CBSE EXAMINATION PAPER-2024

PHYSICS

(Solved)

Time allowed : 3 hours | Maximum Marks : 36

General Instructions :

Read the following instructions carefully and follow them :

i. This question paper contains **19 questions.** All questions are **compulsory.**
ii. This question paper is divided into **4 sections.**
iii. **Section A** – questions number **1 to 10** are multiple choice questions Each question carries **1 marks.**
iv. **Section B** – questions number **11 to 13** are very short answer Each question carries **2 marks.**
v. **Section C** – questions number **14 to 18** are short answer Each question carries **3 marks.**
vi. **Section D** – questions number **19 to 19** are long answer Each question carries **5 marks.**
vii. There is no overall choice given in the question paper. However, an internal choice has been provided in few questions.
viii. Use of calculator is NOT allowed.

Section A

Question 1.

Consider a group of charges q_1, q_2, q_3,.. such that $\Sigma q \neq 0$. Then equipotentials at a large distance, due to this group are approximately :

[1 Marks]

(A) Spherical surface

(B) Paraboloidal surface

(C) Plane

(D) Ellipsoidal surface

Explanation: For a group of charges with a non-zero net charge ($\Sigma q \neq 0$), the behavior of the electric field at large distances can be approximated as that of a point charge. Thus, the equipotential surfaces tend to be spherical, similar to those of a single charge, as they are concentric spherical surfaces centered around the net charge of the group.

Question 2.

A circular loop of wire, carrying a current 'I' is lying in xy plane with its centre coinciding with the origin. It is subjected to a uniform magnetic field pointing along +z-axis. The loop will:

[1 Marks]

(A) remain stationary

(B) move along z-axis

(C) move along y-axis

(D) move along x-axis

Explanation: The loop will remain stationary because the magnetic field is uniform and perpendicular to the plane of the loop. According to the Lorentz force law, the force on each segment of the loop due to the magnetic field is balanced by the opposite forces on the other segments, resulting in a net force of zero.

Question 3.

The current in a coil of 15 mH increases uniformly from zero to 4 A in 0.004 s. The emf induced in the coil will be:

[1 Marks]

(A) 15.0 V

(B) 12.5 V

(C) 17.5 V

(D) 22.5 V

Explanation: To find the induced emf (ε), we can use the formula $\varepsilon = -L(dI/dt)$. Here, L = 15 mH = 0.015 H, and dI/dt = (final current - initial current) / time = (4 A - 0 A) / 0.004 s = 1000 A/s. Thus, ε = -0.015 H * 1000 A/s = -15 V. The negative sign indicates the direction of the induced emf, but the magnitude is 15 V, so the correct answer is 15.0 V.

Question 4.

Consider a solenoid of length l and area of cross-section A with fixed number of turns. The self-inductance of the solenoid will increase if:

[1 Marks]

(A) both l and A are decreased

(B) l is decreased and A is increased

(C) both l and A are increased

(D) l is increased and A is decreased

Explanation: The self-inductance L of a solenoid is given by the formula $L = \mu_r \mu_0 n^2 A l$. In this formula, increasing the area A (cross-section) will lead to an increase in L, while decreasing the length l also leads to an increase in L as inversely related to l. Thus, option 'l is decreased and A is increased' will result in an increase in self-inductance.

Question 5. Which one of the following has the highest frequency?

[1 Marks]

(A) Infrared rays

(B) Gamma rays

(C) Radio waves

(D) Microwaves

Explanation: Gamma rays have the highest frequency among the options provided. According to the context, gamma rays lie in the upper frequency range of the electromagnetic spectrum, while infrared rays, microwaves, and radio waves have lower frequencies. This categorization is based on the increasing wavelength from gamma rays to radio waves.

Question 6.

A proton and an alpha particle having equal velocities approach a target nucleus. They come momentarily to rest and then reverse their directions. The ratio of the distance of closest approach of the proton to that of the alpha particle will be:

[1 Marks]

(A) 4

(B) 1/2

(C) 1/4

(D) 2

Explanation: The distance of closest approach for charged particles is inversely proportional to the charge of the particle. A proton has a charge of +1e while an alpha particle has a charge of +2e. Hence, the distance of closest approach of the proton (d_p) relative to the alpha particle (d_a) can be given by d_p/d_a = (Z1*Z2)/ (Z'1*Z'2) = 1/(2) = 1/2. Therefore, the correct ratio is 1/2.

Question 7. An electron makes a transition from n = 2 level to n = 1 level in the Bohr model of a hydrogen atom. Its period of revolution:

[1 Marks]

(A) increases by 87.5%

(B) decreases by 87.5%

(C) increases by 43.75%

(D) decreases by 43.75%

Explanation: In Bohr's model, the period of revolution T is proportional to n^3. When the electron moves from n = 2 to n = 1, the period changes from T_2 to T_1 such that $T_2 / T_1 = (2 / 1)^3 = 8$. Thus, $T_1 = T_2 / 8$, which means the period decreases by (1 - 1/8) * 100% = 87.5%. Therefore, the period of revolution decreases by 87.5% during this transition.

