CBSE EXAMINATION PAPER-2022

PHYSICS

(Solved)

Time allowed : 3 hours

Maximum Marks : 38

General Instructions :

Read the following instructions carefully and follow them :

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

Section A

Question 1.

Draw energy band diagrams of n-type and p-type semiconductors at temperature T > OK, depicting the donor and acceptor energy levels. Mention the significance of these levels.

[2 Marks]

Answer: In n-type semiconductors, the energy band diagram shows the conduction band (CB) and valence band (VB) with donor energy levels positioned just below the CB. Donor atoms provide extra electrons that increase conductivity. In contrast, p-type semiconductors show acceptor levels just above the VB. These energy levels allow electrons to jump to empty states, creating holes that facilitate charge transport. Overall, donor and acceptor levels are crucial for the semiconductor's electrical properties.

Question 2.

(a) Draw the graph showing the variation of the number (N) of scattered alpha particles with scattering angle (θ) in Geiger — Marsden experiment. Infer two conclusions from the graph.

[2 Marks]

Answer: The graph depicting the number of scattered alpha particles (N) against the scattering angle (θ) typically shows a peak at small angles, then steadily declines. This indicates that most alpha particles pass through with little deflection, while only a small fraction is scattered at larger angles. From this graph, we can conclude that the atom has a dense nucleus, as evidenced by the strong deflection of a very small number of alpha particles at larger angles. Additionally, it shows that the nucleus is positively charged, repelling the positively charged alpha particles.

Question 3.

Write the characteristics of a p-n junction which make it suitable for rectification.

[2 Marks]

Answer: A p-n junction diode exhibits key characteristics making it ideal for rectification. Firstly, it allows current to flow only in one direction due to the depletion region created at the junction, hence blocking reverse current. Secondly, it has a forward voltage drop, ensuring that minimal energy is lost during conduction. Additionally, the p-n junction can quickly switch between conducting and non-conducting states, facilitating efficient conversion of alternating current (AC) to direct current (DC).

Question 4.

(b) Plot suitable graphs to show the variation of photoelectric current with the collector plate potential for the incident radiation of

(i) the same intensity but different frequencies v1, v2, and v3, (v1 < V2 < V3)

(ii) the same frequency but different intensities I1, I2, and I3, (I1 < I2 <I3)

[2 Marks]

Answer: In plotting the graph for varying frequencies, photoelectric current is observed to increase with collector plate potential for the higher frequencies, reflecting that more kinetic energy results in a larger current. For varying intensities, photoelectric current also rises with increased collector plate potential, with the saturation current increasing as intensity increases. The graphs illustrate a linear rise until saturation, followed by a plateau, confirming the effect of frequency and intensity on photocurrent.

Section B

Question 5.

Define the term — Distance of closest approach. How will it be affected, for an α - particle, if kinetic energy of the particle is doubled ?

[3 Marks]

Answer: The distance of closest approach refers to the minimum distance between two charged particles, such as an α - particle and a nucleus, during their interaction before they repel each other due to electrostatic forces. This distance is determined by the kinetic energy of the α - particle and the charge of the nucleus. If the kinetic energy of the α - particle is doubled, the distance of closest approach will decrease. This is because increased kinetic energy results in a greater momentum, allowing the particle to overcome the repulsive force at a closer range. Mathematically, it can be derived from the conservation of energy, where the electrostatic potential energy at the distance of closest approach equals the kinetic energy of the α - particle.

Question 6.

A point source in air is kept 24 cm in front of a concave spherical glass surface ($_a\mu_g$ = 1.5) and radius of curvature 60 cm. Find the nature of the image formed and its distance from the point source.

[3 Marks]

Answer: To find the nature of the image formed by a concave spherical glass lens, we start by using the lens formula: 1/f = 1/v - 1/u. The focal length (f) of the lens can be calculated using the formula f = R/($_a\mu_g$ - 1), where R is the radius of curvature (60 cm) and $_a\mu_g$ (the refractive index) is 1.5. Thus, f = 60/(1.5 - 1) = 120 cm. The object distance (u) is -24 cm (as per the sign convention). Using these in the lens formula, we calculate v. The image formed is real and inverted, and its distance from the point source is calculated accordingly.

Question 7.

Calculate the energy released in MeV in the following reaction :

[3 Marks]

Answer: To calculate the energy released in a nuclear reaction, we need to apply the mass-energy equivalence principle outlined by Einstein's equation $E=mc^2$, where 'E' is the energy, 'm' is the mass defect, and 'c' is the speed of light. First, determine the mass of reactants and products using atomic mass units (u). The mass defect, which is the mass lost during the reaction, can be calculated by subtracting the total mass of products from the total mass of reactants. Once we have the mass defect, we convert it into energy by multiplying by (931.5 MeV/u). This will yield the energy released in MeV. It is essential to ensure accurate measurements of atomic masses for precise calculations. Remember to use the correct conversion factors and units.

Question 8.

Explain with the help of a suitable diagram, the phenomenon on which an optical fibre works. Mention any two uses of optical fibres.

[3 Marks]

Answer: Optical fibres operate based on the principle of total internal reflection. This phenomenon occurs when light travels from a denser medium (like glass) to a less dense medium (like air) at an angle greater than the critical angle, causing the light to be reflected back into the denser medium. The structure of an optical fibre typically consists of a core (made of glass or plastic) surrounded by a cladding with a lower refractive index. When light enters the core at the right angle, it reflects multiple times along the length of the fibre, allowing for efficient transmission of signals. Optical fibres are widely used in telecommunications for high-speed data transmission and in medical instruments for endoscopy, providing clear images of internal organs.

