

CBSE Class 12 Physics 2024 - 55/S/2 - 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 relative magnetic permeability of a medium is 0.075. Its magnetic susceptibility will be:

- (A) 0.925 (B) -0.925
(C) 1.075 (D) -1.075

2. Two circular loops of areas A and 4A carry currents 2I and I respectively. The magnetic fields at their centres will be in the ratio of:

- (A) 3 : 1 (B) 4 : 1
(C) 1 : 1 (D) 1 : 2

3. A conducting sphere of radius R is given a charge Q. Consider three points A, B and C — A at the centre, B at a distance R/2 from the centre and C on the surface of the sphere. The electric potentials at these points are such that:

- (A) $V_A = V_B = V_C$ (B) $V_A = V_B \neq V_C$
(C) $V_A \neq V_B \neq V_C$ (D) $V_A \neq V_B = V_C$

4. The capacitance of a parallel plate capacitor is $10 \mu\text{F}$ when the distance between its plates is 8 cm. If the distance between the plates is halved, the capacitance will become:

- (A) $10 \mu\text{F}$ (B) $15 \mu\text{F}$
(C) $20 \mu\text{F}$ (D) $40 \mu\text{F}$

5. 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

6. The magnetic field of an electromagnetic wave is represented as $B_x = B_0 \sin(ky - \omega t)$. It means that the wave propagation direction and wave vector k are respectively:

- (A) +z axis, $\frac{2\pi}{\nu}$ (B) -z axis, $\frac{2\pi}{T}$
(C) +y axis, $\frac{2\pi}{\lambda}$ (D) -y axis, $\frac{\lambda}{2\pi}$

7. An inductor of resistance 5Ω and self-inductance 25 mH is connected across an ac source of angular frequency 200 rad s^{-1} . The phase angle between the voltage and the current is:

- (A) 30° (B) 45°
(C) 60° (D) 90°

8. 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.

9. The ionisation energy of the hydrogen atom, in Bohr model, is:

- (A) -3.4 eV (B) 3.4 eV
(C) -13.6 eV (D) 13.6 eV

10. 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

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. The current sensitivity of a galvanometer does not depend on the:

- (A) magnetic field in which the coil is suspended. (B) current flowing in the coil.
(C) torsional constant of the spring. (D) area of the coil.

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): Nuclear fission reactions are responsible for energy generation in the Sun.

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

15. 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.

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(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.

17(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 $(0, 0)$.

18. Differentiate between magnetisation and the susceptibility of a material. What can you say about the susceptibility of paramagnetic and diamagnetic materials?

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

20. Name the impurity atoms which are doped in an intrinsic semiconductor to convert it into (a) p-type, and (b) n-type semiconductor. Draw energy band diagrams of p-type and n-type semiconductors at temperature $T > 0\ \text{K}$. Mark the donor and acceptor energy levels, showing the energy difference from the respective bands.

21. 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
-

Section C

22. A particle of mass m and charge q is moving in a magnetic field $\vec{B}$ with a velocity $\vec{v}$. Discuss, giving reasons, the shape of its trajectory when the angle between $\vec{v}$ and $\vec{B}$ is: (a) 0° (b) 90° (c) 120°

23. (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) $\frac{\lambda}{3}$.

24. 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.

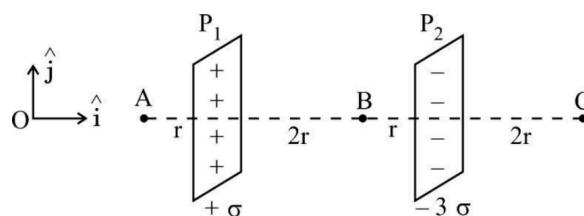
25. Two point charges of $10\ \mu\text{C}$ and $20\ \mu\text{C}$ are located at points $(-4\text{ cm}, 0, 0)$ and $(5\text{ cm}, 0, 0)$ respectively, in a region with electric field $\vec{E} = \frac{A}{r^2} \hat{r}$, where $A = 2 \times 10^6\ \text{NC}^{-1}\text{m}^2$ and $\vec{r}$ is the position vector of the point under consideration. Calculate the electrostatic potential energy of the system.

26. A current of 1 A flows through an inductor connected to a 200 V dc source. When it is connected to a 200 V, 50 Hz ac source, only 0.5 A current flows. Calculate the self-inductance of the inductor.

