

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:

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

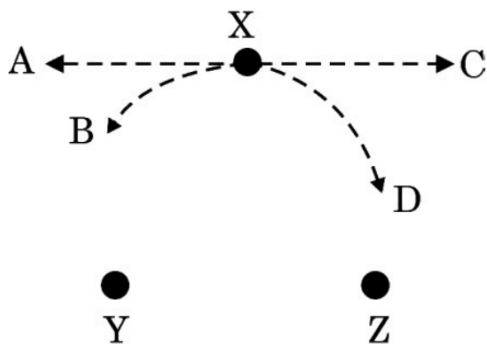
$$\begin{aligned}\text{Mass of electron } (m_e) &= 9.1 \times 10^{-31} \text{ kg} \\\text{Mass of neutron} &= 1.675 \times 10^{-27} \text{ kg} \\\text{Mass of proton} &= 1.673 \times 10^{-27} \text{ kg} \\\text{Avogadro's number} &= 6.023 \times 10^{23} \text{ per gm mole} \\\text{Boltzmann constant}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

Section A

1. A thin plastic rod is bent into a circular ring of radius R . It is uniformly charged with charge density λ . The magnitude of the electric field at its centre is:

- (A) $\frac{\lambda}{2\epsilon_0 R}$ (B) Zero
(C) $\frac{\lambda}{4\pi\epsilon_0 R}$ (D) $\frac{\lambda}{4\epsilon_0 R}$

2. Three small charged spheres X , Y and Z carrying charges $+q$, $-q$ and $+q$ respectively are placed equidistant from each other, as shown in the figure. The spheres Y and Z are held in place. Initially X is also held in place, but is otherwise free to move. When X is released, the path followed by it will be:



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

3. In a uniform straight wire, conduction electrons move along $+x$ direction. Let $\vec{E}$ and $\vec{j}$ be the electric field and current density in the wire, respectively. Then:

- (A) $\vec{E}$ and $\vec{j}$ both are along $+x$ direction. (B) $\vec{E}$ and $\vec{j}$ both are along $-x$ direction.
(C) $\vec{E}$ is along $+x$ direction, but $\vec{j}$ is along $-x$ direction. (D) $\vec{E}$ is along $-x$ direction, but $\vec{j}$ is along $+x$ direction.

4. Two charged particles, P and Q , each having charge q but of masses m_1 and m_2 , are accelerated through the same potential difference V . They enter a region of magnetic field $\vec{B}$ ($\perp \vec{v}$) and describe the circular paths of radii a and b respectively. Then $\left(\frac{m_1}{m_2}\right)$ is equal to:

- (A) $\frac{a}{b}$ (B) $\frac{b}{a}$
(C) $\left(\frac{a}{b}\right)^2$ (D) $\left(\frac{b}{a}\right)^2$

5. A galvanometer of resistance $G \Omega$ is converted into an ammeter of range 0 to I A. If the current through the galvanometer is 0.1% of I A, the resistance of the ammeter is:

- (A) $\frac{G}{999} \Omega$ (B) $\frac{G}{1000} \Omega$
(C) $\frac{G}{1001} \Omega$ (D) $\frac{G}{100.1} \Omega$

6. The primary and secondary coils of a transformer have 500 turns and 5000 turns respectively. The primary coil is connected to an ac source of $220 \text{ V} - 50 \text{ Hz}$. The output across the secondary coil is:

- (A) $220 \text{ V} - 50 \text{ Hz}$ (B) $1100 \text{ V} - 50 \text{ Hz}$
(C) $2200 \text{ V} - 5 \text{ Hz}$ (D) $2200 \text{ V} - 50 \text{ Hz}$

7. The first scientist who produced and observed electromagnetic waves of wavelengths in the range $25 \text{ mm} - 5 \text{ mm}$ was:

- (A) J.C. Maxwell (B) H.R. Hertz
(C) J.C. Bose (D) G. Marconi

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9. The waves associated with a moving electron and a moving proton have the same wavelength λ . It implies that they have the same:

- (A) momentum (B) angular momentum
(C) speed (D) energy

10. Two beams, A and B whose photon energies are 3.3 eV and 11.3 eV respectively, illuminate a metallic surface (work function 2.3 eV) successively. The ratio of maximum speed of electrons emitted due to beam A to that due to beam B is:

