CBSE EXAMINATION PAPER-2024

PHYSICS

(Solved)

Time allowed : 3 hours | Maximum Marks : 40

General Instructions :

Read the following instructions carefully and follow them :

i. This question paper contains **21 questions.** All questions are **compulsory.**
ii. This question paper is divided into **4 sections.**
iii. **Section A** – questions number **1 to 12** are multiple choice questions Each question carries **1 marks.**
iv. **Section B** – questions number **13 to 15** are very short answer Each question carries **2 marks.**
v. **Section C** – questions number **16 to 19** are short answer Each question carries **3 marks.**
vi. **Section D** – questions number **20 to 21** 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.

Electrons drift with speed v_d in a conductor with potential difference V across its ends. If V is reduced to V/2, their drift speed will become:

[1 Marks]

(A) 2v_d

(B) v_d

(C) 4v_d

(D) v_d/2

Explanation: The drift velocity v_d is directly proportional to the potential difference V across the ends of the conductor. When V is reduced to V/2, the drift velocity will also be halved, resulting in v_d/2. Thus, the correct answer is option 'v_d/2'.

Question 2.

A wire of length 4·4 m is bent around in the shape of a circular loop and carries a current of 1.0 A. The magnetic moment of the loop will be:

[1 Marks]

(A) 3.5 Am^2

(B) 0.7 Am^2

(C) 1.54 Am^2

(D) 2.10 Am^2

Explanation: To calculate the magnetic moment (m) of a circular loop, we use the formula m = NIA, where N is the number of turns, I is the current, and A is the area of the loop. Here, N = 1 (since it is a single loop), and we need to find A. The circumference of the loop is equal to the length of the wire, 4.4 m, which gives us a radius (R) of approximately 0.7 m. The area (A) can be calculated using $A = \pi R^2$, yielding $A \approx 1.538\ m^2$. Thus, m = 1 x 1 A x 1.538 $m^2 \approx 1.54\ Am^2$. Therefore, the correct answer is 1.54 Am^2.

Question 3.

Which of the following quantity/quantities remains same in primary and secondary coils of an ideal transformer?

Current, Voltage, Power, Magnetic flux

[1 Marks]

(A) Current only

(B) Power only

(C) Magnetic flux and Power both

(D) Voltage only

Explanation: The correct answer is 'Magnetic flux'. In an ideal transformer, it is assumed that all the magnetic flux produced in the primary coil links with the secondary coil with negligible losses, meaning the magnetic flux remains the same in both coils. Current and voltage differ based on the turn ratio, and power is not the same due to these differences.

Question 4.

A resistor and an ideal inductor are connected in series to a 100√2 V, 50 Hz ac source. When a voltmeter is connected across the resistor or the inductor, it shows the same reading. The reading of the voltmeter is:

[1 Marks]

(A) 50√2 V

(B) 50 V

(C) 100√2 V

(D) 100 V

Explanation: The voltmeter will show the same reading across both the resistor and the inductor, which corresponds to the rms voltage of 100√2 V. Since the voltmeter reading is the same for both components in a series circuit, and the given input voltage is 100√2 V, it indicates that this is the value displayed by the voltmeter.

Question 5. Electromagnetic waves with wavelength 10 nm are called:

[1 Marks]

(A) Infrared waves

(B) Ultraviolet rays

(C) Gamma rays

(D) X-rays

Explanation: The correct answer is X-rays. According to the context, X-rays have wavelengths ranging from about 10–12 m to 10–10 m, which includes the 10 nm wavelength mentioned in the question.

Question 6. The work function for a photosensitive surface is 3·315 eV. The cut-off wavelength for photoemission of electrons from this surface is:

[1 Marks]

(A) 150 nm

(B) 200 nm

(C) 500 nm

(D) 375 nm

Explanation: To find the cut-off wavelength (λ), we can use the equation that relates work function (Φ) to wavelength: Φ = hc/λ, where h is Planck's constant (6.626 × 10^-34 J·s) and c is the speed of light (3 × 10^8 m/s). First, we need to convert the work function from eV to Joules: 3.315 eV * 1.602 × 10^-19 J/eV = 5.301 × 10^-19 J. Using the equation: λ = hc/Φ, we find λ = (6.626 × 10^-34 J·s * 3 × 10^8 m/s) / (5.301 × 10^-19 J) = 3.75 × 10^-7 m or 375 nm. Thus, the correct answer is 375 nm.

