

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. An electric dipole of dipole moment $\vec{p}$ is kept in a uniform electric field $\vec{E}$. The amount of work done to rotate it from the position of stable equilibrium to that of unstable equilibrium will be

- (A) $2pE$ (B) $-2pE$
(C) pE (D) zero

2. An infinite long straight wire having a charge density λ is kept along $y'y$ axis in $x-y$ plane. The Coulomb force on a point charge q at a point $P(x, 0)$ will be

- (A) attractive and $\frac{\lambda q}{2\pi\epsilon_0 x}$ (B) repulsive and $\frac{\lambda q}{2\pi\epsilon_0 x}$
(C) attractive and $\frac{\lambda q}{\pi\epsilon_0 x}$ (D) repulsive and $\frac{\lambda q}{\pi\epsilon_0 x}$

3. The phase difference between electric field $\vec{E}$ and magnetic field $\vec{B}$ in an electromagnetic wave propagating along z -axis is

- (A) zero (B) π
(C) $\frac{\pi}{2}$ (D) $\frac{\pi}{4}$

4. In Balmer series of hydrogen atom, as the wavelength of spectral lines decreases, they appear

- (A) equally spaced and equally intense. (B) further apart and stronger in intensity.
(C) closer together and stronger in intensity. (D) closer together and weaker in intensity.

5. Two long straight parallel conductors A and B , kept at a distance r , carry current I in opposite directions. A third identical conductor C , kept at a distance $(\frac{r}{2})$ from A carries current I , in the same direction as in A . The net magnetic force on unit length of C is

- (A) $\frac{5\mu_0 I^2}{2\pi r}$ towards A (B) $\frac{5\mu_0 I^2}{2\pi r}$ towards B
(C) $\frac{3\mu_0 I^2}{4\pi r}$ towards A (D) $\frac{3\mu_0 I^2}{4\pi r}$ towards B

6. A coil of N turns is placed in a magnetic field $\vec{B}$ such that $\vec{B}$ is perpendicular to the plane of the coil. $\vec{B}$ varies with time as $B = B_0 \cos\left(\frac{2\pi}{T}t\right)$, where T is the time period. The magnitude of induced emf in the coil will be maximum at the time

- (A) $t = \frac{nT}{8}$ (B) $t = \frac{nT}{4}$
(C) $t = \frac{nT}{2}$ (D) $t = nT$

7. A circular loop A of radius R carries a current I . Another circular loop B of radius $\left(\frac{R}{20}\right)$ is placed concentrically in the plane of A . The magnetic flux linked with loop B is proportional to

- (A) R (B) $\sqrt{R}$
(C) $R^{3/2}$ (D) R^2

8. A galvanometer of resistance $100\ \Omega$ is converted into an ammeter of range $(0-1\ \text{A})$ using a resistance of $0.1\ \Omega$. The ammeter will show full scale deflection for a current of about

- (A) $0.1\ \text{mA}$ (B) $1\ \text{mA}$
(C) $10\ \text{mA}$ (D) $0.1\ \text{A}$

9. The r.m.s. value of a current given by $i = (i_1 \cos \omega t + i_2 \sin \omega t)$ is

- (A) $\frac{1}{\sqrt{2}}(i_1 + i_2)$ (B) $\frac{1}{\sqrt{2}}(i_1 - i_2)$
(C) $\frac{1}{\sqrt{2}}\sqrt{i_1^2 + i_2^2}$ (D) $\frac{1}{2}(i_1^2 + i_2^2)$

10. The quantum nature of light explains the observations on photoelectric effect as

- (A) there is a minimum frequency of incident radiation below which no electrons are emitted. (B) the maximum kinetic energy of photoelectrons depends only on the frequency of incident radiation.
(C) when the metal surface is illuminated, electrons are ejected from the surface after sometime. (D) the photoelectric current is independent of the intensity of incident radiation.

11. The magnetic susceptibility for a diamagnetic material is

- (A) small and negative (B) small and positive
(C) large and negative (D) large and positive

12. The radius (r_n) of n^{th} orbit in Bohr model of hydrogen atom varies with n as

- (A) $r_n \propto n$ (B) $r_n \propto \frac{1}{n}$
(C) $r_n \propto n^2$ (D) $r_n \propto \frac{1}{n^2}$

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) If both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A).
(B) If both Assertion (A) and Reason (R) are true and Reason (R) is not the correct explanation of Assertion (A).

