

CBSE Class 12 Physics 2024 - 55/S/1 - Compartment

Question Paper

Conducted by the Central Board of Secondary Education (CBSE)



Time Allowed: 3 Hours

Maximum Marks: 70

General Instructions

- (i) This question paper contains **33 questions**. All questions are **compulsory**.
- (ii) The question paper is divided into Sections A, B, C, D, E.
- (iii) Section A - Questions 1 to 16 carry 1 mark each.
- (iv) Section B - Questions 17 to 21 carry 2 marks each.
- (v) Section C - Questions 22 to 28 carry 3 marks each.
- (vi) Section D - Questions 29 to 30 carry 4 marks each.
- (vii) Section E - Questions 31 to 33 carry 5 marks each.
- (viii) There is no overall choice. Where an internal choice is provided, attempt only one of the alternatives.

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

$$\begin{aligned}c &= 3 \times 10^8 \text{ m/s} \\h &= 6.63 \times 10^{-34} \text{ Js} \\e &= 1.6 \times 10^{-19} \text{ C} \\\mu_0 &= 4\pi \times 10^{-7} \text{ T m A}^{-1} \\\epsilon_0 &= 8.854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2} \\\frac{1}{4\pi\epsilon_0} &= 9 \times 10^9 \text{ N m}^2 \text{ C}^{-2}\end{aligned}$$

$$\begin{aligned}\text{Mass of electron } (m_e) &= 9.1 \times 10^{-31} \text{ kg} \\\text{Mass of neutron} &= 1.675 \times 10^{-27} \text{ kg} \\\text{Mass of proton} &= 1.673 \times 10^{-27} \text{ kg} \\\text{Avogadro's number} &= 6.023 \times 10^{23} \text{ per gm mole} \\\text{Boltzmann constant} &= 1.38 \times 10^{-23} \text{ JK}^{-1}\end{aligned}$$

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 energy. 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 $20\ \Omega$ 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 which have:

- (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 $\theta \simeq \pi$, the impact parameter is large.
(C) The number of alpha particles undergoing head-on (direct) collision is small.
(D) This experiment provides an estimate of the upper limit to the size of the target atom.

7. A straight wire of length 1.0 m is placed along x-axis, in a region with magnetic field $\vec{B} = (3\hat{i} + 2\hat{j})\text{ T}$. 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 moves towards this surface, its image:

- | | |
|------------------------------------|------------------------------------|
| (A) is always real | (B) is always virtual |
| (C) is first virtual and then real | (D) is first real and then virtual |

10. In Bohr's model of the hydrogen atom, an electron makes a transition from orbit $n = 2$ to orbit $n = 1$. Consider the change in the 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 the positive terminal and p-side to the negative 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 this 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 |

Question numbers 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): The 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 (sun-glass) lens are curved, it does not have any power.

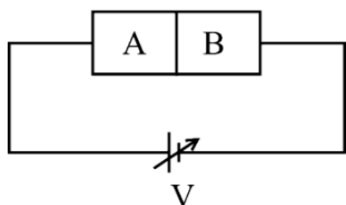
Reason (R): In case of goggles, both curved surfaces are curved on the same side and have equal radii of curvature.

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 the V-I graph for this arrangement.

18. A long straight horizontal wire carries 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.

19. A point light source rests on the bottom of a bucket filled with a liquid of refractive index $\mu = 1.25$ up to a height of 10 cm. Calculate:

(a) the critical angle for the liquid-air interface

(b) the radius of the circular bright patch of light formed on the surface by light emerging from the source

20. State Huygens' principle. Using it, draw a diagram showing the path of a plane wave travelling from a denser into a rarer medium.

21(a). A cell connected across an external resistance of $12\ \Omega$ supplies a current of 0.25 A. When the external resistance is increased by $4\ \Omega$, the current reduces to 0.2 A. Calculate (i) the emf, and (ii) the internal resistance, of the cell.

21(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 the x - y plane. Find the magnitude and direction of the net electric field produced at the origin $(0, 0)$.