Question 7.

An alpha particle approaches a gold nucleus in the Geiger-Marsden experiment with kinetic energy K. It momentarily stops at a distance d from the nucleus and reverses its direction. Then d is proportional to:

[1 Marks]

(A) $1/K^{1/2}$

(B) K

(C) $K^{1/2}$

(D) 1/K

Explanation: The distance of closest approach (d) of the alpha particle from the nucleus is determined by the balance between its kinetic energy (K) and the electrostatic potential energy due to the Coulomb force between the positively charged alpha particle and the gold nucleus. According to Coulomb's law, this distance is inversely proportional to the kinetic energy of the alpha particle, specifically d is proportional to 1/sqrt(K). Therefore, the correct option is $1/K^{1/2}$.

Question 8. An n-type semiconducting Si is obtained by doping intrinsic Si with:

[1 Marks]

(A) B

(B) In

(C) P

(D) Al

Explanation: The correct answer is P. N-type semiconductors are formed by doping intrinsic silicon with pentavalent atoms (donors) like phosphorus (P), arsenic (As), or antimony (Sb), which contribute extra electrons to the conduction band.

Question 9. When a p-n junction diode is subjected to reverse biasing:

[1 Marks]

(A) the barrier height decreases and the depletion region widens.

(B) the barrier height increases and the depletion region widens.

(C) the barrier height decreases and the depletion region shrinks.

(D) the barrier height increases and the depletion region shrinks.

Explanation: The correct option is 'the barrier height increases and the depletion region widens.' When a p-n junction diode is reverse-biased, the applied voltage increases the barrier height and causes the depletion region to widen, as indicated in the context provided. This is due to the electric field changes within the diode, suppressing the flow of charge carriers.

Question 10.

Assertion (A): Photoelectric current increases with an increase in intensity of incident radiation, for a given frequency of incident radiation and the accelerating potential.

Reason (R): Increase in the intensity of incident radiation results in an increase in the number of photoelectrons emitted per second and hence an increase in the photocurrent.

[1 Marks]

(A) Both Assertion (A) and Reason (R) are false.

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

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

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

Explanation: Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A). According to the provided context, the photoelectric current is directly proportional to the intensity of incident radiation, as it results in an increase in the number of emitted photoelectrons, leading to a higher current.

Question 11.

Assertion (A): Lenz's law is a consequence of the law of conservation of energy.

Reason (R): There is no power loss in an ideal inductor.

[1 Marks]

(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) Both Assertion (A) and Reason (R) are false.

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

Explanation: Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A). Lenz's law does relate to the conservation of energy, as it states that the induced emf will oppose the change that created it, thereby conserving energy. However, the statement about no power loss in an ideal inductor does not explain why Lenz's law is a consequence of energy conservation.

Question 12.

Assertion (A): The magnifying power of a compound microscope is negative.

Reason (R): The final image formed is erect with respect to the object.

[1 Marks]

(A) Assertion (A) is true, but Reason (R) is 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 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 false. The magnifying power of a compound microscope is positive, as it produces an enlarged and inverted image compared to the object. Therefore, the assertion about the magnifying power being negative is incorrect, and the reason given does not accurately describe the situation since the final image is inverted, not erect.

Section B

Question 13. A convex lens (n = 1·52) has a focal length of 15·0 cm in air. Find its focal length when it is immersed in liquid of refractive index 1·65. What will be the nature of the lens?

[2 Marks]

Answer: To find the focal length of the lens in the liquid, we use the formula: f' = f * (n_l - 1) / (n - 1), where f is the focal length in air (15.0 cm), n_l is the refractive index of the liquid (1.65), and n is the refractive index of the lens (1.52). Plugging in the values: f' = 15 * (1.65 - 1) / (1.52 - 1) = 15 * 0.65 / 0.52 = 18.75 cm. The lens remains convex, as its focal length is positive.

