

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 $1.0 \times 10^{-12} \text{ Cm}$ lies along x -axis. An electric field of magnitude $2.0 \times 10^4 \text{ N C}^{-1}$ is switched on at an instant in the region. The unit vector along the electric field is $\frac{4}{5}\hat{i} + \frac{3}{5}\hat{j}$. The magnitude of the torque acting on the dipole at that instant is :

- (A) $0.5 \times 10^{-8} \text{ Nm}$ (B) $1.0 \times 10^{-8} \text{ Nm}$
(C) $2.0 \times 10^{-8} \text{ Nm}$ (D) $4.0 \times 10^{-8} \text{ Nm}$

2. When the switch of the circuit is turned on, the filament of the bulb glows instantaneously because :

- (A) the electrons coming from the power source move fast through the initially empty filament. (B) the filament may be old having low resistance.
(C) electric field is established instantaneously across the filament which pushes the electrons. (D) free electrons in the filament travel with the speed of light.

3. A particle with charge q moving with velocity $\vec{v} = v_0\hat{i}$ enters a region with magnetic field $\vec{B} = B_1\hat{j} + B_2\hat{k}$. The magnitude of force experienced by the particle is :

- (A) $qv_0(B_1 + B_2)$ (B) $qv_0^2(B_1 + B_2)$
(C) $qv_0\sqrt{B_1^2 + B_2^2}$ (D) $qv_0^2\sqrt{B_1^2 + B_2^2}$

4. A bar magnet is initially at right angles to a uniform magnetic field. The magnet is rotated till the torque acting on it becomes one-half of its initial value. The angle through which the bar magnet is rotated is :

- (A) 30° (B) 45°
(C) 60° (D) 75°

5. The materials having negative magnetic susceptibility are :

- (A) diamagnetic (B) paramagnetic
(C) ferromagnetic (D) non-magnetic

6. When current in a coil changes at a steady rate from 8 A to 6 A in 4 ms, an emf of 1.5 V is induced in it. The value of self-inductance of the coil is :

- (A) 6 mH (B) 12 mH
(C) 3 mH (D) 9 mH

7. The electric field in space between the plates of a parallel plate capacitor (each of area $2.5 \times 10^{-3} \text{ m}^2$) is changing at the rate of $4 \times 10^6 \text{ V m}^{-1} \text{ s}^{-1}$. The displacement current between the plates of the capacitor is :

- (A) $1.8 \times 10^{-5} \text{ A}$ (B) $3.47 \times 10^{-8} \text{ A}$
(C) $8.85 \times 10^{-8} \text{ A}$ (D) $6.32 \times 10^{-4} \text{ A}$

8. A long straight wire is held vertically and carries a steady current in upward direction. The shape of magnetic field lines produced by the current-carrying wire are :

- (A) horizontal straight lines directed radially out from the wire. (B) straight lines parallel to the current-carrying wire.
(C) concentric horizontal circles around the wire. (D) coaxial helixes around the wire.

9. Which of the following is an electrical conductor at room temperature?

- (A) Sn (B) Mica
(C) Si (D) C

10. The magnification produced by a spherical mirror is -2.0 . The mirror used and the nature of the image formed will be :

- (A) Convex and virtual (B) Concave and real
(C) Concave and virtual (D) Convex and real

11. Choose the correct statement :

- (A) Photons of light show diffraction whereas electrons do not show diffraction. (B) Electrons have momentum whereas photons do not have momentum.
(C) Photons of light and electrons both exhibit dual nature. (D) All electromagnetic radiations do not have photons.

12. A beam of red light and a beam of blue light have equal intensities. Which of the following statements is true ?

- (A) The blue beam has more number of photons than the red beam. (B) The red beam has more number of photons than the blue beam.
(C) Wavelength of red light is lesser than wavelength of blue light. (D) The blue light beam has lesser energy per photon than that in the red light beam.

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): For monochromatic incident radiation, the emitted photoelectrons from a given metal have speed ranging from zero to a certain maximum value.

Reason (R): Each metal has a definite work function.

14. Assertion (A): In double slit experiment if one slit is closed, diffraction pattern due to the other slit will appear on the screen.

Reason (R): For interference, at least two waves are required.

15. Assertion (A): A series LCR circuit behaves as a pure resistive circuit at resonance.

Reason (R): At resonance, $X_L = X_C$ gives $\omega = \frac{1}{\sqrt{LC}}$.

16. Assertion (A): n-type semiconductor is not negatively charged.

Reason (R): Neutral pentavalent impurity atom doped in intrinsic semiconductor (neutral) donates its fifth unpaired electron to the crystal lattice and becomes a positive donor.