(C) If Assertion (A) is true and Reason (R) is false.
(D) If both Assertion (A) and Reason (R) are false.

13. Assertion (A): When electrons drift in a conductor, it does not mean that all free electrons in the conductor are moving in the same direction.

Reason (R): The drift velocity is superposed over large random velocities of electrons.

14. Assertion (A): In interference and diffraction of light, light energy reduces in one region producing a dark fringe. It increases in another region and produces a bright fringe.

Reason (R): This happens because energy is not conserved in the phenomena of interference and diffraction.

15. Assertion (A): The temperature coefficient of resistance is positive for metals and negative for p -type semiconductors.

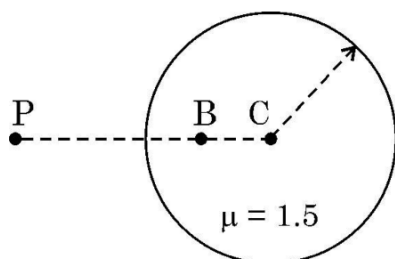
Reason (R): The charge carriers in metals are negatively charged, whereas the majority charge carriers in p -type semiconductors are positively charged.

16. Assertion (A): Electrons are ejected from the surface of zinc when it is irradiated by yellow light.

Reason (R): Energy associated with a photon of yellow light is more than the work function of zinc.

Section B

17(a). An air bubble is trapped at point B (CB = 20 cm) in a glass sphere of radius 40 cm and refractive index 1.5, as shown in the figure. Find the nature and position of the image of this bubble as seen by an observer at point P.



OR

17(b). In normal adjustment, for a refracting telescope, the distance between objective and eyepiece lens is 1.00 m. If the magnifying power of the telescope is 19, find the focal length of the objective and the eyepiece lens.

18. The ratio of de Broglie wavelengths of a proton and a deuteron accelerated by potential V_p and V_d respectively, $\left(\frac{\lambda_p}{\lambda_d}\right)$ is $\frac{1}{2}$. Find $\frac{V_p}{V_d}$.

19. A ray of light is incident normally on one face of an equilateral glass prism of refractive index μ . When the prism is completely immersed in a transparent medium, it is observed that the emergent ray just grazes the adjacent face. Find the refractive index of the medium.

20. Find the temperature at which the resistance of a conductor increases by 25% of its value at 27°C . The temperature coefficient of resistance of the conductor is $2.0 \times 10^{-4} \text{ }^\circ\text{C}^{-1}$.

21. Draw the circuit diagram of a p - n junction diode in (i) forward biasing and (ii) reverse biasing. Also draw its I - V characteristics in the two cases.

Section C

22(a). (i) Define mutual inductance. Write its SI unit.

(ii) Derive an expression for the mutual inductance of a system of two long coaxial solenoids of same length l , having turns N_1 and N_2 and of radii r_1, r_2 ($r_2 > r_1$).

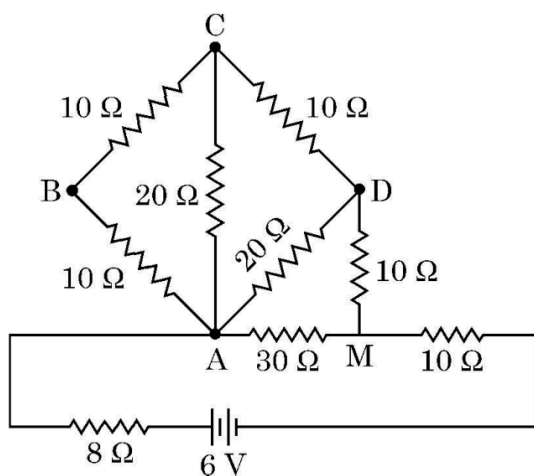
22(b). What are ferromagnetic materials? Explain ferromagnetism with the help of suitable diagrams, using the concept of magnetic domain.