Question 9.

a) A parallel beam of light of wavelength 600 nm is incident normally on a slit of width 0.2 mm. If the resulting diffraction pattern is observed on a screen 1 m away, find the distance of

(i) first minimum, and

(ii) second maximum, from the central maximum.

[3 Marks]

Answer: To find the distances of the first minimum and second maximum in the single-slit diffraction pattern, we use the formulas derived from diffraction theory. For a single slit, the position of the minima is given by the formula: $a \sin(\theta) = n\lambda$, where 'a' is the slit width, 'n' is the order of the minimum, and 'λ' is the wavelength. For the first minimum (n=1), $\sin(\theta) \approx \theta$, hence position $y1 = (\lambda L)/a = (600 \times 10^{-9}\ m)(1\ m)/(0.2 \times 10^{-3}\ m) = 3.0$ mm. For the second maximum, it is located approximately halfway between the first minimum and the second minimum. Using similar reasoning for maxima, y2 is found to be 4.5 mm from the central maximum. Therefore, the distances are 3.0 mm for the first minimum and 4.5 mm for the second maximum.

Question 10.

Photoelectrons are emitted from a metal surface when illuminated with UV light of wavelength 330 nm. The minimum amount of energy required to emit the electrons from the surface is 3.5×10^{-19} J. Calculate :

(i) the energy of the incident radiation, and

(ii) the kinetic energy of the photoelectron.

[3 Marks]

Answer: To find the energy of the incident radiation, we can use the formula $E = hc/\lambda$, where h is Planck's constant (6.626×10^{-34} J·s) and c is the speed of light (3×10^{8} m/s). The wavelength λ is 330 nm, which is 330×10^{-9} m. Substituting these values gives us $E = (6.626 \times 10^{-34})(3 \times 10^{8}) / (330 \times 10^{-9}) = 6.03 \times 10^{-19}$ J. The kinetic energy (KE) of the emitted photoelectron can be calculated using the formula $KE = E - \varphi$, where φ is the work function (3.5×10^{-19} J). Thus, $KE = 6.03 \times 10^{-19}$ J $- 3.5 \times 10^{-19}$ J $= 2.53 \times 10^{-19}$ J.

Question 11.

State the working principle of an LED. Write any two important advantages and two disadvantages of LED.

[3 Marks]

Answer: The working principle of a light-emitting diode (LED) is based on the phenomenon of electroluminescence. When a forward voltage is applied across the LED, electrons recombine with holes in the semiconductor material, releasing energy in the form of photons, which produces light. Two significant advantages of LEDs are their energy efficiency, as they consume less power compared to traditional incandescent bulbs, and their long lifespan, typically lasting tens of thousands of hours. However, there are some disadvantages, including their higher initial cost compared to incandescent lights and limited color offerings in some cases, which may restrict their use in certain applications.

Question 12.

(a) (i) Monochromatic light is incident on a surface separating two media. The frequency of the light after refraction remains unaffected but its wavelength changes. Why ?

(ii) The frequency of an electromagnetic radiation is 1.0×10^{11} Hz. Identify the radiation and mention its two uses.

[3 Marks]

Answer: (i) When monochromatic light passes from one medium to another, its speed changes due to the differing optical densities of the media. While the frequency (ν) of the light remains constant during refraction, the wavelength (λ) changes according to the equation $v = \lambda\nu$, where v is the speed of light in the medium. Therefore, as speed decreases in a denser medium, the wavelength also decreases to keep the frequency constant. (ii) The radiation with a frequency of 1.0×10^{11} Hz corresponds to microwave radiation. Two common uses of microwaves include radar technology for detecting objects and cooking food in microwave ovens, where they heat food by causing water molecules to vibrate, thus generating heat.

Question 13.

(b) A thin equiconvex lens of radius of curvature R made of material of refractive index μ_1 is kept coaxially, in contact with an equiconcave lens of the same radius of curvature and refractive index μ_2 ($>\mu_1$)

Find :

i) the ratio of their powers, and

i) the power of the combination and its nature.

[3 Marks]

Answer: To find the ratio of the powers of the equiconvex and equiconcave lenses, we use the lens maker's formula: $P = (n_2 - n_1) / (n_1 * R)$. Let P_1 be the power of the convex lens and P_2 be the power of the concave lens. Thus, $P_1 = (\mu_1 - 1) / R$ and $P_2 = (\mu_2 - 1) / (-R)$. The ratio $P_1:P_2$ is given by $(\mu_1 - 1):(-(\mu_2 - 1))$. For the power of the combination, we use $1/F = P_1 + P_2$, leading to the net power $P = P_1 + P_2$. The combination is a lens since its power will determine if it's converging (positive) or diverging (negative) based on the resultant power.

Question 14.

(b) (i) Trace the path of a ray of light PQ which is incident at an angle i on one face of a glass prism of angle A. It then emerges out from the other face at an angle e. Use the ray diagram to prove

that the angle through which the ray is deviated is given by $<\delta = <i + <e - <A$

(ii) What will be the minimum value of 6 if the ray passes symmetrically through the prism ?

[3 Marks]

Answer: To trace the path of the ray PQ through the prism, we start with the ray incident at angle i on face AB of the prism. When the ray enters the prism, it bends towards the normal, resulting in an angle of refraction r_1. The ray then travels to the second face AC, where it refracts again, emerging at angle e in air. The angle of deviation δ is defined as the difference between the angle of incidence i, the angle of emergence e, and the prism angle A, expressed by the equation $\delta = i + e - A$. For the minimum angle of deviation, the ray must pass symmetrically, leading to $\sin(i) = \sin(e)$. This occurs at the angle of deviation δ when i = e, and the minimum value of δ can be calculated using the formula δ = 2i - A, which simplifies to δ_min = 2(A/2) - A = 0, indicating that when the ray enters symmetrically, the deviation is minimized.