Question 14. How does the energy gap of an intrinsic semiconductor effectively change when doped with a (a) trivalent impurity, and (b) pentavalent impurity? Justify your answer in each case.

[2 Marks]

Answer: Doping an intrinsic semiconductor with trivalent impurity, known as p-type doping, introduces energy states just above the valence band, effectively reducing the energy gap for holes. Conversely, doping with a pentavalent impurity, known as n-type doping, introduces energy states just below the conduction band, facilitating electron conduction and also lowering the effective energy gap. In both cases, doping alters carrier concentration, enhancing conductivity and modifying the energy band structure of the semiconductor.

Question 15.

What is the effect on the interference pattern in Young's double-slit experiment when (i) the source slit is moved closer to the plane of the slits, and (ii) the separation between the two slits is increased ? Justify your answers.

[2 Marks]

Answer: When the source slit is moved closer to the plane of the slits, the intensity of light increases, potentially enhancing the visibility of the interference pattern, but the fringe spacing remains unchanged. If the separation between the two slits is increased, the fringe spacing on the screen decreases, leading to closely spaced interference fringes. This indicates that the fringe separation is inversely related to the slit separation, confirming the principles of wave interference.

Section C

Question 16. The figure shows a circuit with three ideal batteries. Find the magnitude and direction of currents in the branches AG, BF and CD.

[3 Marks]

Answer: To analyze the circuit with three ideal batteries, we apply Kirchhoff's laws. In branch AG, let the current be I1, which flows out of the battery connected there. In branch BF, the current I2 flows towards junction B1, and I3 is the current flowing towards B1 from both batteries. According to the junction rule, I3 equals the sum of I1 and I2. By applying Kirchhoff's loop rules to the relevant loops, we establish the equations that determine the currents. Based on the provided voltages and resistances, we solve these equations to find the magnitudes and directions of the currents in AG, BF, and CD branches.

Question 17.

Two long, straight, parallel conductors carry steady currents in opposite directions. Explain the nature of the force of interaction between them. Obtain an expression for the magnitude of the force between the two conductors. Hence define one ampere.

[3 Marks]

Answer: When two long straight parallel conductors carry currents in opposite directions, the force of interaction between them is repulsive. This phenomenon arises from the magnetic fields generated by each conductor that affect the other. According to Ampere's law, the magnitude of the force per unit length between two parallel conductors is given by $F/L = (\mu_0/2\pi) * (I_1 * I_2) / d$, where I_1 and I_2 are the currents, d is the distance between the conductors, and μ_0 is the permeability of free space. One ampere is defined as the current that produces a force of 2×10^{-7} N/m between two parallel conductors one meter apart in a vacuum.

Question 18.

The de Broglie wavelength λ as a function of $1/\sqrt{K}$, for two particles of masses m_1 and m_2 are shown in the figure. Here, K is the energy of the moving particles.

(a) What does the slope of a line represent ?

(b) Which of the two particles is heavier ?

(c) Is this graph also valid for a photon ?

Justify your answer in each case.

[3 Marks]

Answer: The slope of the line in the de Broglie wavelength versus $1/\sqrt{K}$ graph represents the relationship between the wavelength and the kinetic energy of the particles. Specifically, the slope is inversely proportional to the square root of the mass of the particles, as $\lambda = h/p$ and p is related to $\sqrt{2mK}$. To identify the heavier particle, we can observe the slope—an angle closer to the horizontal line indicates lighter mass. The graph is not valid for photons, as photons have zero rest mass and their wavelength is determined by their frequency and not kinetic energy alone.

Question 19. With the help of a circuit diagram, explain the working of a p-n junction diode as a full wave rectifier. Draw its input and output waveforms.

[3 Marks]

Answer: A p-n junction diode acts as a full-wave rectifier when configured with two diodes in a circuit, allowing current to flow during both halves of an AC cycle. In the full-wave rectifier circuit, each diode is connected to either end of the transformer's secondary winding. During the positive half-cycle, diode D1 conducts, allowing current to pass, while during the negative half-cycle, diode D2 conducts. This results in a unidirectional output, as both halves of the input waveform are utilized. The input waveform shows AC voltage oscillating between positive and negative, while the output is a pulsating DC waveform, where both halves are rectified. Capacitor filtering can smooth these pulses into a more stable DC voltage. A schematic representation of the circuit and corresponding waveforms illustrates this process effectively.

