

प्रश्न-पत्र कोड
Q.P. Code

55/S/1

रोल नं.
Roll No.



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. Two particles A and B of the same mass but having charges q and $4q$ respectively, are accelerated from rest through different potential differences V_A and V_B such that they attain same kinetic energies. The value of $\left(\frac{V_A}{V_B}\right)$ is :
- (A) $\frac{1}{4}$ (B) $\frac{1}{2}$ (C) 2 (D) 4
2. A coil of resistance 20Ω and self-inductance 10 mH is connected to an ac source of frequency $1000/\pi \text{ Hz}$. The phase difference between current in the circuit and the source voltage is :
- (A) 30° (B) 60° (C) 75° (D) 45°
3. Isotones are nuclides having :
- (A) same number of neutrons but different number of protons
(B) same number of protons but different number of neutrons
(C) same number of protons and also same number of neutrons
(D) different number of protons and also different number of neutrons
4. A bulb is rated (100 W, 110 V). It is operated by current of 1.0 A supplied by a step down transformer. If the input voltage and efficiency of the transformer are 220 V and 0.9 respectively, the input current drawn from the mains is :
- (A) $\frac{1}{2} \text{ A}$ (B) $\frac{3}{8} \text{ A}$ (C) $\frac{5}{9} \text{ A}$ (D) $\frac{4}{7} \text{ A}$
5. Which of the following substances has relative magnetic permeability $\mu_r \gg 1$?
- (A) Aluminium (B) Copper chloride
(C) Nickel (D) Sodium chloride

6. Which of the following statements is correct for alpha particle scattering experiment ?
- (A) For angle of scattering $\theta \approx 0$, the impact parameter is small.
 - (B) For angle of scattering $\theta \approx \pi$, the impact parameter is large.
 - (C) The number of alpha particles undergoing head-on collision is small.
 - (D) The experiment provides an estimate of the upper limit to the size of target atom.

7. A straight wire of length 1.0 m is placed along x-axis, in a region with magnetic field $\vec{B} = (3\hat{i} + 2\hat{j})$ T. A current of 2.0 A flows in the wire along +x direction. The magnetic force acting on the wire is :
- (A) 2.0 N, along z-axis
 - (B) 2.0 N, along -z-axis
 - (C) 4.0 N, along z-axis
 - (D) 4.0 N, along -z-axis

8. The electric field E associated with an electromagnetic wave is represented by

$$E_y = E_0 \sin(kx - \omega t)$$

Which of the following statements is correct ?

- (A) The wave is propagating along +x-axis.
 - (B) The wave is propagating along +z-axis.
 - (C) The magnetic field \vec{B} of the wave is acting along +y-axis.
 - (D) The magnetic field \vec{B} of the wave is acting along -x-axis.
9. A point object is placed in air at a distance of 4R on the principal axis of a convex spherical surface of radius of curvature R separating two mediums, air and glass. As the object is moved towards the surface, the image formed is :
- (A) always real
 - (B) always virtual
 - (C) first virtual and then real
 - (D) first real and then virtual

10. An electron makes a transition from orbit $n = 2$ to orbit $n = 1$, in Bohr's model of hydrogen atom. Consider change in magnitudes of its kinetic energy (K) and potential energy (U).
- (A) K increases and U decreases (B) K decreases and U increases
(C) Both K and U decrease (D) Both K and U increase
11. Which of the following statements is *not* true for a p-n junction diode under reverse bias ?
- (A) The current is almost independent of the applied voltage.
(B) Holes flow from p-side to n-side.
(C) Electric field in the depletion region increases.
(D) n-side of the junction is connected to +ve terminal and p-side to -ve terminal of the battery.
12. A parallel plate capacitor is charged by a battery. The battery is then disconnected and the plates of the charged capacitor are then moved farther apart. In the process :
- (A) the charge on the capacitor increases.
(B) the potential difference across the plates decreases.
(C) the capacitance of the capacitor increases.
(D) the electrostatic energy stored in the capacitor increases.