23. Two conducting spherical shells A and B of radii R and $2R$ are kept far apart and charged to the same charge density σ . They are connected by a wire. Obtain an expression for final potential of shell A .

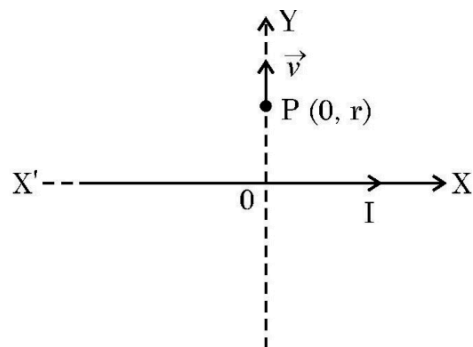
24. Draw the graph showing variation of scattered particles detected (N) with the scattering angle (θ) in Geiger-Marsden experiment. Write two conclusions that you can draw from this graph. Obtain the expression for the distance of closest approach in this experiment.

25. In the given network, calculate:

- (i) effective resistance between points A and M , and
- (ii) power supplied by the battery.



26. An infinite straight conductor is kept along $X'X$ axis and carries a current I . A charge q at point $P(0, r)$ starts moving with velocity $\vec{v} = v_0 \hat{j}$ as shown in figure. Find the direction and magnitude of force initially experienced by the charge.



27. Explain the following giving reasons:

- (i) 'Electromagnetic waves differ considerably in their mode of interaction with matter'.
- (ii) 'Food items to be heated in microwave oven must contain water'.
- (iii) 'Welders wear face mask with glasses during welding'.

28. (a) Differentiate between nuclear fission and fusion.

(b) The fission properties of ${}_{94}^{239}\text{Pu}$ are very similar to those of ${}_{92}^{235}\text{U}$. How much energy (in MeV), is released if all the atoms in 1 g of pure ${}_{94}^{239}\text{Pu}$ undergo fission? The average energy released per fission is 180 MeV.

Section D

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

29(i). When Ge is doped with pentavalent impurity, the energy required to free the weakly bound electron from the dopant is about

- (A) 0.001 eV (B) 0.01 eV
(C) 0.72 eV (D) 1.1 eV

29(ii). At a given temperature, the number of intrinsic charge carriers in a semiconductor is $2.0 \times 10^{19} \text{ cm}^{-3}$. It is doped with pentavalent impurity atoms. As a result, the number of holes in it becomes $8 \times 10^{13} \text{ cm}^{-3}$. The number of electrons in the semiconductor is

- (A) $2 \times 10^{24} \text{ m}^{-3}$ (B) $4 \times 10^{23} \text{ m}^{-3}$
(C) $1 \times 10^{22} \text{ m}^{-3}$ (D) $5 \times 10^{22} \text{ m}^{-3}$

29(iii)(a). During the formation of a p - n junction —

- (A) electrons diffuse from p -region into n -region and holes diffuse from n -region into p -region.
(B) both electrons and holes diffuse from n -region into p -region.
(C) electrons diffuse from n -region into p -region and holes diffuse from p -region into n -region.
(D) both electrons and holes diffuse from p -region into n -region.

29(iii)(b). Initially during the formation of a p - n junction —

- (A) diffusion current is large and drift current is small.
(B) diffusion current is small and drift current is large.
(C) both the diffusion and the drift currents are large.
(D) both the diffusion and the drift currents are small.

29(iv). An ac voltage $V = 0.5 \sin(100\pi t)$ volt is applied, in turn, across a half-wave rectifier and a full-wave rectifier. The frequency of the output voltage across them respectively will be

- (A) 25 Hz, 50 Hz (B) 25 Hz, 100 Hz
(C) 50 Hz, 50 Hz (D) 50 Hz, 100 Hz

30(i). A thin converging lens of focal length 20 cm and a thin diverging lens of focal length 15 cm are placed coaxially in contact. The power of the combination is

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

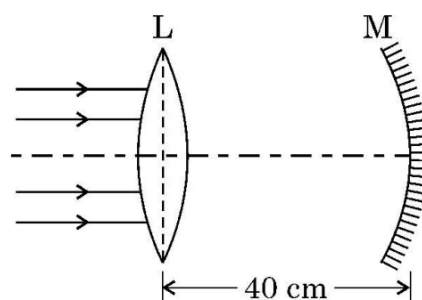
30(ii). The radii of curvature of two surfaces of a convex lens are R and $2R$. If the focal length of this lens is $(\frac{5}{3})R$, the refractive index of the material of the lens is

