

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

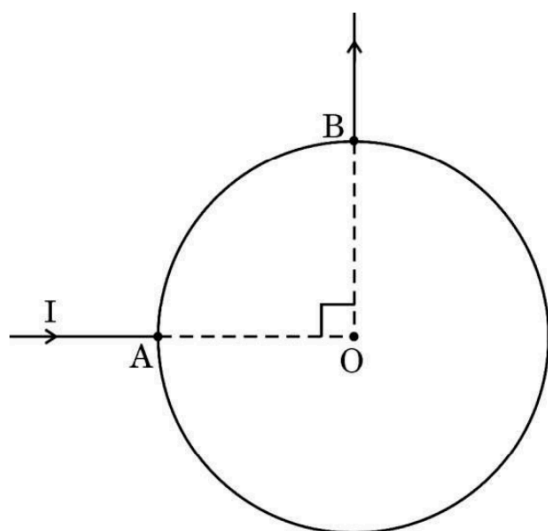
1. The electric field (E) and electric potential (V) at a point inside a charged hollow metallic sphere are respectively:

- (A) $E = 0, V = 0$ (B) $E = 0, V = V_0$ (a constant)
 (C) $E \neq 0, V \neq 0$ (D) $E = E_0$ (a constant), $V = 0$

2. The dimensions of 'self-inductance' are:

- (A) $[MLT^{-2}A^{-2}]$ (B) $[ML^2T^{-1}A^{-1}]$
 (C) $[ML^{-1}T^{-2}A^{-2}]$ (D) $[ML^2T^{-2}A^{-2}]$

3. In a circular loop of radius R , current I enters at point A and exits at point B , as shown in the figure. The value of the magnetic field at the centre O of the loop is:



- (A) $\frac{\mu_0 I}{R}$ (B) zero
 (C) $\frac{\mu_0 I}{2R}$ (D) $\frac{\mu_0 I}{4R}$

4. The frequency of a photon of energy 1.326 eV is:

- (A) 1.18×10^{14} Hz (B) 3.20×10^{14} Hz
 (C) 4.20×10^{15} Hz (D) 4.80×10^{15} Hz

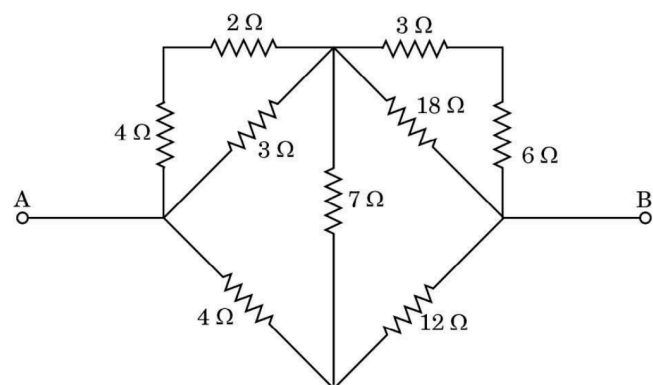
5. A metal rod of length 50 cm is held vertically and moved with a velocity of 10 m/s towards east. The horizontal component of the Earth's magnetic field at the place is 0.4 G. The emf induced across the ends of the rod is:

- (A) 0.1 mV (B) 0.2 mV
 (C) 0.8 mV (D) 1.6 mV

6. Germanium crystal is doped at room temperature with a minute quantity of boron. The charge carriers in the doped semiconductors will be:

- (A) electrons only (B) holes only
 (C) holes and few electrons (D) electrons and few holes

7. The effective resistance between points A and B in the given circuit (a bridge network with arms $2\ \Omega, 3\ \Omega, 4\ \Omega, 3\ \Omega, 18\ \Omega, 6\ \Omega, 7\ \Omega$ at the centre, $4\ \Omega$ and $12\ \Omega$) is:



- (A) $6\ \Omega$ (B) $\frac{8}{3}\ \Omega$
 (C) $\frac{16}{3}\ \Omega$ (D) $2\ \Omega$

8. A capacitor and an inductor are connected in series across an ac source of voltage of variable frequency. The frequency is increased continuously. The nature of the circuit before and after the resonance will be:

- | | |
|---|---|
| (A) inductive only | (B) capacitive only |
| (C) capacitive and inductive respectively | (D) inductive and capacitive respectively |

9. An alternating current is given by $I = I_0 \cos(100\pi)t$. The least time the current takes to decrease from its maximum value to zero will be:

- | | |
|------------------------------------|------------------------------------|
| (A) $\left(\frac{1}{50}\right)$ s | (B) $\left(\frac{1}{100}\right)$ s |
| (C) $\left(\frac{1}{200}\right)$ s | (D) $\left(\frac{1}{400}\right)$ s |

