

CBSE Class 12 Physics 2024 - 55/S/3 - 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. 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. |

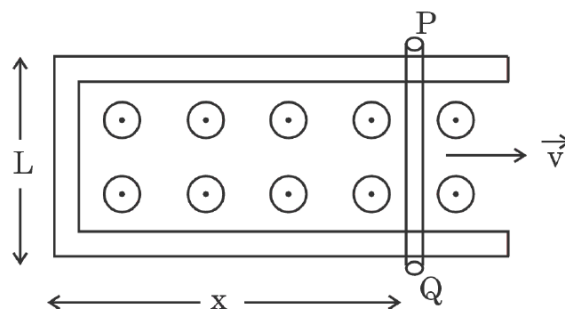
2. A capacitor of $5\ \mu\text{F}$ is connected to an ac source of $200\ \text{V}$, $\frac{1000}{\pi}$ Hz through a resistor of $100\ \Omega$. The phase difference between the voltage (V) applied and current (I) is:

- | | |
|-----------------|----------------|
| (A) 120° | (B) 90° |
| (C) 60° | (D) 45° |

3. m , m_n and m_p represent the masses of $\frac{A}{Z}\text{X}$ nucleus, a neutron and a proton, respectively. Then:

- | | |
|-----------------------------|-----------------------------|
| (A) $m < (A - Z)m_n + Zm_p$ | (B) $m = (A - Z)m_n + Zm_p$ |
| (C) $m = (A - Z)m_p + Zm_n$ | (D) $m > (A - Z)m_n + Zm_p$ |

4. A rod PQ of resistance R lies across frictionless conducting rails in a constant uniform magnetic field $\vec{B}$, as shown in the figure. Assuming that the rails have negligible resistance, the force required to pull the rod to the right at constant velocity $\vec{v}$ is:



- | | |
|---------------------|---------------------------|
| (A) 0 | (B) Blv |
| (C) $\frac{Blv}{R}$ | (D) $\frac{B^2 l^2 v}{R}$ |

5. When a ferromagnetic substance is heated to a temperature above its Curie temperature, it will:

- | | |
|---|--|
| (A) behave like a diamagnetic material. | (B) behave like a paramagnetic material. |
| (C) permanently demagnetise. | (D) remain a ferromagnetic. |

6. 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 |

7. A current of $5\ \text{A}$ is flowing in a wire of length $1.5\ \text{cm}$. A force of $7.5\ \text{mN}$ acts on it when it is placed in a uniform magnetic field of $0.2\ \text{T}$. The angle between the magnetic field and the direction of current is:

- | | |
|----------------|----------------|
| (A) 30° | (B) 45° |
| (C) 60° | (D) 90° |

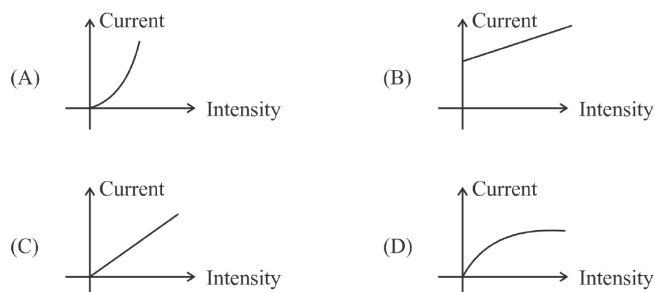
8. Two particles A and B of the same mass but having charges q and $4q$ respectively, are accelerated from rest through different potential differences V_A and V_B such that they attain same kinetic energy. The value of $\left(\frac{V_A}{V_B}\right)$ is:

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

9. 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.

10. Which one of the given graphs correctly represents the variation of photoelectric current with the intensity of incident radiation, keeping other parameters fixed?



11. When intrinsic silicon semiconductor is doped with Al atom, then it:

- (A) decreases the number of holes in the conduction band. (B) increases the number of holes in the valence band.
(C) increases the energy gap value. (D) increases the number of electrons in the valence band.

12. Two cells of emf 2 V and 3 V, and internal resistance $1\ \Omega$ and $2\ \Omega$, respectively, are connected in parallel. The effective emf and internal resistance of the combination cell are respectively:

- (A) 3 V, $1\ \Omega$ (B) 5 V, $3\ \Omega$
(C) $\frac{7}{3}$ V, $\frac{2}{3}\ \Omega$ (D) $\frac{6}{5}$ V, $\frac{2}{3}\ \Omega$

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):** 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.

14. **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.

15. **Assertion (A):** Nuclear fission reactions are responsible for energy generation in the Sun.

Reason (R): Light nuclei fuse together in the nuclear fission reactions.

16. **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.

Section B

17. Explain the terms depletion layer and potential barrier for a junction diode and their formation.

18. An electron is passing through a region and experiences no force. Under what condition is it possible when the region has (a) only the magnetic field, and (b) both the electric and the magnetic fields? Justify your answers.

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

19(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 $(0, 0)$.

20. 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 $10\ \text{cm}$. Calculate:

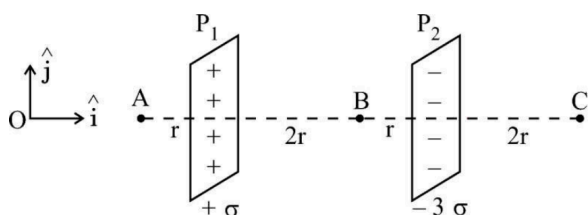
- (a) the critical angle for the liquid-air interface
 - (b) the radius of the circular bright patch of light formed on the surface by light emerging from the source
-

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

Section C

22(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.

22(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.



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. 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.

25. Radiations of frequency $3.0 \times 10^{15} \text{ Hz}$ are incident on a photosensitive surface of threshold frequency $1.0 \times 10^{15} \text{ Hz}$. Calculate: (a) work function of the surface, (b) maximum kinetic energy of photoelectrons.

