CBSE EXAMINATION PAPER-2024

PHYSICS

(Solved)

Time allowed : 3 hours Maximum Marks : 41

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 11** are multiple choice questions Each question carries **1 marks.**
iv. **Section B** – questions number **12 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.

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

[1 Marks]

(A) λ/2ε0R

(B) λ/4ε0R

(C) Zero

(D) λ/4πε0R

Explanation: The correct answer is 'Zero'. For a uniformly charged thin circular ring, the electric field at its center cancels out due to symmetry, as each small element of charge creates an electric field that points radially outward, but they all cancel at the center. Therefore, the net electric field at the center is zero.

Question 2.

A loop carrying a current I clockwise is placed in x-y plane, in a uniform magnetic field directed along z-axis. The tendency of the loop will be to:

[1 Marks]

(A) move along y-axis

(B) shrink

(C) expand

(D) move along x-axis

Explanation: According to the right-hand rule, the magnetic moment of the loop, which has a clockwise current, points downward along the negative z-axis. In a uniform magnetic field directed along the positive z-axis, the torque will cause the loop to experience a force that tends to align the magnetic moment with the magnetic field. This results in a tendency to expand (or experience torque) rather than move along the axes.

Question 3.

A galvanometer of resistance G ohm 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 :

[1 Marks]

(A) G/999Ω

(B) G/1000Ω

(C) G/100.1Ω

(D) G/1001Ω

Explanation: The correct option is G/1000Ω. When converting a galvanometer into an ammeter, a shunt resistance (rs) is connected in parallel to allow most of the current to bypass the galvanometer. Since the galvanometer measures only 0.1% of the total current (I A), the ratio of the galvanometer current to the ammeter current gives us the relationship needed to calculate the shunt resistance. The shunt resistance is thus calculated to be G divided by the factor of (1/0.001), which simplifies to G/1000.

Question 4.

The reactance of a capacitor of capacitance C connected to an ac source of frequency ω is 'X'. If the capacitance of the capacitor is doubled and the frequency of the source is tripled, the reactance will become :

[1 Marks]

(A) X/6

(B) 2/3X

(C) 6X

(D) 3/2X

Explanation: The reactance of a capacitor is given by the formula $X_c = 1/(\omega C)$. If the capacitance C is doubled (becoming 2C) and the frequency ω is tripled (becoming 3ω), the new reactance Xc' can be calculated as follows: $X_c' = 1/(3\omega * 2C) = 1/(6\omega C) = X/6$. Therefore, the correct answer is X/6.

Question 5.

Ge is doped with As. Due to doping,

[1 Marks]

(A) the structure of Ge lattice is distorted.

(B) the number of conduction electrons decreases.

(C) the number of conduction electrons increases.

(D) the number of holes increases.

Explanation: The number of conduction electrons increases. When Ge is doped with a pentavalent element like Arsenic (As), the fifth electron from the As atom is weakly bound and can easily contribute to electrical conduction, thus increasing the number of conduction electrons.

Question 6.

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 :

[1 Marks]

(A) 3

(B) 1/3

(C) 1/9

(D) 9

Explanation: The maximum kinetic energy of the emitted electrons can be calculated using the equation KE = E - φ, where E is the photon energy and φ is the work function. For beam A (3.3 eV), KE_A = 3.3 eV - 2.3 eV = 1 eV. For beam B (11.3 eV), KE_B = 11.3 eV - 2.3 eV = 9 eV. The maximum speed of electrons is proportional to the square root of their kinetic energy. Therefore, the ratio of the maximum speeds is sqrt(KE_A) / sqrt(KE_B) = sqrt(1 eV) / sqrt(9 eV) = 1/3. Hence, the correct answer is 1/3.

Question 7.

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

[1 Marks]

(A) momentum

(B) angular momentum

(C) speed

(D) energy

Explanation: The correct option is 'momentum'. According to the de Broglie relation λ = h/p, where λ is the wavelength and p is the momentum, if two particles have the same wavelength, they must have the same momentum. This is because wavelength is inversely proportional to momentum for matter waves.

Question 8.

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.

[1 Marks]

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

(B) Both Assertion (A) and Reason (R) are true and Reason (R) is 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.

(E) Assertion (A) is false and Reason (R) is true..

Explanation: Assertion (A) is true, but Reason (R) is false. The kinetic energy of emitted photoelectrons is determined by the frequency of the incident light, not its intensity. Intensity affects the number of emitted photoelectrons (photoelectric current), while the wavelength (or frequency) affects their kinetic energy.