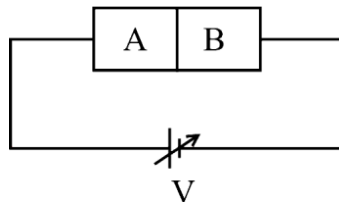
Questions number 13 to 16 are Assertion (A) and Reason (R) type questions. Two statements are given — one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer from the codes (A), (B), (C) and (D) as given below.

- (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) Both Assertion (A) and Reason (R) are false.

13. *Assertion (A)* : The current density (\vec{J}) at a point in a conducting wire is in the direction of electric field (\vec{E}) at that point.
Reason (R) : A conducting wire obeys Ohm's law.
14. *Assertion (A)* : The torque acting on a current carrying coil is maximum when it is suspended in a radial magnetic field.
Reason (R) : The torque tends to rotate the coil on its own axis.
15. *Assertion (A)* : Although the surfaces of a goggle lens are curved, it does not have any power.
Reason (R) : In case of goggles, both the curved surfaces are curved on the same side and have equal radii of curvature.
16. *Assertion (A)* : Nuclear fission reactions are responsible for energy generation in the Sun.
Reason (R) : Light nuclei fuse together in the nuclear fission reactions.

SECTION B

17. Two halves of a silicon crystal (A and B) are doped with arsenic and boron respectively, forming a p-n junction in it. A battery is connected across it as shown in the figure.



- (a) Will the junction be forward biased or reverse biased ? Give reason.
- (b) Draw V-I graph for this arrangement.

2

18. A long straight horizontal wire is carrying a current I . At an instant, an alpha particle at a distance r from it, is travelling with speed v parallel to the wire in a direction opposite to the current. Find the magnitude and direction of the force experienced by the particle at this instant. 2
19. A point light source rests on the bottom of a bucket filled with a liquid of refractive index $\mu = 1.25$ up to height of 10 cm. Calculate :
 (a) the critical angle for liquid-air interface
 (b) radius of circular light patch formed on the surface by light emerging from the source. 2
20. State Huygens principle. Using it draw a diagram showing the details of passage of a plane wave from a denser into a rarer medium. 2
21. (a) A cell is connected across an external resistance 12Ω and supplies 0.25 A current. When the external resistance is increased by 4Ω , the current reduces to 0.2 A . Calculate (i) the emf, and (ii) the internal resistance, of the cell. 2

OR

- (b) Two point charges of $3 \mu\text{C}$ and $4 \mu\text{C}$ are kept in air at $(0.3 \text{ m}, 0)$ and $(0, 0.3 \text{ m})$ in x - y plane. Find the magnitude and direction of the net electric field produced at the origin $(0, 0)$. 2

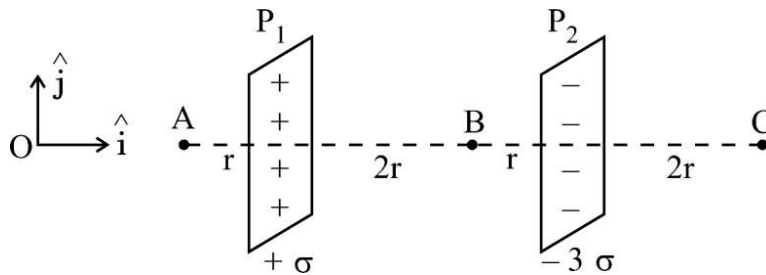
SECTION C

22. A small circular loop of area $\frac{6}{\pi} \text{ cm}^2$ is placed inside a long solenoid at its centre such that its axis makes an angle of 60° with the axis of the solenoid. The number of turns per cm is 10 in the solenoid. The current in the solenoid changes uniformly from 5 A to zero in 10 ms. Calculate the emf induced in the loop. 3
23. Two point charges of $10 \mu\text{C}$ and $20 \mu\text{C}$ are located at points $(-4 \text{ cm}, 0, 0)$ and $(5 \text{ cm}, 0, 0)$ respectively, in a region with electric field $E = \frac{A}{r^2}$, where $A = 2 \times 10^6 \text{ NC}^{-1} \text{ m}^2$ and \vec{r} is the position vector of the point under consideration. Calculate the electrostatic potential energy of the system. 3