Section B

17. In an intrinsic semiconductor, carrier's concentration is $5 \times 10^8 \text{ m}^{-3}$. On doping with impurity atoms, the hole concentration becomes $8 \times 10^{12} \text{ m}^{-3}$.

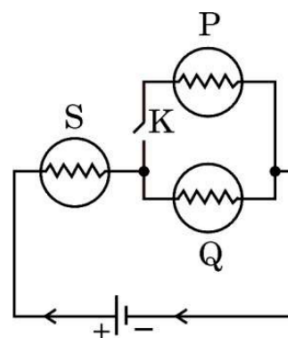
- (a) Identify (i) the type of dopant and (ii) the extrinsic semiconductor so formed.
 (b) Calculate the electron concentration in the extrinsic semiconductor.

18. In a double slit experiment, the two slits are 1.5 mm apart. The slits are illuminated by a mixture of lights of wavelengths of 600 nm and 400 nm and the interference pattern is observed on a screen 1.5 m away from the slits. Find the minimum distance of the point from the central maximum at which bright fringes of the interference patterns of the two wavelengths coincide.

19. Find the focal length of plano-convex lens of refractive index 1.5 and radius of curvature 10 cm when it is immersed in a liquid of refractive index 1.25.

20. Find the ratio of minimum to maximum wavelength of radiations emitted when electron jumps from higher energy state into ground state of hydrogen atom.

21. (a) In the given figure, three identical bulbs P , Q and S are connected to a battery.

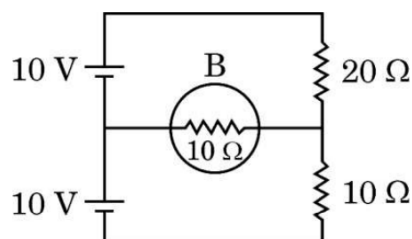


- (i) Compare the brightness of bulbs P and Q with that of bulb S when key K is closed.
 (ii) Compare the brightness of the bulbs S and Q when the key K is opened.

Justify your answer in both cases.

OR

(b) Two cells of emf 10 V each, two resistors of 20Ω and 10Ω and a bulb B of 10Ω resistance are connected together as shown in the figure. Find the current that flows through the bulb.



Section C

22. Explain the following observations using Einstein's photoelectric equation :

(a) Photoelectric emission does not occur from a surface when the frequency of the light incident on it is less than a certain minimum value.

(b) It is the frequency, and not the intensity of the incident light which affects the maximum kinetic energy of the photoelectrons.

(c) The cut-off voltage (V_0) versus frequency (ν) of the incident light curve is a straight line with a slope $\frac{h}{e}$.

23. (a) A charged particle q moving with a velocity $\vec{v}$ is subjected to a uniform magnetic field $\vec{B}$ acting perpendicular to $\vec{v}$. If a uniform electric field $\vec{E}$ is also set up in the region along the direction of $\vec{B}$, describe the path followed by the particle and draw its shape.

(b) How will the magnetic field inside a long solenoid be affected when :

(i) the radius of the turns of the solenoid is increased,

(ii) the length of solenoid as well as the total number of its turns are doubled ?

24. (a) Differentiate between magnetic flux through an area and magnetic field at a point.

(b) A bar magnet is held with its length along the axis of a closed coil. Initially the south pole of the magnet faces the coil. If the magnet is moved towards the coil, explain how a current is induced in the coil and in what direction.

25. (a) State any three characteristics of electromagnetic waves.

(b) Briefly explain how and where the displacement current exists during the charging of a capacitor.

26. (a) Define 'wavefront' of a light wave. A plane wavefront is refracted from a convex lens. Draw the shape of the refracted wavefront.

(b) A plane wave travelling in a medium is incident on a plane surface separating this medium from a rarer medium. Draw a diagram to show refraction of the wave. Hence, verify Snell's law.

27. (a) What are majority and minority charge carriers of p-type and n-type semiconductors ?

(b) Explain briefly the formation of diffusion current and drift current in a p-n junction diode.

28. Explain the following observations using Einstein's photoelectric equation :

(a) Photoelectric emission does not occur from a surface when the frequency of the light incident on it is less than a certain minimum value.

(b) It is the frequency, and not the intensity of the incident light which affects the maximum kinetic energy of the photoelectrons.

(c) The cut-off voltage (V_0) versus frequency (ν) of the incident light curve is a straight line with a slope $\frac{h}{e}$.

