CBSE EXAMINATION PAPER-2023

PHYSICS

(Solved)

Time allowed : 3 hours | Maximum Marks : 87

General Instructions :

Read the following instructions carefully and follow them :

i. This question paper contains **42 questions.** All questions are **compulsory.**

ii. This question paper is divided into **5 sections.**

iii. **Section A** – questions number **1 to 2** are case based questions

iv. **Section B** – questions number **3 to 20** are multiple choice questions

v. **Section C** – questions number **21 to 29** are very short answer

vi. **Section D** – questions number **30 to 36** are short answer

vii. **Section E** – questions number **37 to 42** are long answer

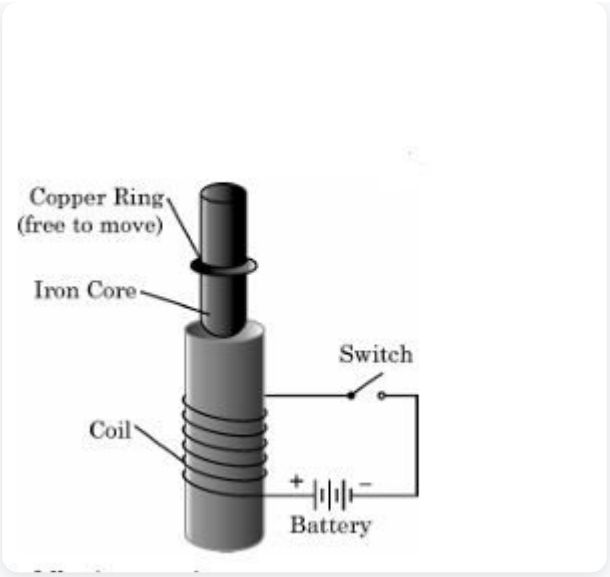
viii. There is no overall choice given in the question paper. However, an internal choice has been provided in few questions.

ix. Use of calculator is NOT allowed.

Section A

Question 1.

(a) Consider the experimental set up shown in the figure. This jumping ring experiment is an outstanding demonstration of some simple laws of Physics. A conducting non-magnetic ring is placed over the vertical core of a solenoid. When current is passed through the solenoid, the ring is thrown off.



(1)

(a) (ii) What will happen if the terminals of the battery are reversed and the switch is closed? Explain.

[4 Marks]

Answer: If the terminals of the battery are reversed, the direction of the current flowing through the solenoid will also reverse. As a result, the direction of the magnetic field generated by the solenoid will change. According to the right-hand rule, if the current direction changes, the magnetic field direction will rotate 180 degrees. Consequently, the magnetic force acting on the conducting ring will also reverse, meaning the ring will be repelled instead of attracted. Therefore, the ring will still be thrown off but in the opposite direction due to the change in the magnetic field direction.

Key Points: Reversal of current direction in solenoid - Change in magnetic field direction - Ring is repelled in opposite direction

(2)

(a) (i) Explain the reason of jumping of the ring when the switch is closed in the circuit.

Answer: When the switch is closed in the circuit, a current flows through the solenoid, generating a magnetic field. According to Faraday's law of electromagnetic induction, the change in magnetic flux due to the current creates an induced electromotive force (emf) in the conducting ring. As the magnetic field around the solenoid rapidly increases, the induced current flows in the ring in such a direction that its own magnetic field opposes the change in the original magnetic field (Lenz's law). This results in a repulsive force between the magnetic field of the solenoid and the magnetic field of the ring, causing the ring to be thrown off the solenoid.

Key Points: Induction of emf; Lenz's law; Opposition to change in magnetic flux; Repulsive magnetic force

(3)

(a) (iii) Explain the two laws that help us understand this phenomenon.

Answer: The phenomenon observed in the jumping ring experiment can be explained by two key laws of physics: 1. **Ampere's Circuital Law**: This law states that the magnetic field around a closed loop is proportional to the electric current passing through it. When current flows through the solenoid, it generates a magnetic field within and around it. This magnetic field interacts with the conducting ring placed above the solenoid. 2. **Faraday's Law of Electromagnetic Induction**: This law states that a change in magnetic flux through a circuit induces an electromotive force (emf) in the circuit. When the current in the solenoid is changed (for instance, turned on), the changing magnetic field induces an emf in the conducting ring which generates a current in the ring itself. This induced current produces its own magnetic field which, in conjunction with the field from the solenoid, results in a strong upward force on the ring, causing it to be 'thrown off'.