- (A) $\frac{1}{3}$ (B) $\frac{1}{9}$
(C) 3 (D) 9

11. The transition of electron that gives rise to the formation of the second spectral line of the Balmer series in the spectrum of hydrogen atom corresponds to:

- (A) $n_f = 2$ and $n_i = 3$ (B) $n_f = 3$ and $n_i = 4$
(C) $n_f = 2$ and $n_i = 4$ (D) $n_f = 2$ and $n_i = \infty$

12. Ge is doped with As. Due to doping,

- (A) the structure of Ge lattice is distorted. (B) the number of conduction electrons increases.
(C) the number of holes increases. (D) the number of conduction electrons 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) Assertion (A) is false and Reason (R) is also false.

13. Assertion (A): Two long parallel wires, freely suspended and connected in series to a battery, move apart.

Reason (R): Two wires carrying current in opposite directions repel each other.

14. Assertion (A): Plane and convex mirrors cannot produce real images under any circumstance.

Reason (R): A virtual image cannot serve as an object to produce a real image.

15. Assertion (A): The mutual inductance between two coils is maximum when the coils are wound on each other.

Reason (R): The flux linkage between two coils is maximum when they are wound on each other.

16. Assertion (A): In photoelectric effect, the kinetic energy of the emitted photoelectrons increases with increase in the intensity of the incident light.

Reason (R): Photoelectric current depends on the wavelength of the incident light.

Section B

17. A uniform wire of length L and area of cross-section A has resistance R . The wire is uniformly stretched so that its length increases by 25%. Calculate the percentage increase in the resistance of the wire.

18. An object is placed 30 cm in front of a concave mirror of radius of curvature 40 cm. Find the (i) position of the image formed and (ii) magnification of the image.

19. Consider a neutron (mass m) of kinetic energy E and a photon of the same energy. Let λ_n and λ_p be the de Broglie wavelength of neutron and the wavelength of photon respectively. Obtain an expression for $\frac{\lambda_n}{\lambda_p}$.

20(a). Monochromatic light of frequency 5.0×10^{14} Hz passes from air into a medium of refractive index 1.5. Find the wavelength of the light (i) reflected, and (ii) refracted at the interface of the two media.

20(b). A plano-convex lens of focal length 16 cm is made of a material of refractive index 1.4. Calculate the radius of the curved surface of the lens.

21. Differentiate between 'diffusion current' and 'drift current'. Explain their role in the formation of p-n junction.

Section C

22. An air-filled parallel plate capacitor with plate separation 1 mm has a capacitance of 20 pF. It is charged to $4.0 \mu\text{C}$. Calculate the amount of work done to pull its plates to a separation of 5 mm. Assume the charge on the plates remains the same.

23(a). Define 'current density'. Is it a scalar or a vector? An electric field $\vec{E}$ is maintained in a metallic conductor. If n be the number of electrons (mass m , charge $-e$) per unit volume in the conductor and τ its relaxation time, show that the current density $\vec{j} = \sigma \vec{E}$, where $\sigma = \frac{ne^2\tau}{m}$.

23(b). What is a Wheatstone bridge? Obtain the necessary conditions under which the Wheatstone bridge is balanced.

24. A circular coil with cross-sectional area 0.2 cm^2 carries a current of 4 A. It is kept in a uniform magnetic field of magnitude 0.5 T normal to the plane of the coil. Calculate:

- (a) the net force on the coil.
- (b) the torque on the coil.
- (c) the average force on each electron in the coil due to the magnetic field. The free electron density in the material of the coil is 10^{28} m^{-3} .

25. (a) Draw the graphs showing the variation of the following with the frequency of ac source in a circuit:

- (i) Resistance
- (ii) Capacitive reactance
- (iii) Inductive reactance

(b) Can the voltage drop across the inductor or the capacitor in a series LCR circuit be greater than the applied voltage of the ac source? Justify your answer.

26. (a) State any two properties of a nucleus.

(b) Why is the density of a nucleus much more than that of an atom?

(c) Show that the density of the nuclear matter is the same for all nuclei.

27. State the three postulates of Bohr's theory of hydrogen atom.

A hydrogen atom de-excites from level n to level $(n - 1)$. Show that, according to Bohr's theory, the frequency of radiation emitted $\nu = \frac{C}{n^3}$ for large values of n , where C is a constant. This result exactly agrees with that obtained from classical physics — one of the successes of Bohr's theory.