Question 9.

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.

[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 and Reason (R) is the correct explanation of Assertion (A) because mutual inductance is indeed highest when the coils are wound on top of each other, leading to the maximum possible flux linkage. This relationship is fundamental in electromagnetic theory.

Question 10.

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.

[1 Marks]

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

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

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

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

Explanation: Assertion (A) is false and Reason (R) is also false. The correct principle is that two wires carrying current in the same direction attract each other, while those carrying current in opposite directions repel, as stated in the context provided. Therefore, both assertion and reason are incorrect.

Question 11.

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.

[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 true, but Reason (R) is false.

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

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

Explanation: Assertion (A) is true because plane and convex mirrors indeed cannot produce real images; they only create virtual images. Reason (R) is also true, as virtual images are formed where the rays do not converge and therefore cannot act as objects to create real images. However, Reason (R) does not serve as a correct explanation of

Assertion (A) since the reason focuses on the functionality of virtual images in general rather than explaining the specific characteristics of plane and convex mirrors.

Section B

Question 12.

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) reflected at the interface of the two media.

[2 Marks]

Answer: The wavelength of light in air ($\lambda 1$) can be calculated using the formula $\lambda = v/f$, where v is the speed of light in air (approximately 3×10^8 m/s) and f is the frequency. Thus, $\lambda 1 = (3 \times 10^8 \text{ m/s}) / (5.0 \times 10^{14} \text{ Hz}) = 6.0 \times 10^{-7}$ m. In the medium with refractive index 1.5, the wavelength ($\lambda 2$) can be found using $\lambda 2 = \lambda 1/n$. Therefore, $\lambda 2 = (6.0 \times 10^{-7} \text{ m}) / 1.5 = 4.0 \times 10^{-7}$ m.

Question 13.

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.

[2 Marks]

Answer: To solve the problem, first, we calculate the focal length (f) of the concave mirror, which is half the radius of curvature: f = -20 cm (negative for concave). Using the mirror formula $1/v + 1/u = 1/f$ with u = -30 cm, we find the image distance v = -12 cm, which indicates a real and inverted image. The magnification (m) can be calculated as $m = -v/u = 0.4$.

Question 14.

Plot a graph showing the variation of current with voltage for the material GaAs. On the graph, mark the region where :

a) resistance is negative, and

b) Ohm's law is obeyed.

[2 Marks]

Answer: The graph plotting current (I) against voltage (V) for GaAs typically shows a non-linear behavior. Initially, as voltage increases, current also increases, obeying Ohm's law within a certain range. However, beyond a specific voltage, the current increases disproportionately, indicating negative resistance. This region occurs at higher voltages. The Ohm's law obeying region is shown in the lower voltage area where the I-V relationship is linear.

Question 15.

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.

[2 Marks]

Answer: To find the radius of the curved surface of a plano-convex lens, we can use the lens maker's formula: f = R / (n - 1). Here, f = 16 cm and n = 1.4. Rearranging gives R = f(n - 1) = 16 * (1.4 - 1) = 16 * 0.4 = 6.4 cm. Therefore, the radius of the curved surface is 6.4 cm.

Section C

Question 16.

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 ?

[3 Marks]

Answer: (a) The wavelength of electromagnetic waves is related to the size of the system that emits them as smaller systems emit waves of shorter wavelength. For example, gamma rays with wavelength around 10^{-14} m to 10^{-15} m originate from atomic nuclei which are very small.
Another example is radio waves which have wavelengths more than 0.1 meters and are emitted by large systems like antennas.
(b)(i) Long distance radio broadcasts use short-wave bands because short waves can be reflected by the Earth's ionosphere allowing them to travel long distances around the globe.
(ii) Optical and radio waves can pass through the Earth's atmosphere and so telescopes can be built on the ground. But X-rays are absorbed by the atmosphere, so X-ray astronomy requires satellites orbiting the Earth to detect X-rays from space.

Question 17.

Write the drawbacks of Rutherford's atomic model. How did Bohr remove them? Show that different orbits in Bohr's atom are not equally spaced.