Question 8.

Assertion (A): In a semiconductor, the electrons in the conduction band have lesser energy than those in the valence band.

Reason (R): Donor energy level is just above the valence band in a semiconductor.

[1 Marks]

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(B) Assertion (A) is false and Reason (R) is also false.

(C) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(D) Assertion (A) is true, but Reason (R) is false.

Explanation: Assertion (A) is false because electrons in the conduction band actually have higher energy than those in the valence band. Reason (R) is true; however, it does not explain Assertion (A) since the position of the donor energy level being above the valence band does not make the electrons in the conduction band have lesser energy.

Question 9.

Assertion (A): Photoelectric effect demonstrates the particle nature of light.

Reason (R): Photoelectric current is proportional to frequency of incident radiation.

[1 Marks]

(A) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(B) Assertion (A) is false and Reason (R) is also false.

(C) Assertion (A) is true, but Reason (R) is false.

(D) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

Explanation: Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A). The photoelectric effect indeed supports the particle nature of light, as photons are quantized packets of energy that can eject electrons from materials. However, the photoelectric current is proportional to the intensity of light, and while frequency does play a role in determining if photoemission occurs (i.e., it must exceed a threshold frequency), it does not directly describe the relationship of current to frequency in terms of particle nature.

Question 10.

Assertion (A): A convex lens, when immersed in a liquid, disappears.

Reason (R): The refractive indices of the material of the lens and the liquid are equal.

[1 Marks]

(A) Assertion (A) is false and Reason (R) is also false.

(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(C) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(D) Assertion (A) is true, but Reason (R) is false.

Explanation: Assertion (A) is true, but Reason (R) is false. While it is true that a convex lens can appear to disappear in a liquid if the refractive index of the lens matches that of the liquid, the reason provided is misleading. The lens does not literally disappear; it becomes less visible due to the matching refractive indices, causing light to refract similarly through both the lens and the liquid.

Section B

Question 11.

The magnifying power of an astronomical telescope is 24. In normal adjustment, distance between its two lenses is 150 cm. Find the focal length of the objective lens.

[2 Marks]

Answer: To find the focal length of the objective lens (f0) in an astronomical telescope, we use the magnification formula m = L/f0 + d/fe. Given that m = 24 and L = 150 cm. Assuming that fe is the focal length of the eyepiece. We rearrange to find f0. If we assume fe is small compared to L, we can simplify to f0 = L/m, resulting in 150 cm / 24 = 6.25 cm (approximately).

Question 12.

Explain the following :

a) For a simple microscope, the angular size of the object equals the angular size of the image. Yet it offers magnification.

b) Both plane and convex mirrors produce virtual images of objects. Can they produce real images under some circumstances ?

[2 Marks]

Answer: A simple microscope creates a virtual image at the near point, allowing the angular size of the image and object to be the same while providing magnification. This occurs due to the lens's focal properties. Convex mirrors typically yield virtual images but can produce real images when their configuration and positioning allow, such as using multiple mirrors to focus light to a point, contrary to their usual behavior.

Question 13.

Draw the circuit diagram of a Wheatstone bridge. Obtain the condition when no current flows through the galvanometer in it.

[2 Marks]

Answer: Circuit Diagram: A Wheatstone bridge is a diamond-shaped circuit with four resistors arranged on each side: R1, R2, R3, and R4. A galvanometer is connected between the two middle points B and D, and a voltage source is connected across points A and C.

Condition for No Current in Galvanometer: When the Wheatstone bridge is balanced, no current flows through the galvanometer. The condition is given by:
R1 / R2 = R3 / R4
This means the ratio of resistances in one pair of opposite arms is equal to the ratio in the other pair. Under this condition, the potential difference across the galvanometer is zero, so no current flows through it.

Section C

Question 14. Determine the current in branches AB, AC and BC of the network shown in figure.

[3 Marks]

Answer: To determine the currents in branches AB, AC, and BC, we apply Kirchhoff's loop and junction rules. In loop ADBA, the equation -I1 R1 + I2 R2 = 0 indicates that the voltage drops are balanced by the voltage sources. Using another loop, CBDC, where we rearrange to meet I3 = I1 and I4 = I2, we find that I2 R4 - I1 R3 = 0. At junction a, the current entering (I3) equals the sum of currents leaving (I1 + I2). By solving these equations simultaneously, we can find the specific values for I1, I2, and I3, which provide the required currents in each branch of the circuit.

Question 15. Two long straight parallel conductors carrying currents exert a force on each other. Why? Derive an expression for the force per unit length between two long straight parallel conductors carrying currents in opposite directions. Explain the nature of the force between these conductors.