10. The mass numbers of two nuclei A and B are 27 and 64 respectively. The ratio of their radii $\left(\frac{r_A}{r_B}\right)$ will be:

- | | |
|---------------------------|--------------------|
| (A) $\frac{27}{64}$ | (B) $\frac{9}{16}$ |
| (C) $\frac{3\sqrt{3}}{2}$ | (D) $\frac{3}{4}$ |

11. Isotones are the nuclides having:

- | | |
|--|---|
| (A) same mass numbers | (B) same atomic numbers |
| (C) same neutron number, but different atomic number | (D) different neutron number, and different mass number |

12. A p-n junction diode is forward biased. As a result,

- | | |
|--|--|
| (A) both the potential barrier height and the width of depletion layer decrease. | (B) both the potential barrier height and the width of depletion layer increase. |
| (C) the potential barrier height decreases and the width of depletion layer increases. | (D) the potential barrier height increases and the width of depletion layer decreases. |

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): A ray of light is incident normally on the face of a prism. The emergent ray will graze along the opposite face of the prism when the critical angle at glass-air interface is equal to the angle of the prism.

Reason (R): The refractive index of a prism depends on angle of the prism.

Select the correct answer:

14. Assertion (A): A charged particle is moving with velocity v in x - y plane, making an angle θ ($0 < \theta < \frac{\pi}{2}$) with x -axis. If a uniform magnetic field $\vec{B}$ is applied in the region, along y -axis, the particle will move in a helical path with its axis parallel to x -axis.

Reason (R): The direction of the magnetic force acting on a charged particle moving in a magnetic field is along the velocity of the particle.

Select the correct answer:

15. Assertion (A): The minimum negative potential applied to the anode in a photoelectric experiment at which photoelectric current becomes zero, is called cut-off voltage.

Reason (R): The threshold frequency for a metal is the minimum frequency of incident radiation below which emission of photoelectrons does not take place.

Select the correct answer:

16. Assertion (A): EM waves do not require a medium for their propagation.

Reason (R): EM waves are transverse waves.

Select the correct answer:

Section B

17. Two wires made of the same material have the same length (l) but different cross-sectional areas A_1 and A_2 . They are connected together with a cell of voltage V . Find the ratio of the drift velocities of free electrons in the two wires when they are joined in (i) series, and (ii) parallel.

18. Draw energy band diagrams of n-type and p-type semiconductors at temperature $T > 0$ K. Show the donor/acceptor energy levels with the order of difference of their energies from the bands.

19. The ratio of the intensities at maxima to minima in Young's double-slit experiment is 25 : 9. Calculate the ratio of intensities of the interfering waves.

20. (a) Using the mirror equation and the formula of magnification, deduce that “the virtual image produced by a convex mirror is always diminished in size and is located between the pole and the focus.”

OR

(b) A convex lens of focal length 10 cm, a concave lens of focal length 15 cm and a third lens of unknown focal length are placed coaxially in contact. If the focal length of the combination is +12 cm, find the nature and focal length of the third lens, if all lenses are thin. Will the answer change if the lenses were thick?

21. Calculate the binding energy per nucleon (in MeV) of a helium nucleus (${}^4_2\text{He}$).

Given: $m({}^4_2\text{He}) = 4.002603$ u, $m_n = 1.008665$ u, $m_p = 1.007825$ u, $1 \text{ u} = 931.5 \text{ MeV}/c^2$.

Section C

22. Write the mathematical forms of three postulates of Bohr's theory of the hydrogen atom. Using them prove that, for an electron revolving in the n^{th} orbit,

(a) the radius of the orbit is proportional to n^2 , and

(b) the total energy of the atom is proportional to $\left(-\frac{1}{n^2}\right)$.

23. (a) Briefly explain Einstein's photoelectric equation.

(b) Four metals with their work functions are listed below:

$K = 2.3 \text{ eV}$, $Na = 2.75 \text{ eV}$, $Mo = 4.17 \text{ eV}$ and $Ni = 5.15 \text{ eV}$.

The radiation of wavelength 330 nm from a laser source placed 1 m away, falls on these metals. Which of these metals will not show photoelectric emission? What will happen if the laser source is brought closer to a distance of 50 cm?

24. (a) (i) Write Biot-Savart's law in vector form.

(ii) Two identical circular coils A and B , each of radius R , carrying currents I and $\sqrt{3}I$ respectively, are placed concentrically in XY and YZ planes respectively. Find the magnitude and direction of the net magnetic field at their common centre.

OR

(b) (i) A rectangular loop of sides l and b carries a current I clockwise. Write the magnetic moment $\vec{m}$ of the loop and show its direction in a diagram.

(ii) The loop is placed in a uniform magnetic field $\vec{B}$ and is free to rotate about an axis which is perpendicular to $\vec{B}$. Prove that the loop experiences no net force, but a torque $\vec{\tau} = \vec{m} \times \vec{B}$.