24. (a) The radius of a conducting wire AB uniformly decreases from its one end A to another end B. It is connected across a battery. How will (i) electric field, (ii) current density, and (iii) mobility of electrons change from end A to end B ? Justify your answer in each case. 3

OR

- (b) Two large plane sheets P_1 and P_2 having charge densities $+\sigma$ and -3σ respectively are arranged parallel to each other as shown in the figure. Find the net electric field (\vec{E}) at points A, B and C. 3



25. In photoelectric effect experiment, show the variation of
- (a) photocurrent with collector plate potential for a given surface for different intensities of incident radiation. Do the curves meet at any point ? If so, why ?
- (b) photocurrent with intensity of radiation incident on a surface keeping the frequency and plate potential fixed. 3

26. Explain the following, giving proper reason : 3

- (a) During charging of a capacitor, displacement current exists in the capacitor. But there is no displacement current when it gets fully charged.
- (b) The frequency of microwaves in ovens matches with the resonant frequency of water molecules.
- (c) Infrared waves are also known as heat waves.

27. A galvanometer is converted into a voltmeter of range $(0 - V)$ volt using a resistor of 9900Ω . If a resistor of 4900Ω is used, the range becomes half, i.e. $(0 - \frac{V}{2})$ volt. Calculate :
- (a) resistance of the galvanometer
 - (b) resistance required to convert it into a voltmeter of range $(0 - 2V)$ volt. 3
28. (a) A ray of light is incident on a surface separating air from a denser medium A of refractive index μ_1 . It is then made incident on the parallel surface of another medium B of refractive index μ_2 at the same angle of incidence. If the angle of refraction in the two media are 30° and 35° respectively, then in which one of the two media (A or B) will light travel faster and why ?
- (b) The intensity of the two interfering waves in Young's double slit experiment is I_0 each. Find the intensity at a point on the screen where path difference between the interfering waves is (i) $\frac{\lambda}{2}$, and (ii) $\frac{\lambda}{3}$. 3

SECTION D

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

29. Dipoles, whether electric or magnetic, are characterised by their dipole moments, which are vector quantities. Two equal and opposite charges separated by a small distance constitute an electric dipole, while a current carrying loop behaves as a magnetic dipole. Electric dipoles create electric fields around them. Electric dipoles experience a torque when placed in an external electric field.

- (i) Two identical electric dipoles, each consisting of charges $-q$ and $+q$ separated by distance d , are arranged in x - y plane such that their negative charges lie at the origin O and positive charges lie at points $(d, 0)$ and $(0, d)$ respectively. The net dipole moment of the system is : /

(A) $-q d (\hat{i} + \hat{j})$ (B) $q d (\hat{i} + \hat{j})$
 (C) $q d (\hat{i} - \hat{j})$ (D) $q d (\hat{j} - \hat{i})$

- (ii) E_1 and E_2 are magnitudes of electric field due to a dipole, consisting of charges $-q$ and $+q$ separated by distance $2a$, at points r ($\gg a$) (1) on its axis, and (2) on equatorial plane, respectively. Then $\left(\frac{E_1}{E_2} \right)$ is : /

(A) $\frac{1}{4}$ (B) $\frac{1}{2}$ (C) 2 (D) 4

- (iii) An electric dipole of dipole moment 5.0×10^{-8} Cm is placed in a region where an electric field of magnitude 1.0×10^3 N/C acts at a given instant. At that instant the electric field \vec{E} is inclined at an angle of 30° to dipole moment \vec{P} . The magnitude of torque acting on the dipole, at that instant is : /