28. (a) "The wavelength of the electromagnetic wave is often correlated with the characteristic size of the system that radiates." Give two examples to justify this statement.

(b) (i) Long distance radio broadcasts use short-wave bands. Why?

(ii) Optical and radio telescopes are built on the ground, but X-ray astronomy is possible only from satellites orbiting the Earth. Why?

Section D

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

29. A lens is a transparent medium bounded by two surfaces, with one or both surfaces being spherical. The focal length of a lens is determined by the radii of curvature of its two surfaces and the refractive index of its medium with respect to that of the surrounding medium. The power of a lens is reciprocal of its focal length. If a number of lenses are kept in contact, the power of the combination is the algebraic sum of the powers of the individual lenses.

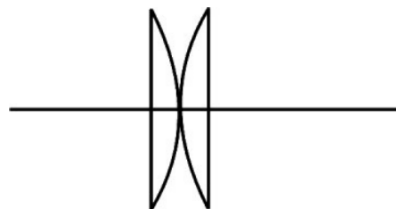
29(i). A double-convex lens, with each face having same radius of curvature R , is made of glass of refractive index n . Its power is:

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

29(ii). A double-convex lens of power P , with each face having same radius of curvature, is cut into two equal parts perpendicular to its principal axis. The power of one part of the lens will be:

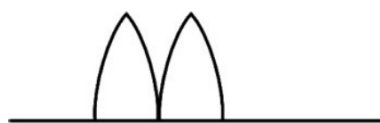
- | | |
|----------|-------------------|
| (A) $2P$ | (B) P |
| (C) $4P$ | (D) $\frac{P}{2}$ |

29(iii). The above two parts are kept in contact with each other as shown in the figure. The power of the combination will be:



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

29(iv)(a). A double-convex lens of power P , with each face having same radius of curvature, is cut along its principal axis. The two parts are arranged as shown in the figure. The power of the combination will be:



- | | |
|----------|-------------------|
| (A) Zero | (B) P |
| (C) $2P$ | (D) $\frac{P}{2}$ |

29(iv)(b). Two convex lenses of focal lengths 60 cm and 20 cm are held coaxially in contact with each other. The power of the combination is:

- | | |
|----------------------|----------------------|
| (A) 6.6 D | (B) 15 D |
| (C) $\frac{1}{15}$ D | (D) $\frac{1}{30}$ D |

30. Junction Diode as a Rectifier:

The process of conversion of an ac voltage into a dc voltage is called rectification and the device which performs this conversion is called a rectifier. The characteristics of a p-n junction diode reveal that when a p-n junction diode is forward biased, it offers a low resistance and when it is reverse biased, it offers a high resistance. Hence, a p-n junction diode conducts only when it is forward biased. This property of a p-n junction diode makes it suitable for its use as a rectifier.

Thus, when an ac voltage is applied across a p-n junction, it conducts only during those alternate half cycles for which it is forward biased. A rectifier which rectifies only half cycle of an ac voltage is called a half-wave rectifier and one that rectifies both the half cycles is known as a full-wave rectifier.

30(i). The root mean square value of an alternating voltage applied to a full-wave rectifier is $\frac{V_0}{\sqrt{2}}$. Then the root mean square value of the rectified output voltage is:

- | | |
|-----------------------------|-----------------------------|
| (A) $\frac{V_0}{\sqrt{2}}$ | (B) $\frac{V_0}{2}$ |
| (C) $\frac{2V_0}{\sqrt{2}}$ | (D) $\frac{V_0}{2\sqrt{2}}$ |

30(ii). In a full-wave rectifier, the current in each of the diodes flows for:

- | | |
|--|--|
| (A) Complete cycle of the input signal | (B) Half cycle of the input signal |
| (C) Less than half cycle of the input signal | (D) Only for the positive half cycle of the input signal |

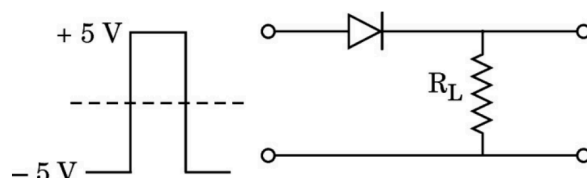
30(iii). In a full-wave rectifier:

- | | |
|---|--|
| (A) Both diodes are forward biased at the same time. | (B) Both diodes are reverse biased at the same time. |
| (C) One is forward biased and the other is reverse biased at the same time. | (D) Both are forward biased in the first half of the cycle and reverse biased in the second half of the cycle. |

30(iv)(a). An alternating voltage of frequency of 50 Hz is applied to a half-wave rectifier. Then the ripple frequency of the output will be:

- | | |
|------------|------------|
| (A) 100 Hz | (B) 50 Hz |
| (C) 25 Hz | (D) 150 Hz |

30(iv)(b). A signal, as shown in the figure, is applied to a p-n junction diode. Identify the output across resistance R_L :



- | | |
|-----|-----|
| (A) | (B) |
| (C) | (D) |

31(a)(i). A resistor and a capacitor are connected in series to an ac source $v = v_m \sin \omega t$. Derive an expression for the impedance of the circuit.

31(a)(ii). When does an inductor act as a conductor in a circuit? Give reason for it.

31(a)(iii). An electric lamp is designed to operate at 110 V dc and 11 A current. If the lamp is operated on 220 V, 50 Hz ac source with a coil in series, then find the inductance of the coil.

31(b)(i). Draw a labelled diagram of a step-up transformer and describe its working principle. Explain any three causes for energy losses in a real transformer.

31(b)(ii). A step-up transformer converts a low voltage into high voltage. Does it violate the principle of conservation of energy? Explain.

31(b)(iii). A step-up transformer has 200 and 3000 turns in its primary and secondary coils respectively. The input voltage given to the primary coil is 90 V. Calculate:

- (1) The output voltage across the secondary coil
- (2) The current in the primary coil if the current in the secondary coil is 2.0 A.

32(a)(i). Derive an expression for potential energy of an electric dipole $\vec{p}$ in an external uniform electric field $\vec{E}$. When is the potential energy of the dipole (1) maximum, and (2) minimum?

32(a)(ii). An electric dipole consists of point charges -1.0 pC and $+1.0 \text{ pC}$ located at $(0, 0)$ and $(3 \text{ mm}, 4 \text{ mm})$ respectively in $x - y$ plane. An electric field $\vec{E} = \left(\frac{2 \times 10^5 \text{ V}}{\text{m}} \right) \hat{i}$ is switched on in the region. Find the torque $\vec{\tau}$ acting on the dipole.

32(b)(i). An electric dipole (dipole moment $\vec{p} = p\hat{i}$), consisting of charges $-q$ and q , separated by distance $2a$, is placed along the x-axis, with its centre at the origin. Show that the potential V , due to this dipole, at a point x , ($x \gg a$) is equal to $\frac{1}{4\pi\epsilon_0} \cdot \frac{\vec{p} \cdot \hat{i}}{x^2}$.

33(b)(ii). Two isolated metallic spheres S_1 and S_2 of radii 1 cm and 3 cm respectively are charged such that both have the same charge density $\left(\frac{2}{\pi} \times 10^{-9}\right) \text{ C/m}^2$. They are placed far away from each other and connected by a thin wire. Calculate the new charge on sphere S_2 .

33(a)(i). A ray of light passes through a triangular prism. Show graphically, how the angle of deviation varies with the angle of incidence? Hence define the angle of minimum deviation.

33(a)(ii). A ray of light is incident normally on a refracting face of a prism of prism angle A and suffers a deviation of angle δ . Prove that the refractive index n of the material of the prism is given by $n = \frac{\sin(A + \delta)}{\sin A}$.

33(a)(iii). The refractive index of the material of a prism is $\sqrt{2}$. If the refracting angle of the prism is 60° , find the:

- (1) Angle of minimum deviation, and
 - (2) Angle of incidence.
-

33(b)(i). State Huygens' principle. A plane wave is incident at an angle i on a reflecting surface. Construct the corresponding reflected wavefront. Using this diagram, prove that the angle of reflection is equal to the angle of incidence.

33(b)(ii). What are the coherent sources of light? Can two independent sodium lamps act like coherent sources? Explain.

33(b)(iii). A beam of light consisting of a known wavelength 520 nm and an unknown wavelength λ , used in Young's double slit experiment produces two interference patterns such that the fourth bright fringe of unknown wavelength coincides with the fifth bright fringe of known wavelength. Find the value of λ .

- End of Question Paper -