25. (a) How are electromagnetic waves produced?

(b) Write the wavelength range and one use of:

(i) Microwaves, and

(ii) Ultraviolet waves.

26. (a) Two concentric circular coils of radii r_1 and r_2 ($r_2 \gg r_1$) are placed coaxially with their centres coinciding. If a current I is passed through the outer coil, obtain the expression for mutual inductance of the arrangement.

(b) The current in a solenoid decreases steadily from 6 mA to 2 mA in 50 ms. If an average emf of 0.4 V is induced, find the self-inductance of the solenoid.

27. Explain the process of formation of 'depletion layer' and 'potential barrier' in a p-n junction region of a diode, with the help of a suitable diagram. Which feature of junction diode makes it suitable for its use as a rectifier?

28. Two point charges of $-5 \mu\text{C}$ and $2 \mu\text{C}$ are located in free space at $(-4 \text{ cm}, 0)$ and $(6 \text{ cm}, 0)$ respectively.

(a) Calculate the amount of work done to separate the two charges at infinite distance.

(b) If this system of charges was initially kept in an electric field $\vec{E} = \frac{A}{r^2} \hat{r}$, where $A = 8 \times 10^4 \text{ N C}^{-1} \text{ m}^2$, calculate the electrostatic potential energy of the system.

Section D

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

29. When light travels from an optically denser medium to an optically rarer medium, at the interface it is partly reflected back into the same medium and partly refracted to the second medium. The angle of incidence corresponding to an angle of refraction 90° is called the critical angle (i_c) for the given pair of media. This angle is related to the refractive index of medium 1 with respect to medium 2. Refraction of light through a prism involves refraction at two plane interfaces. A relation for the refractive index of the material of the prism can be obtained in terms of the refracting angle of the prism and the angle of minimum deviation. For a thin prism, this relation reduces to a simple equation. Laws of refraction are also valid for refraction of light at a spherical interface. When an object is placed in front of a spherical surface separating two media, its image is formed. A relation between object and image distance, in terms of refractive indices of two media and the radius of curvature of the spherical surface can be obtained. Using this relation for two surfaces of a lens, 'lens maker formula' is obtained.

29(i). A small bulb is placed at the bottom of a tank containing a transparent liquid (refractive index n) to a depth H . The radius of the circular area of the surface of liquid, through which light from the bulb can emerge out, is R . Then $\left(\frac{R}{H}\right)$ is:

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

29(ii). (a) A parallel beam of light is incident on a face of a prism with refracting angle 60° . The angle of minimum deviation is found to be 30° . The refractive index of the material of the prism is close to:

OR

(b) The angle of minimum deviation for a ray of light incident on a thin prism, made of crown glass ($n = 1.52$) is D_m . If the prism was made of dense flint glass ($n = 1.62$) instead of crown glass, the angle of minimum deviation will:

- | | |
|--|--|
| (A) (a) 1.3 OR (b) decrease by 4% | (B) (a) 1.4 OR (b) increase by 4% |
| (C) (a) 1.5 OR (b) decrease by 19% | (D) (a) 1.6 OR (b) increase by 19% |

29(iii). (iii) An object is placed in front of a convex spherical glass surface ($n = 1.5$ and radius of curvature R) at a distance of $4R$ from it. As the object is moved slowly close to the surface, the image formed is:

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

29(iv). (iv) A double-convex lens, made of glass of refractive index 1.5, has focal length 10 cm. The radius of curvature of its each face, is:

- | | |
|-----------|-----------|
| (A) 10 cm | (B) 15 cm |
| (C) 20 cm | (D) 40 cm |

30. In a metallic conductor, an electron, moving due to thermal motion, suffers collisions with the heavy fixed ions but after collision, it will emerge out with the same speed but in random directions. If we consider all the electrons, their average velocity will be zero. When an electric field is applied, electrons move with an average velocity, known as drift velocity (v_d). The average time between successive collisions is known as relaxation time (τ). The magnitude of drift velocity per unit electric field is called mobility (μ). An expression for current through the conductor can be obtained in terms of drift velocity, number of electrons per unit volume (n), electronic charge ($-e$), and the cross-sectional area (A) of the conductor. This expression leads to an expression between current density ($\vec{J}$) and the electric field ($\vec{E}$). Hence, an expression for resistivity (ρ) of a metal is obtained. This expression helps us to understand increase in resistivity of a metal with increase in its temperature, in terms of change in the relaxation time (τ) and change in the number density of electrons (n).