[3 Marks]

Answer: Rutherford's atomic model has significant drawbacks. Firstly, it suggests that electrons in orbit around the nucleus should emit radiation and spiral into the nucleus, leading to instability, which contradicts the existence of stable matter. Secondly, it fails to explain the discrete line spectra observed in atoms, as different elements emit specific wavelengths that cannot be accounted for. Bohr addressed these limitations by postulating quantized energy levels for electrons, allowing stable orbits without radiation emission. He introduced the idea that electrons occupy certain orbits with fixed radii and energies. Additionally, in Bohr's model, these orbits are not equally spaced; the energy difference between successive orbits decreases as one moves away from the nucleus, leading to the observed spectral lines.

Question 18.

(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.

[3 Marks]

Answer: The nucleus has several key properties. Firstly, it is incredibly small compared to the overall size of the atom, mostly concentrated in a central region. Secondly, it contains protons and neutrons, which are bound together by the strong nuclear force, demonstrating stability. The density of a nucleus is significantly higher than that of an atom due to the mass being compacted into a tiny volume, making it about 2.3×10^{17} kg/m^3. This high density is a result of the tightly packed nuclear particles and the empty space in atomic structures, which leads to a negligible average density for the atom as a whole. The density of nuclear matter is consistent across all nuclei because it is derived from the proportionality of volume to mass number (A); as the nucleus grows, its volume increases with the cube of the radius while its mass increases linearly with A. Hence, nuclear density remains approximately 2.3×10^{17} kg/m^3 across different elements, showing that different nuclei behave like drops of liquid of uniform density.

Question 19.

What is a Wheatstone bridge ? Obtain the necessary conditions under which the Wheatstone bridge is balanced.

[3 Marks]

Answer: A Wheatstone bridge is an electrical circuit used to measure unknown resistances by balancing two legs of a bridge circuit. It consists of four resistors arranged in a diamond shape, with a galvanometer connected between two points. For the bridge to be in a balanced state, the ratio of the resistances in one leg must equal the ratio in the other leg, which is expressed as R1/R2 = R3/R4. Under these conditions, the current through the galvanometer is zero, indicating a null deflection, allowing for the precise calculation of the unknown resistance R4 from the known values of R1, R2, and R3.

Section D

Question 20.

(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.

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

(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 :

- The output voltage across the secondary coil
- The current in the primary coil if the current in the secondary coil is 2·0 A.

[5 Marks]

Answer: A step-up transformer is an electrical device that increases voltage from the primary to the secondary coil while decreasing current. It consists of two coils, the primary and the secondary, wound around a magnetic core. Based on the turns ratio, the output voltage (Vs) can be calculated using the formula Vs/Vp = Ns/Np. For this transformer, the output voltage is (3000/200) * 90 V = 1350 V. Energy losses occur due to: 1. Flux Leakage: Inadequate magnetic coupling leads to some flux not linking both coils, causing energy loss. 2. Copper Losses: Resistance in wire contributes to heat loss due to currents mainly in the windings. 3. Eddy Currents: Induced currents in the core create losses, which can be reduced by using laminated cores. The conservation of energy principle holds; although voltage increases, the current decreases proportionately, ensuring the product of current and voltage remains constant.

Question 21.

(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.

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

(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.

[5 Marks]

Answer: Huygens' principle states that every point on a wavefront can be considered a source of secondary wavelets, which spread out in all directions with a speed equal to the speed of the wave. The new wavefront is the envelope of these wavelets. Regarding the angle of incidence and reflection, consider a plane wave incident at an angle i on a reflecting surface. When the wavefront strikes the surface, it can be represented as series of wavelets emanating from the incident points on the wavefront. The angle at which these wavelets reflect, known as the angle of reflection (r), will be equal to the angle of incidence (i). This can be visually supported by constructing the incident and reflected wavefronts on a diagram where the distance from the wavefront to the reflecting surface remains the same for both angles. Coherent sources of light are sources that emit light waves with a constant phase difference and the same frequency, maintaining a stable interference pattern. Two independent sodium lamps cannot be coherent sources because they operate independently, meaning their phase relationship does not remain fixed, leading to incoherent light. In a Young's double-slit experiment, the interference pattern formed by two wavelengths will show bright fringes. Given that the fourth bright fringe of the unknown wavelength λ coincides with the fifth bright fringe of 520 nm, we can set up the equation: (mλ = nλ known) where m = 4, n = 5, λ known = 520 nm. So, λ = (n/m) * λ known = (5/4) * 520 nm which equals 650 nm. Thus, the unknown wavelength λ equals 650 nm.