27. Two circular coils of radius R each and having equal number of turns N , carry equal currents I in the same direction. They are placed coaxially at a distance $\sqrt{3}R$ apart. Find the magnitude and direction of the net magnetic field produced at the midpoint of the line joining their centres.

28(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.

28(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.

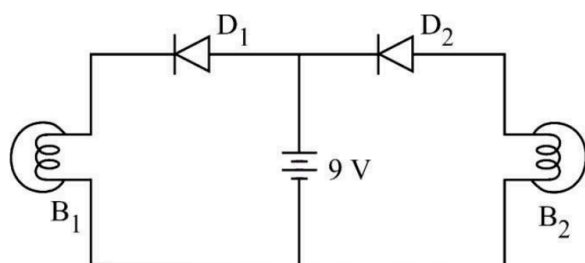


Section D

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

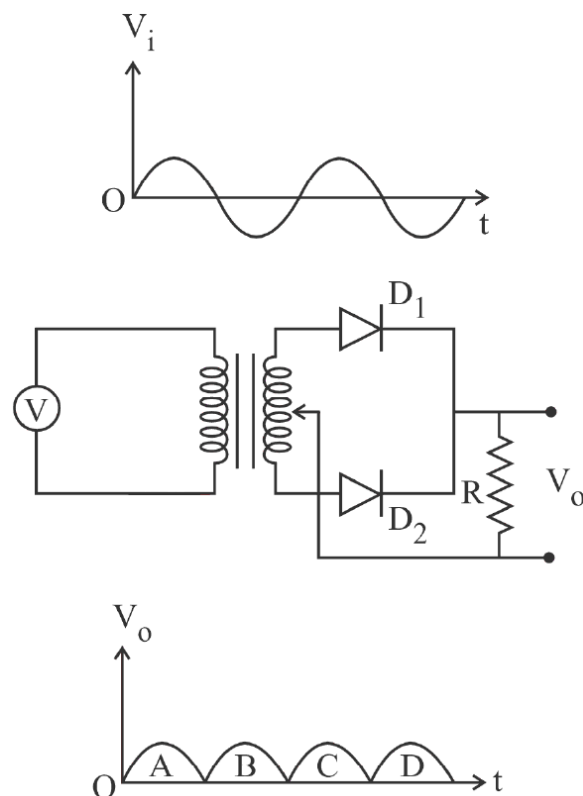
29. The process of converting ac into dc is called rectification and the device used is called a rectifier. When an ac signal is fed to a junction diode during the positive half cycle, the diode is forward biased and current flows through it. During the negative half cycle, the diode is reverse biased 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) $\frac{1}{4} evr$

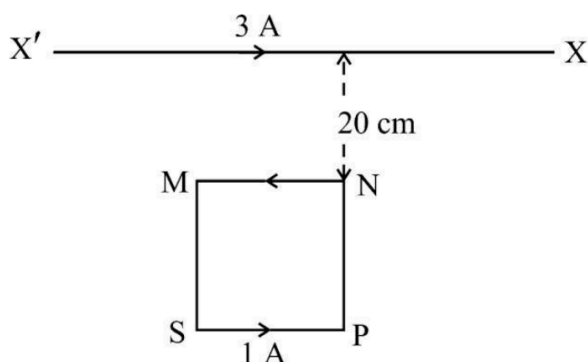
30(iv)(b). A square loop of side 5.0 cm carries a current of 2.0 A. The magnitude of the magnetic dipole moment associated with the loop is:

- (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.

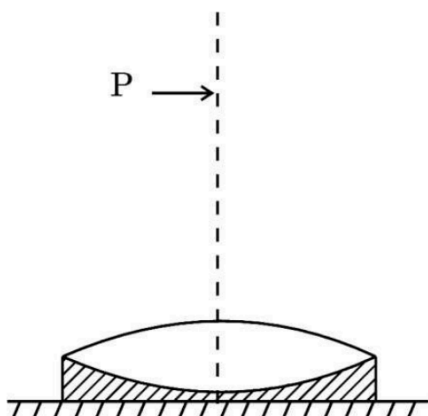
31(b)(ii). A resistance of $20\ \Omega$, a capacitance of $80\ \mu\text{F}$ and an inductor of $50\ \text{mH}$ are connected in series. This combination is connected across a 220 V ac supply of variable frequency. When the frequency of the supply equals the natural (resonant) frequency of the circuit,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