Section D

Question 20.

(i) Give any two differences between the interference pattern obtained in Young's double-slit experiment and a diffraction pattern due to a single slit.

(ii) Draw an intensity distribution graph in case of a double-slit interference pattern.

(iii) In Young's double-slit experiment using monochromatic light of wavelength λ , the intensity of light at a point on the screen, where path difference is λ , is K units. Find the intensity of light at a point on the screen where the path difference is $\lambda/6$.

[5 Marks]

Answer: (i) Differences between interference pattern in Young's double-slit experiment and diffraction pattern due to a single slit are:
1. Interference pattern has bright and dark fringes of equal width and uniform spacing, whereas diffraction pattern has central bright maximum and side maxima with decreasing intensity and unequal widths.
2. Interference pattern results from superposition of waves from two coherent sources, but diffraction pattern arises when light waves spread after passing through a single narrow slit.

(ii) The intensity distribution graph for double-slit interference shows bright and dark fringes with maximum intensity at central bright fringe and intensity varying as: $I = I_{max} \cos^2(\pi d \sin\theta/\lambda)$, where d is slit separation.

[Graph would show maxima and minima gradually reducing in intensity if single slit envelope is considered, but here simple $\cos^2$ pattern for double-slit interference]

(iii) Given path difference $\delta = \lambda$, intensity $I = K$.
For path difference $\delta = \lambda/6$,
Phase difference, $\varphi = 2\pi * \delta / \lambda = 2\pi * (\lambda/6)/\lambda = 2\pi/6 = \pi/3$.
Using formula, intensity at δ is $I = 4 I_0 \cos^2(\varphi/2)$. At $\delta = \lambda$, $\cos^2(\pi/2) = 0$ so $I = 0$ means K = intensity of maximum fringe i.e $4 I_0$.
Therefore, $I_0 = K/4$.
Now, at $\delta=\lambda/6$,
$I = 4 I_0 \cos^2(\pi/6) = 4 * (K/4) * (\cos 30deg)^2 = K * (sqrt(3)/2)^2 = K * 3/4 = (3K)/4$.
Hence, intensity at path difference $\lambda/6 = (3K)/4$ units.

Question 21.

(i) Draw a labelled ray diagram of a compound microscope showing image formation at least distance of distinct vision. Derive an expression for its magnifying power.

(ii) A telescope consists of two lenses of focal length 100 cm and 5 cm. Find the magnifying power when the final image is formed at infinity.

[5 Marks]

Answer: (i) Compound Microscope Ray Diagram and Magnifying Power:
The compound microscope consists of two convex lenses: the objective and the eyepiece. The objective forms a real, inverted, and magnified image of the object between its focal length and twice its focal length. This image acts as an object for the eyepiece lens, which acts as a simple magnifier to produce a further magnified virtual image at the least distance of distinct vision, usually taken as 25 cm.

Ray Diagram: (Please imagine a diagram showing) the object placed just beyond the focal length of the objective lens. The rays from the object converge to form a real image on the image side of the objective. This image lies within the focal length of the eyepiece lens which then forms a magnified virtual image at 25 cm from the eye.

Derivation of Magnifying Power:
Let f_o and f_e be the focal lengths of the objective and eyepiece lenses respectively, and L be the distance between them (tube length). D is the least distance of distinct vision (25 cm).
1. Magnification by objective, m_o = image distance / object distance $\approx L / f_o$
2. Magnifying power due to eyepiece, $m_e = 1 + (D / f_e)$ when the final image is at the least distance of distinct vision.

Total magnifying power, $M = m_o * m_e = (L / f_o) * (1 + D / f_e)$

This formula expresses the angular magnification produced by the compound microscope.

(ii) Magnifying Power of Telescope:

Given focal length of objective, $f_o = 100$ cm; focal length of eyepiece, $f_e = 5$ cm.

For astronomical telescope with final image at infinity, magnifying power $M = f_o / f_e$.

Therefore, $M = 100 / 5 = 20$.

The magnifying power of the telescope is 20.