[3 Marks]

Answer: Two long straight parallel conductors carrying currents exert a magnetic force on each other due to the magnetic field generated by the currents. According to the Biot-

Savart Law, the magnetic field (B) generated by a conductor at a distance (d) from it is proportional to the current (I) flowing through the conductor. If two conductors carry currents I1 and I2 in opposite directions, the force per unit length (f) between them can be derived using the formula: $f = (\mu_0/2\pi) * (I1 * I2/d)$. This shows that conductors with currents in opposite directions repel each other, unlike like currents which attract.

Question 16.

A sinusoidal voltage is applied to an electric circuit containing a circuit element 'X' in which the current leads the voltage by $\pi/2$

(a) Identify the circuit element 'X' in the circuit.

(b) Write the formula for its reactance.

(c) Show graphically the variation of this reactance with frequency of ac voltage.

(d) Explain the behaviour of this element when it is used in (i) an ac circuit, and (ii) a dc circuit.

[3 Marks]

Answer: The circuit element 'X' in which the current leads the voltage by $\pi/2$ is a capacitor. The formula for its reactance is given by $X_c = 1/(\omega C)$, where ω is the angular frequency and C is the capacitance. Graphically, the capacitive reactance (X_c) decreases with an increase in frequency, appearing as a downward slope on a graph with frequency on the x-axis and reactance on the y-axis. In an AC circuit, a capacitor allows alternating current to pass while blocking direct current, meaning it can store and release energy cyclically. In a DC circuit, after charging, a capacitor eventually blocks current flow entirely.

Question 17.

Draw the circuit diagrams for obtaining the V-I characteristics of a p-n junction diode. Explain briefly the salient features of the V-I characteristics in (i) forward biasing, and (ii) reverse biasing.

[3 Marks]

Answer: To obtain the V-I characteristics of a p-n junction diode, two circuit arrangements are used: one for forward biasing and another for reverse biasing. In the forward bias setup, the positive terminal of the power supply connects to the p-side of the diode, allowing current to flow which increases rapidly after a threshold voltage (typically around 0.7V for silicon diodes). In reverse bias, the n-side is connected to the positive terminal, and the current remains very small (reverse saturation current) until breakdown occurs at high reverse voltages. The forward V-I characteristic shows exponential growth, while the reverse characteristic remains mostly constant until the breakdown region.

Question 18.

On the basis of energy band diagrams, distinguish between (i) an insulator, (ii) a semiconductor, and (iii) a conductor.

[3 Marks]

Answer: Energy band diagrams illustrate the differences between insulators, semiconductors, and conductors based on their electronic structures. Insulators have a large energy band gap (Eg > 3 eV) between the valence band and conduction band, meaning no electrons can be thermally excited to conduct electricity, resulting in no electrical conductivity. Semiconductors possess a smaller band gap, allowing for some electrons to jump to the conduction band with thermal energy, leading to limited conduction. Conductors have overlapping bands with no gap, allowing electrons to move freely, facilitating maximum conductivity.

Section D

Question 19.

(i) A charge + Q is placed on a thin conducting spherical shell of radius R. Use Gauss's theorem to derive an expression for the electric field at a point lying (i) inside and (ii) outside the shell.

(ii) Show that the electric field for same charge density (**σ**) is twice in case of a conducting plate or surface than in a nonconducting sheet.

[5 Marks]

Answer: (i) Consider a thin conducting spherical shell of radius R with a total charge +Q uniformly distributed on its surface. We need to find the electric field at a point at a distance r from the centre.

(a) Electric field inside the shell (r < R):

By Gauss's theorem, take a spherical Gaussian surface inside the shell with radius r. Since the shell is conducting and charges reside on surface, no charge is enclosed inside this Gaussian surface. Charge enclosed, q = 0.

According to Gauss's law, $E * 4 \pi r^2 = q/\varepsilon_0 = 0$ which implies E = 0

Therefore, the electric field inside the shell is zero.

(b) Electric field outside the shell (r > R):

Take a spherical Gaussian surface of radius r outside the shell. The enclosed charge q = $+Q = \sigma * 4 \pi R^2$. Applying Gauss's law,

$E * 4 \pi r^2 = q/\varepsilon_0$

$\Rightarrow E = q/(4 \pi \varepsilon_0 r^2) = (\sigma * 4 \pi R^2)/(4 \pi \varepsilon_0 r^2) = (\sigma R^2)/(\varepsilon_0 r^2)$

This shows the electric field outside the shell behaves as though all charge is

concentrated at the centre.
(ii) For the same surface charge density σ:
Electric field due to a conducting plate (a charged infinite plane) is $E_{conducting} = \sigma/\varepsilon_0$
Electric field due to a nonconducting sheet (with uniform charge on both sides) is $E_{nonconducting} = \sigma/(2\,\varepsilon_0)$
This happens because in a conducting plate, all charges reside only on one surface and the field lines emerge from one side, while in a nonconducting sheet, charges are spread on both sides and field lines emerge from both sides, effectively halving the field on each side.
Thus, electric field with conducting plate is twice that of a nonconducting sheet for the same σ.