(A) 2.5×10^{-5} Nm (B) 5.0×10^{-5} Nm
 (C) 1.0×10^{-4} Nm (D) 2.0×10^{-6} Nm

- (iv) (a) An electron is revolving with speed v around the proton in a hydrogen atom, in a circular orbit of radius r . The magnitude of magnetic dipole moment of the electron is : /

(A) $4 evr$ (B) $2 evr$
 (C) $\frac{1}{2} evr$ (D) $\frac{1}{4} evr$

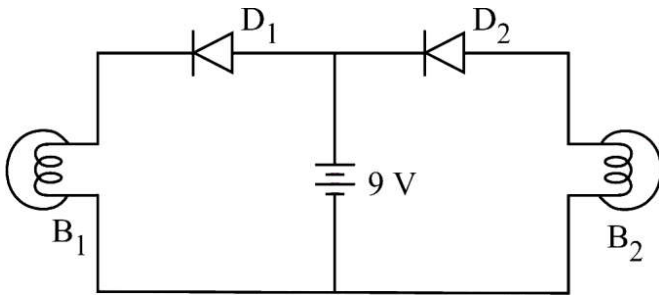
OR

- (b) A square loop of side 5.0 cm carries a current of 2.0 A. The magnitude of magnetic dipole moment associated with the loop is : /

(A) 1.0×10^{-3} Am² (B) 5.0×10^{-3} Am²
 (C) 1.0×10^{-2} Am² (D) 5.0×10^{-2} Am²

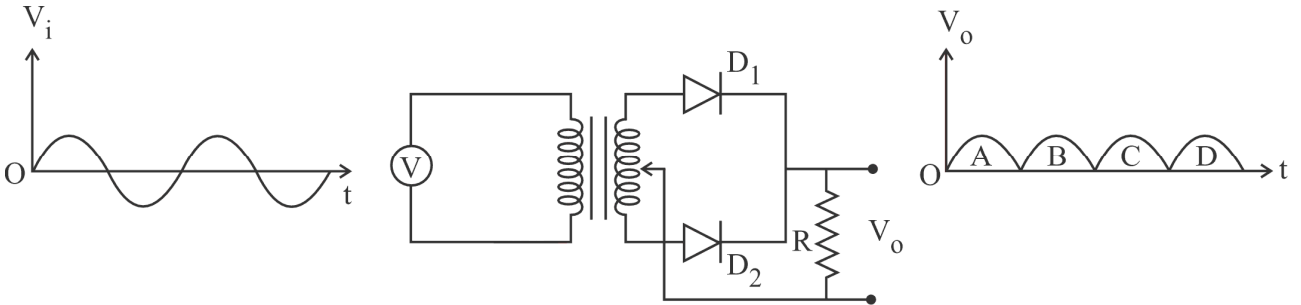
30. The process of converting ac into dc is called rectification and the device used is called a rectifier. When ac signal is fed to a junction diode during positive half cycle, the diode is forward biased and current flows through it. During the negative half cycle, the diode is reverse biased and it does not conduct. Thus the ac signal is rectified. The p-n junction diodes can be used as half-wave and full-wave rectifiers.

(i) Which bulb/bulbs will glow in the given circuit ? 1



- (A) B_1 only (B) B_2 only
 (C) Both B_1 and B_2 (D) Neither B_1 nor B_2

(ii) (a) A full-wave rectifier circuit is shown in the figure. The contribution in output waveform from junction diode D_1 is : 1



- (A) A, D (B) A, C
 (C) B, D (D) B, C

OR

(b) The output in a half-wave rectifier is : 1

- (A) unidirectional without ripple (B) steady and continuous
 (C) unidirectional with ripple (D) steady but discontinuous