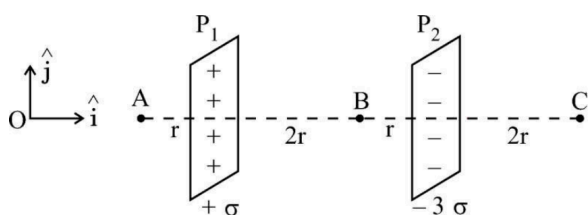
Section C

22. A small circular loop of area $\frac{6}{\pi} \text{ cm}^2$ is placed inside a long solenoid, at its centre, such that the axis of the loop makes an angle of 60° with the axis of the solenoid. The number of turns per cm in the solenoid is 10. The current in the solenoid changes uniformly from 5 A to zero in 10 ms. Calculate the emf induced in the loop.

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 $\vec{E} = \frac{A}{r^2} \hat{r}$, 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.

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.

24(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.



25. In a 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.

26. Explain the following, giving proper reason:

(a) During the charging of a capacitor, displacement current exists in the capacitor. But there is no displacement current once the capacitor is fully charged.

(b) The frequency of microwaves in an oven 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. $\left(0 - \frac{V}{2}\right)$ volt. Calculate:

(a) resistance of the galvanometer

(b) resistance required to convert it into a voltmeter of range $(0 - 2V)$ volt

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 angles 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 the path difference between the interfering waves is (i) $\frac{\lambda}{2}$, and (ii) $\frac{\lambda}{3}$.

Section D

Question numbers 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.

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

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

29(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 its equatorial plane, respectively. Then $\left(\frac{E_1}{E_2}\right)$ is:

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

29(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 the 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

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

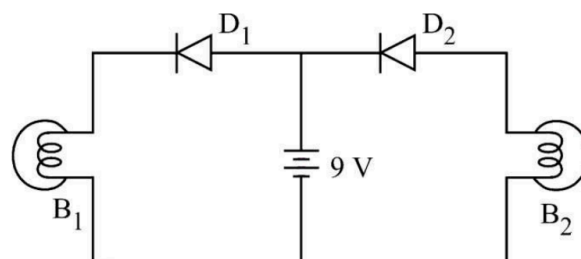
- (A) $4 evr$ (B) $2 evr$
(C) $\frac{1}{2} evr$ (D) $\frac{1}{4} evr$

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

- (A) $1.0 \times 10^{-3} \text{ Am}^2$ (B) $5.0 \times 10^{-3} \text{ Am}^2$
(C) $1.0 \times 10^{-2} \text{ Am}^2$ (D) $5.0 \times 10^{-2} \text{ Am}^2$

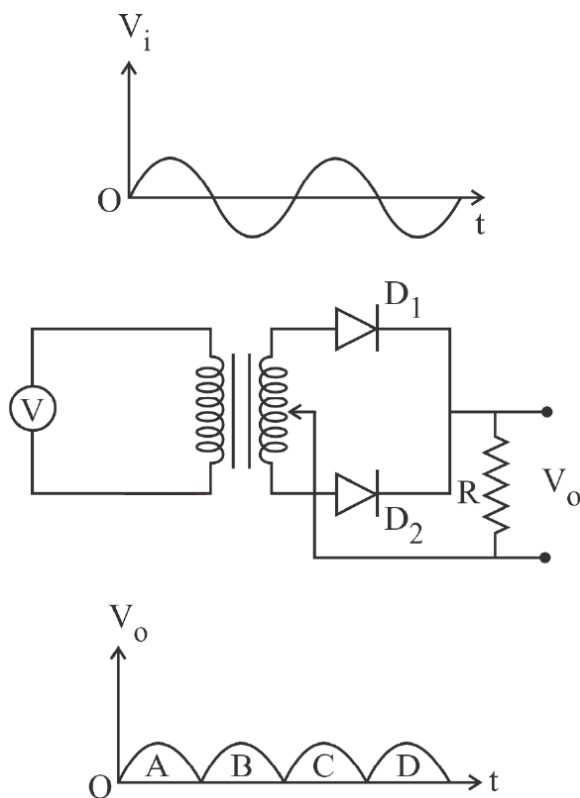
30. The process of converting ac into dc is called rectification and the device used is called a rectifier. When an ac signal is fed to a junction diode during the positive half cycle, the diode is forward biased and current flows through it. During the negative half cycle, the diode is reverse biased 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.