30(i). Consider two cylindrical conductors A and B , made of the same metal connected in series to a battery. The length and the radius of B are twice that of A . If μ_A and μ_B are the mobility of electrons in A and B respectively, then $\frac{\mu_A}{\mu_B}$ is:

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

30(ii). A wire of length 0.5 m and cross-sectional area $1.0 \times 10^{-7} \text{ m}^2$ is connected to a battery of 2 V that maintains a current of 1.5 A in it. The conductivity of the material of the wire (in $\Omega^{-1} \text{ m}^{-1}$) is:

- (A) 2.5×10^4 (B) 3.0×10^5
(C) 3.75×10^6 (D) 5.0×10^7

30(iii). (iii) The temperature coefficient of resistance of nichrome is $1.70 \times 10^{-4} \text{ }^\circ\text{C}^{-1}$. In order to increase resistance of a nichrome wire by 8.5%, the temperature of the wire should be increased by:

- (A) 250°C (B) 500°C
(C) 850°C (D) 1000°C

30(iv). (iv) (a) Consider the contribution of the following two factors I and II in resistivity of a metal:

- I. Relaxation time of electrons
II. Number of electrons per unit volume

The resistivity of a metal increases with increase in its temperature because:

OR

(b) A steady current flows in a copper wire of non-uniform cross-section. Consider the following three physical quantities:

- I. Electric field
II. Current density
III. Drift speed

Then at the different points along the wire:

- (A) (a) I decreases and II increases. OR (b) II and III change, but I is constant.
(B) (a) I increases and II is almost constant. OR (b) I and II change, but III is constant.
(C) (a) Both I and II increase. OR (b) I and III change, but II is constant.
(D) (a) I decreases and II is almost constant. OR (b) All I, II and III change.

Section E

31. (a) (i) Explain with the help of a labelled ray diagram the formation of final image by an astronomical telescope at infinity. Write the expression for its magnifying power.

(ii) The total magnification produced by a compound microscope is 20. The magnification produced by the eyepiece is 5. When the microscope is focussed on a certain object, the distance between the objective and eyepiece is observed to be 14 cm. Calculate the focal lengths of the objective and the eyepiece. (Given that the least distance of distinct vision = 25 cm)

OR

(b) (i) Two coherent light waves, each of intensity I_0 superpose each other and produce interference pattern on a screen. Obtain the expression for the resultant intensity at a point where the phase difference between the waves is ϕ . Write its maximum and minimum possible values.

(ii) In a single slit diffraction experiment, the aperture of the slit is 3 mm and the separation between the slit and the screen is 1.5 m. A monochromatic light of wavelength 600 nm is normally incident on the slit. Calculate the distance of (I) first order minimum, and (II) second order maximum, from the centre of the screen.

32. (a) (i) A parallel plate capacitor with plate area A and plate separation d has a capacitance C_0 . A slab of dielectric constant K having area A and thickness $\left(\frac{d}{2}\right)$ is inserted in the capacitor, parallel to the plates. Find the new value of its capacitance.

(ii) You are provided with a large number of $1\ \mu\text{F}$ identical capacitors and a power supply of 1200 V. The dielectric medium used in each capacitor can withstand up to 200 V only. Find the minimum number of capacitors and their arrangement, required to build a capacitor system of equivalent capacitance of $2\ \mu\text{F}$ for use with this supply.

OR

(b) (i) An electric dipole of dipole moment $\vec{p}$ consists of point charges q and $-q$, separated by $2a$. Derive an expression for electric potential in terms of its dipole moment at a point at a distance x ($\gg a$) from its centre and lying (I) along its axis, and (II) along its bisector line.

(ii) An electric dipole of dipole moment $\vec{p} = (0.8\hat{i} + 0.6\hat{j}) \times 10^{-29}\ \text{C m}$ is placed in an electric field $\vec{E} = 1.0 \times 10^7\ \hat{k}\ \text{V/m}$. Calculate the magnitude of the torque acting on it and the angle it makes with the x -axis, at this instant.

33. (a) (i) With the help of a labelled diagram, explain the principle of working of a moving coil galvanometer. Write the purpose of using (i) radial magnetic field, and (ii) soft iron core, in it.

(ii) Define current sensitivity of a galvanometer. "Increasing the current sensitivity may not necessarily increase the voltage sensitivity." Give reason.

OR

(b) (i) (I) Write Ampere's circuital law in mathematical form and explain the terms used.

(II) As the current carrying solenoid is made longer, the magnetic field produced outside it approaches zero. Why?

(III) A flexible loop of irregular shape carrying current when located in an external magnetic field, changes to a circular shape. Give reason.

(ii) A galvanometer of resistance G is converted into a voltmeter to measure up to V volts, by connecting a resistance R_1 in series with the coil. If R_1 is replaced by R_2 , then it can only measure up to $\frac{V}{2}$ volt. Find the value of the resistance R_3 (in terms of R_1 and R_2) needed to convert it into a voltmeter that can read up to $2V$.

- End of Question Paper -