Section D

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

29(i). Case Study (Q30): A hydrogen atom consists of an electron revolving in a circular orbit of radius r with certain velocity v around a proton located at the nucleus of the atom. The electrostatic force of attraction between the revolving electron and the proton provides the requisite centripetal force to keep it in the orbit. According to Bohr's model, an electron can revolve only in certain stable orbits. The angular momentum of the electron in these orbits is some integral multiple of $\frac{h}{2\pi}$, where h is the Planck's constant. Further, when an electron makes a transition from one orbit of higher energy to that of lower energy, a photon is emitted having energy equal to the difference between energies of the initial and final states. Assuming the mass and charge of an electron as m and e respectively, answer the following questions.

The expression for the speed of electron v in terms of radius of the orbit (r) and physical constant $\left(K = \frac{1}{4\pi\epsilon_0}\right)$ is :

- (A) $\frac{Ke^2}{mr}$ (B) $\frac{Ke^2}{mr^2}$
(C) $\sqrt{\frac{Ke^2}{mr}}$ (D) $\sqrt{\frac{Ke^2}{mr^2}}$

29(ii). The total energy of the atom in terms of r and physical constant K is :

- (A) $\frac{Ke^2}{r}$ (B) $-\frac{Ke^2}{2r}$
(C) $\frac{Ke^2}{2r}$ (D) $-\frac{3Ke^2}{2r}$

29(iii). (iii) A photon of wavelength 500 nm is emitted when an electron makes a transition from one state to the other state in an atom. The change in the total energy of the electron and change in its kinetic energy in eV as per Bohr's model, respectively will be :

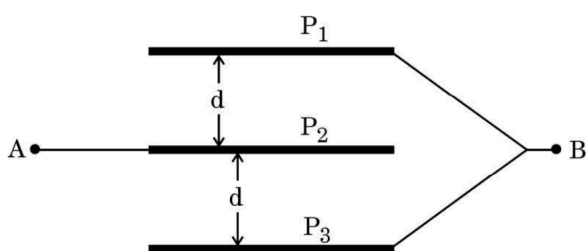
- (A) 2.48, -2.48 (B) -1.24, 1.24
(C) -2.48, 2.48 (D) 1.24, -1.24

OR

29(iv). (iv) OR: An electron makes a transition from -3.4 eV state to the ground state in hydrogen atom. Its radius of orbit changes by : (radius of orbit of electron in ground state = 0.53 Å)

- (A) 0.53 Å (B) 1.06 Å
(C) 1.59 Å (D) 2.12 Å

30(i). Case Study (Q29): A parallel plate capacitor consists of two conducting plates kept generally parallel to each other at a distance. When the capacitor is charged, the charge resides on the inner surfaces of the plates and an electric field is set up between them. Thus, electrostatic energy is stored in the capacitor. The figure shows three large square metallic plates, each of side ' L ' held parallel and equidistant from each other. The space between P_1 and P_2 and P_2 and P_3 is completely filled with mica sheets of dielectric constant ' K '. The plate P_2 is connected to point A and other plates P_1 and P_3 are connected to point B . Point A is maintained at a positive potential with respect to point B and the potential difference between A and B is V .



The capacitance of the system between A and B will be :

- | | |
|-----------------------------------|-----------------------------------|
| (A) $\frac{\epsilon_0 K L^2}{d}$ | (B) $\frac{\epsilon_0 K L^2}{2d}$ |
| (C) $\frac{2\epsilon_0 K L^2}{d}$ | (D) $\frac{2\epsilon_0 K d}{L^2}$ |

30(ii). The charge on plate P_2 is :

- | | |
|-------------------------------------|-------------------------------------|
| (A) $\frac{\epsilon_0 V K L^2}{2d}$ | (B) $\frac{\epsilon_0 V K L^2}{d}$ |
| (C) $\frac{2\epsilon_0 V K L^2}{d}$ | (D) $\frac{\epsilon_0 V K L^2}{4d}$ |

30(iii). (iii) The electric field in the region between P_1 and P_2 is :

- | | |
|--------------------|--------------------|
| (A) $\frac{V}{d}$ | (B) $\frac{2V}{d}$ |
| (C) $\frac{V}{2d}$ | (D) $\frac{d}{V}$ |

30(iv). (iv) The separation between the plates of same area (L^2) of a parallel plate air capacitor having capacitance equal to that of this system, will be :

