 2.0 Ω (D) 2.5 Ω

SECTION E

31. (a) (i) Give any two differences between the interference pattern obtained in Young's double-slit experiment and a diffraction pattern due to a single slit.

(ii) Draw an intensity distribution graph in case of a double-slit interference pattern.

(iii) In Young's double-slit experiment using monochromatic light of wavelength λ , the intensity of light at a point on the screen, where path difference is λ , is K units. Find the intensity of light at a point on the screen where the path difference is $\frac{\lambda}{6}$. 5

OR

(b) (i) Draw a labelled ray diagram of a compound microscope showing image formation at least distance of distinct vision. Derive an expression for its magnifying power.

(ii) A telescope consists of two lenses of focal length 100 cm and 5 cm. Find the magnifying power when the final image is formed at infinity. 5

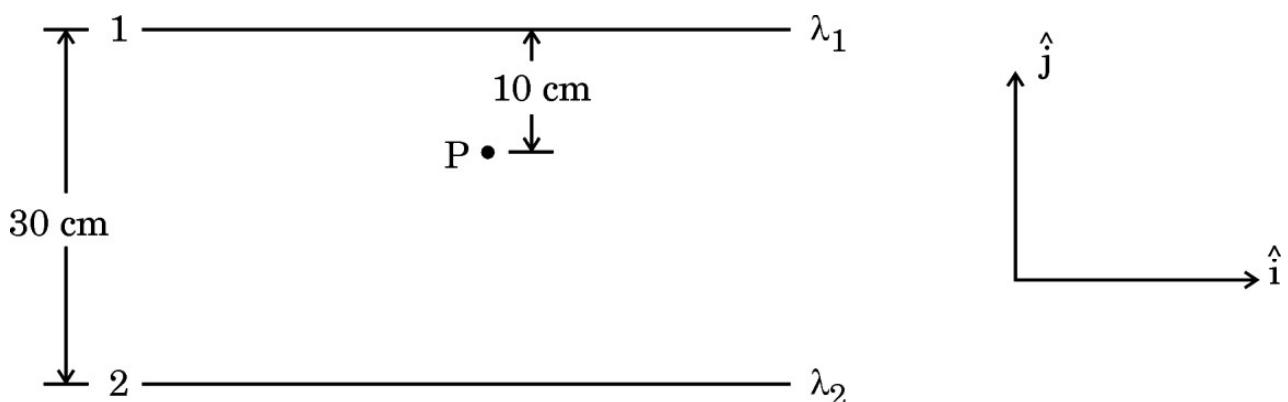
32. (a) (i) Obtain an expression for the electric potential due to a small dipole of dipole moment \vec{p} , at a point \vec{r} from its centre, for much larger distances compared to the size of the dipole.

(ii) Three point charges q , $2q$ and nq are placed at the vertices of an equilateral triangle. If the potential energy of the system is zero, find the value of n . 5

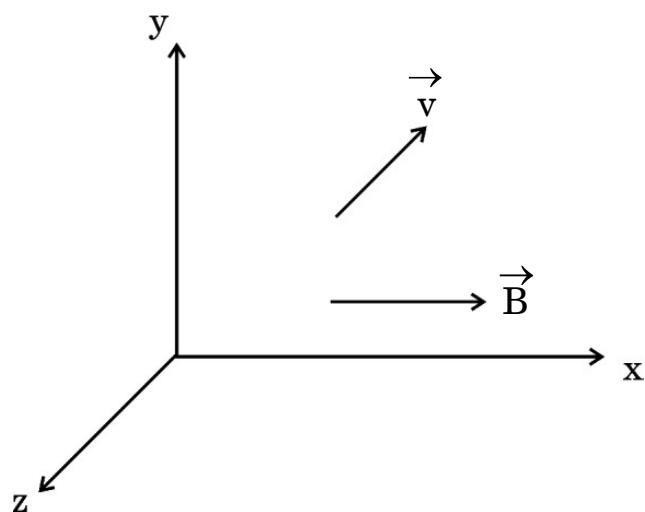
OR

(b) (i) State Gauss's Law in electrostatics. Apply this to obtain the electric field \vec{E} at a point near a uniformly charged infinite plane sheet.

(ii) Two long straight wires 1 and 2 are kept as shown in the figure. The linear charge density of the two wires are $\lambda_1 = 10 \mu\text{C/m}$ and $\lambda_2 = -20 \mu\text{C/m}$. Find the net force \vec{F} experienced by an electron held at point P. 5



33. (a) (i) A particle of mass m and charge q is moving with a velocity \vec{v} in a magnetic field \vec{B} as shown in the figure. Show that it follows a helical path. Hence, obtain its frequency of revolution.



(ii) In a hydrogen atom, the electron moves in an orbit of radius 2 \AA making 8×10^{14} revolutions per second. Find the magnetic moment associated with the orbital motion of the electron. 5

OR

(b) (i) What is current sensitivity of a galvanometer ? Show how the current sensitivity of a galvanometer may be increased. “Increasing the current sensitivity of a galvanometer may not necessarily increase its voltage sensitivity.” Explain.

(ii) A moving coil galvanometer has a resistance $15\ \Omega$ and takes 20 mA to produce full scale deflection. How can this galvanometer be converted into a voltmeter of range 0 to 100 V ? 5