- (iii) In a p-n junction diode, the majority charge carriers on p-side and on n-side are, respectively : 1
- (A) electrons, electrons (B) electrons, holes
 (C) holes, holes (D) holes, electrons
- (iv) If the frequency of the half-wave rectifier is 50 Hz, the frequency of full-wave rectifier is : 1
- (A) 25 Hz (B) 50 Hz
 (C) 100 Hz (D) 200 Hz

SECTION E

31. (a) (i) What are matter waves ? A particle of mass m and charge q is accelerated from rest through a potential difference V . Obtain an expression for de Broglie wavelength associated with the particle.
- (ii) Monochromatic light of frequency 5.0×10^{14} Hz is produced by a source of power output 3.315 mW. Calculate :
- (1) energy of the photon in the beam
 (2) number of photons emitted per second by the source 5

OR

- (b) (i) State Bohr's postulates and derive an expression for the energy of electron in n^{th} orbit in Bohr's model of hydrogen atom.
- (ii) Calculate binding energy per nucleon (in MeV) of ${}^{12}_6\text{C}$. 5

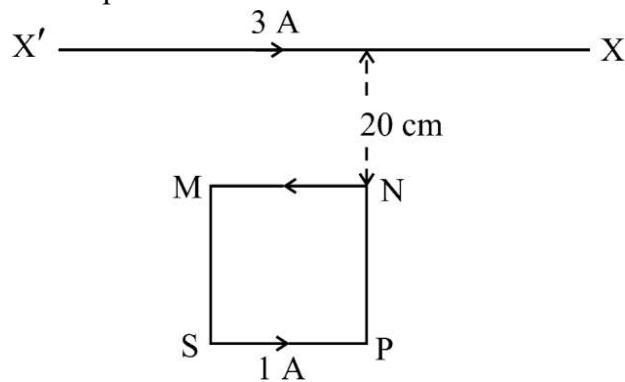
Given :

$$m \left({}^{12}_6\text{C} \right) = 12.000000 \text{ u}$$

$$m \left({}^1_0\text{n} \right) = 1.008665 \text{ u}$$

$$m \left({}^1_1\text{H} \right) = 1.007825 \text{ u}$$

32. (a) (i) With the help of a labelled diagram, explain the working of an ac generator. Obtain the expression for the emf induced at an instant 't'.
- (ii) A long, straight horizontal wire $X'X$ is held stationary and carries a current of 3.0 A. A square loop MNPS of side 10 cm, carrying a current of 1.0 A is kept near the wire $X'X$ as shown in the figure. Find the magnitude and direction of the net magnetic force acting on the loop due to the wire.



OR

- (b) (i) State Faraday's law of electromagnetic induction and mention the utility of Lenz's law. Obtain an expression for self-inductance of a coil in terms of its geometry and permeability of the medium.
- (ii) A resistance of 20Ω , a capacitance of $80 \mu\text{F}$ and an inductor of 50 mH are connected in series. This combination is connected across a 220 V ac supply of variable frequency. When the frequency of supply equals the natural frequency of the circuit, calculate :
- (1) angular frequency of supply
 - (2) impedance of the circuit

33. (a) (i) What are the two main considerations for designing the objective and eyepiece lenses of an astronomical telescope ? Obtain the expression for magnifying power of the telescope when the final image is formed at infinity.
- (ii) A ray of light is incident at an angle of 45° at one face of an equilateral triangular prism and passes symmetrically through the prism. Calculate :
- (1) the angle of deviation produced by the prism
 - (2) the refractive index of the material of the prism

5

OR

- (b) (i) Describe a simple activity to observe diffraction pattern due to a single slit.
- (ii) The figure below shows an equiconvex lens (of refractive index 1.50) in contact with a liquid layer on top of a plane mirror. A small needle with its tip on the principal axis is moved along the axis until its inverted image is found at the position of the needle. The distance of the needle from the lens is measured to be 45.0 cm. When the liquid is removed and the experiment is repeated, the new distance is 30.0 cm. Find the refractive index of the liquid.

5