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

OR

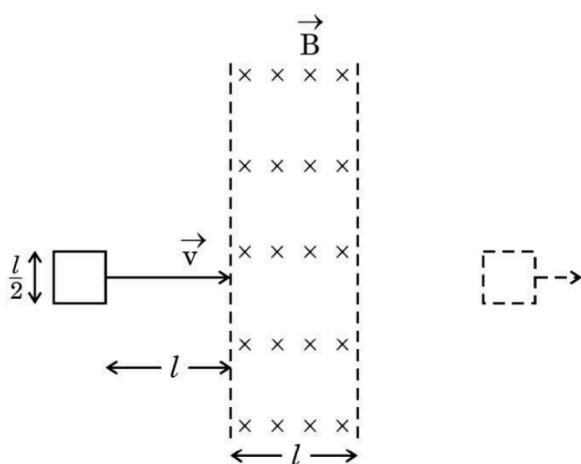
30(iv). (iv) OR: If the source of potential difference applied between A and B is removed, and then A and B are connected by a conducting wire, the net charge on the system will be :

- | | |
|-------------------------------------|-------------------------------------|
| (A) $\frac{\epsilon_0 V K L^2}{4d}$ | (B) $\frac{\epsilon_0 V K L^2}{2d}$ |
| (C) $\frac{\epsilon_0 V K L^2}{d}$ | (D) Zero |

31. (a)

(i) State Lenz's law and explain how this law is a consequence of conservation of energy principle.

(ii) A square shaped loop of side ℓ is initially lying outside a region of uniform magnetic field $\vec{B}$ as shown in the figure. The loop is moved towards right with a constant velocity v till it goes out of the region of magnetic field.



(I) What will be the directions of induced current when the loop enters the field and when it leaves the field ?

(II) Draw the plots showing the variation of magnetic flux ϕ linked with the loop with time t and variation of induced emf E with time t . Mark the relevant values of E , ϕ and t on the graphs.

OR

(b)

(i) Differentiate between peak and rms values of alternating current. How are they related ?

(ii) A current element X is connected across an ac source of emf $V = V_0 \sin 2\pi\nu t$. It is found that the voltage leads the current in phase by $\frac{\pi}{2}$ radian. If element X was replaced by element Y , the voltage lags behind the current in phase by $\frac{\pi}{2}$ radian.

(I) Identify elements X and Y by drawing phasor diagrams.

31. (continued)

(II) Obtain the condition of resonance when both elements X and Y are connected in series to the source and obtain expression for resonant frequency. What is the impedance value in this case ?

32. (a)

(i) An object is placed 30 cm from a thin convex lens of focal length 10 cm. The lens forms a sharp image on a screen. If a thin concave lens is placed in contact with the convex lens, the sharp image on the screen is formed when the screen is moved by 45 cm from its initial position. Calculate the focal length of the concave lens.

(ii) Calculate the angle of minimum deviation of an equilateral prism. The refractive index of the prism is $\sqrt{3}$. Calculate the angle of incidence for this case of minimum deviation also.

OR

(b)

(i) A physics teacher wants to demonstrate interference with the help of double slit experiment using a laser beam of 633 nm wavelength. Since the hall is large enough, interference pattern is formed on the wall 5.0 m from the slits. For clear and comfortable view by all the students they want the fringe width 5 mm.

(I) Find the slit separation for obtaining the desired interference pattern.

(II) How far will the first minimum be from the central maximum ?

(ii) A parallel beam of light of wavelength 650 nm passes through a slit of width 0.6 mm. The diffraction pattern is obtained on a screen kept 60 cm away from the slit. Find the distance between first order minima on both sides of the central maximum.

33. (a)

(i) Two point charges $+q$ and $-q$ are held at $(a, 0)$ and $(-a, 0)$ in $x-y$ plane. Obtain an expression for the net electric field due to the charges at a point $(0, y)$. Hence, find electric field at a far off point ($y \gg a$).

(ii) Three point charges of -2 nC , -1 nC , and $+5 \text{ nC}$ are kept at the vertices A , B and C of an equilateral triangle of side 0.2 m. Find the total amount of work done in shifting the charges from A to A_1 , B to B_1 and C to C_1 . Here A_1 , B_1 and C_1 are the midpoints of sides AB , BC and CA , respectively.

OR

(b)

(i) Show that Gauss's theorem is consistent with Coulomb's law. Using it, derive an expression for the electric field due to a uniformly charged thin spherical shell of radius r at a point at a distance y from the centre of the shell such that (I) $y > r$, and (II) $y < r$.

(ii) A point charge of $+2 \text{ nC}$ is kept at the origin of a three-dimensional coordinate system. Find the type and magnitude of the charge which should be kept at $(0, 0, -6 \text{ m})$ so that the potential due to the system becomes zero at $(0, 0, 2 \text{ m})$.

- End of Question Paper -