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



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

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



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

30(ii)(b). The output in a half-wave rectifier is:

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

30(iii). In a p-n junction diode, the majority charge carriers on the p-side and on the n-side are, respectively:

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

30(iv). If the frequency of the half-wave rectifier is 50 Hz, the frequency of the full-wave rectifier is:

- (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 the de Broglie wavelength associated with this particle.

31(a)(ii). Monochromatic light of frequency 5.0×10^{14} Hz is produced by a source of power output 3.315 mW. Calculate: (1) the energy of the photon in the beam, (2) the number of photons emitted per second by the source.

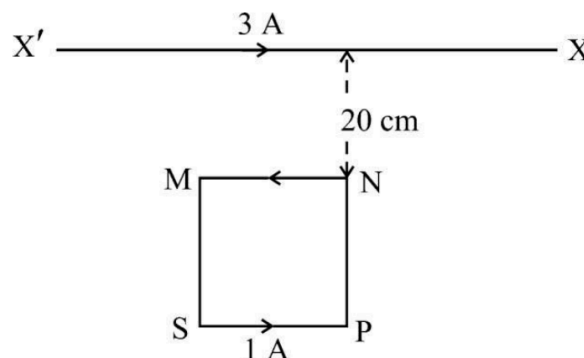
31(b)(i). State Bohr's postulates and derive an expression for the energy of the electron in the n^{th} orbit in Bohr's model of the hydrogen atom.

31(b)(ii). Calculate the binding energy per nucleon (in MeV) of ${}^{12}_6\text{C}$.

Given: $m({}^{12}_6\text{C}) = 12.000000$ u, $m({}^1_0\text{n}) = 1.008665$ u, $m({}^1_1\text{H}) = 1.007825$ 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'.

32(a)(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.



32(b)(i). State Faraday's law of electromagnetic induction and mention the utility of Lenz's law. Obtain an expression for the self-inductance of a coil in terms of its geometry and the permeability of the medium.

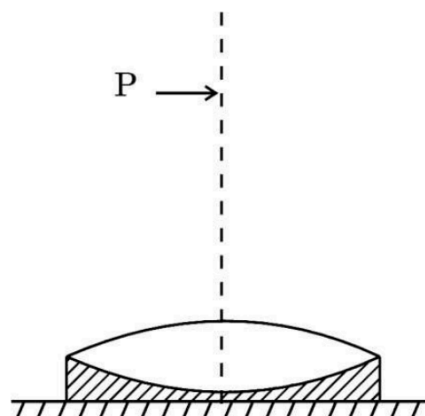
32(b)(ii). A resistance of $20\ \Omega$, a capacitance of $80\ \mu\text{F}$ and an inductor of $50\ \text{mH}$ are connected in series. This combination is connected across a $220\ \text{V}$ ac supply of variable frequency. When the frequency of the supply equals the natural (resonant) frequency of the circuit, calculate: (1) the angular frequency of the supply, (2) the impedance of the circuit.

33(a)(i). What are the two main considerations kept in mind while designing the objective and eyepiece lenses of an astronomical telescope? Obtain the expression for the magnifying power of the telescope when the final image is formed at infinity.

33(a)(ii). A ray of light is incident at an angle of 45° on 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.

33(b)(i). Describe a simple activity to observe the diffraction pattern due to a single slit.

33(b)(ii). An equiconvex lens (of refractive index 1.50) is kept in contact with a layer of liquid on top of a plane mirror, as shown in the figure below. A small needle, with its tip on the principal axis, is moved up and down along the axis until its inverted image is found to coincide with the needle itself. The distance of the needle from the lens is measured to be $45.0\ \text{cm}$. When the liquid is removed and the experiment is repeated, the new distance is found to be $30.0\ \text{cm}$. Find the refractive index of the liquid.



- End of Question Paper -