- (A) $\frac{7}{5}$ (B) $\frac{8}{5}$
(C) $\frac{19}{15}$ (D) $\frac{3}{2}$

30(iii). The focal length of an equiconvex lens

- (A) increases when the lens is dipped in water. (B) increases when the wavelength of incident light decreases.
(C) increases with decrease in radius of curvature of its surface. (D) decreases when the lens is cut into two identical parts along its principal axis.

30(iv)(a). A thin convex lens L of focal length 10 cm and a concave mirror M of focal length 15 cm are placed coaxially 40 cm apart as shown in figure. A beam of light coming parallel to the principal axis is incident on the lens. The final image will be formed at a distance of



- (A) 10 cm, left of lens (B) 10 cm, right of lens
(C) 20 cm, left of lens (D) 20 cm, right of lens

30(iv)(b). A beam of light coming parallel to the principal axis of a convex lens L_1 of focal length 16 cm is incident on it. Another convex lens L_2 of focal length 12 cm is placed coaxially at a distance 40 cm from L_1 . The nature and distance of the final image from L_2 will be

- (A) real, 24 cm (B) virtual, 12 cm
(C) real, 32 cm (D) virtual, 18 cm

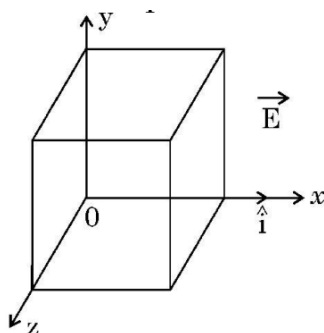
Section E

31(a). (i) A dielectric slab of dielectric constant K and thickness t is inserted between plates of a parallel plate capacitor of plate separation d and plate area A . Obtain an expression for its capacitance.

(ii) Two capacitors of different capacitances are connected first (1) in series and then (2) in parallel across a dc source of 100 V. If the total energy stored in the combination in the two cases are 40 mJ and 250 mJ respectively, find the capacitance of the capacitors.

31(b). (i) Using Gauss's law, show that the electric field $\vec{E}$ at a point due to a uniformly charged infinite plane sheet is given by $\vec{E} = \frac{\sigma}{2\epsilon_0} \hat{n}$ where symbols have their usual meanings.

(ii) Electric field $\vec{E}$ in a region is given by $\vec{E} = (5x^2 + 2)\hat{i}$, where E is in N/C and x is in meters. A cube of side 10 cm is placed in the region as shown in figure. Calculate (1) the electric flux through the cube, and (2) the net charge enclosed by the cube.



32(a). (i) Draw a ray diagram for the formation of the image of an object by a convex mirror. Hence, obtain the mirror equation.

(ii) Why are multi-component lenses used for both the objective and the eyepiece in optical instruments?

(iii) The magnification of a small object produced by a compound microscope is 200. The focal length of the eyepiece is 2 cm and the final image is formed at infinity. Find the magnification produced by the objective.

32(b). (i) Differentiate between a wavefront and a ray.

(ii) State Huygen's principle and verify laws of reflection using suitable diagram.

(iii) In Young's double slit experiment, the slits S_1 and S_2 are 3 mm apart and the screen is placed 1.0 m away from the slits. It is observed that the fourth bright fringe is at a distance of 5 mm from the second dark fringe. Find the wavelength of light used.

33(a). (i) Mention the factors on which the resonant frequency of a series LCR circuit depends. Plot a graph showing variation of impedance of a series LCR circuit with the frequency of the applied a.c. source.

(ii) With the help of a suitable diagram, explain the working of a step-up transformer.

(iii) Write two causes of energy loss in a real transformer.

33(b). (i) With the help of a diagram, briefly explain the construction and working of ac generator.

(ii) An electron is revolving around a proton in an orbit of radius r with a speed v . Obtain expression for magnetic moment associated with the electron.

- End of Question Paper -