26. 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.

27. An ideal resistor R, an ideal inductor L and an ideal capacitor C are connected, one by one, across the same source of ac voltage $v = v_0 \sin \omega t$. It is observed that the same current I flows in each case.

- (a) What will be the instantaneous value of current that will flow through their series combination when connected across the same source?

28. (a) Draw the shape of the intensity distribution curve of the fringes due to diffraction at a single slit.

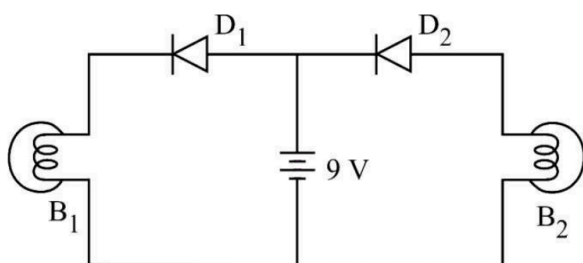
- (b) Derive the relation for the power of a combination of two thin lenses placed in contact coaxially.

Section D

Question numbers 29 and 30 are Case Study-based questions. Read the following paragraphs and answer the questions that follow.

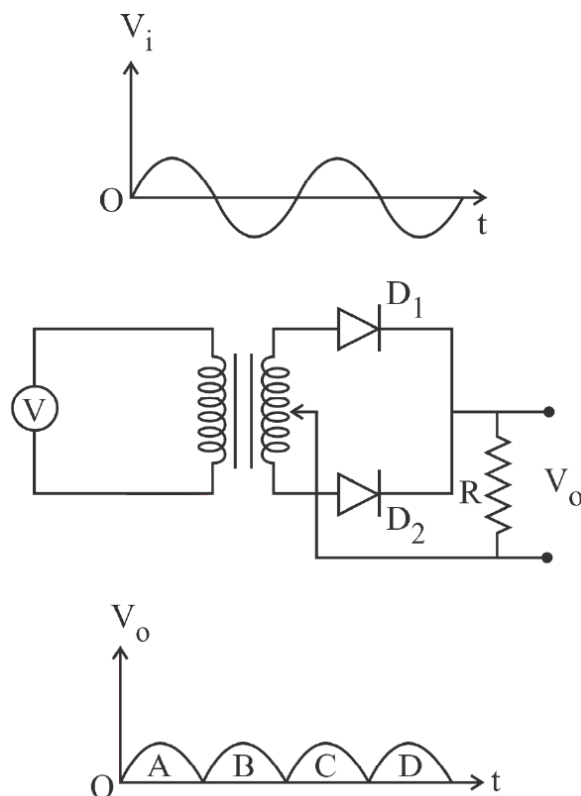
29. The process of converting ac into dc is called rectification and the device used is called a rectifier. When an ac signal is fed to a junction diode during the positive half cycle, the diode is forward biased and current flows through it. During the negative half cycle, the diode is reverse biased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

29(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

29(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

29(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

29(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

29(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

30. 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.

30(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) $qd(\hat{j} - \hat{i})$

30(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

30(iii). An electric dipole of dipole moment $5.0 \times 10^{-8} \text{ Cm}$ is placed in a region where an electric field of magnitude $1.0 \times 10^3 \text{ N/C}$ 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) $2.5 \times 10^{-5} \text{ Nm}$ (B) $5.0 \times 10^{-5} \text{ Nm}$
(C) $1.0 \times 10^{-4} \text{ Nm}$ (D) $2.0 \times 10^{-6} \text{ Nm}$

30(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) $\frac{1}{4} evr$

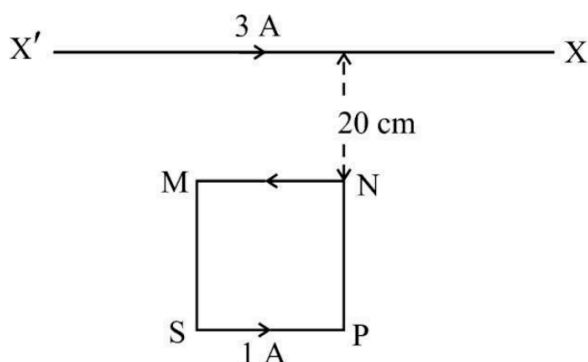
30(iv)(b). A square loop of side 5.0 cm carries a current of 2.0 A. The magnitude of the magnetic dipole moment associated with the loop is:

- (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) $5.0 \times 10^{-2} \text{ Am}^2$

Section E

31(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'.

31(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.



31(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.

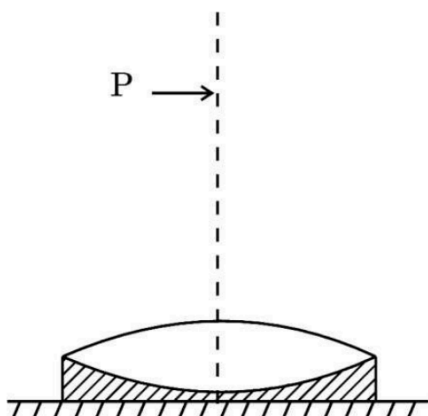
31(b)(ii). A resistance of $20\ \Omega$, a capacitance of $80\ \mu\text{F}$ and an inductor of $50\ \text{mH}$ are connected in series. This combination is connected across a 220 V ac supply of variable frequency. When the frequency of the supply equals the natural (resonant) frequency of the circuit,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

32(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.

32(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.

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

32(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 cm. When the liquid is removed and the experiment is repeated, the new distance is found to be 30.0 cm. Find the refractive index of the liquid.



33(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.

33(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.

33(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.

33(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

- End of Question Paper -