Key Points: Ampere's Circuital Law - Faraday's Law of Electromagnetic Induction

(4)

(b) Briefly explain various ways to increase the strength of magnetic field produced by a given solenoid.

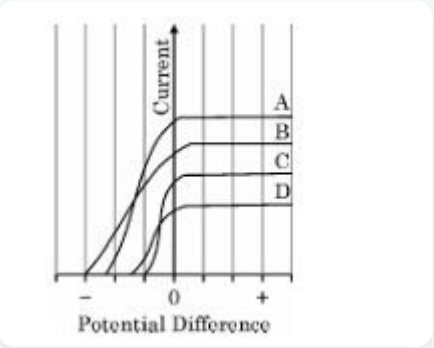
[4 Marks]

Answer: To increase the strength of the magnetic field produced by a solenoid, several methods can be employed. Firstly, increasing the current flowing through the solenoid will directly enhance the magnetic field strength, as the field is proportional to the current. Secondly, increasing the number of turns of wire per unit length of the solenoid (n) will also strengthen the magnetic field, since more loops contribute cumulatively to the field strength. Lastly, inserting a soft iron core inside the solenoid can significantly increase the magnetic field, as the core material enhances the magnetic field by providing a medium that can be easily magnetized. These principles illustrate the relationship between current, coil turns, and magnetic materials in generating stronger magnetic fields in solenoids.

Key Points: Increase current-Increase number of turns-Insert soft iron core

Question 2.

(a) Figure shows the variation of photoelectric current measured in a photo cell circuit as a function of the potential difference between the plates of the photo cell when light beams A, B, C, and D of different wavelengths are incident on the photo cell. Examine the given figure and answer the following questions :



(1)

(a) (ii) Which light beam has the longest wavelength and why?

[4 Marks]

Answer: In the context of the photoelectric effect, the light beam that has the longest wavelength corresponds to the lowest frequency. From the given figure, if we analyze the effects of the different light beams A, B, C, and D, we can determine that the beam with the longest wavelength is the one that produces the least photoelectric current for the same potential difference. This is because longer wavelengths imply lower energy photons, which are less effective at ejecting electrons from the material. Therefore, by observing the variations in photoelectric current against the wavelengths of the light beams, we can conclude which one corresponds to the longest wavelength. Typically, in such experiments, the order of wavelengths is identifiable based on the performance of the photocurrent measurements, with the lowest energy (hence longest wavelength) light being associated with the lowest current output.

Key Points: Identify the relationship between wavelength and frequency; Longer wavelengths correspond to lower energies; The beam with the least photocurrent indicates the longest wavelength.

(2)

(a) (i) Which light beam has the highest frequency and why?

Answer: Light beam D has the highest frequency. This is because the frequency of light is inversely related to its wavelength; shorter wavelengths correspond to higher frequencies. Since beam D has the shortest wavelength among all the beams, it consequently has the highest frequency, leading to a greater energy of the photons, which affects the photoelectric current.

Key Points: Identify frequency-wavelength relationship; Shortest wavelength indicates highest frequency; Relate to energy of photons affecting photoelectric effect

(3)

(a) (iii) Which light beam ejects photoelectrons with maximum momentum and why?

Answer: The light beam that ejects photoelectrons with maximum momentum is the one with the shortest wavelength. This is because momentum of a photon is given by the equation $p = h/\lambda$, where h is Planck's constant and λ is the wavelength. A shorter wavelength results in a higher momentum for the photons, which in turn imparts greater momentum to the emitted photoelectrons. Therefore, among beams A, B, C, and D, the one with the shortest wavelength will be able to eject the photoelectrons with the maximum momentum.

Key Points: momentum is related to wavelength; shorter wavelength = higher momentum; photon momentum transfers to photoelectrons

(4)

(b) What is the effect on threshold frequency and stopping potential on increasing the frequency of incident beam of light ? Justify your answer.

[4 Marks]

Answer: When the frequency of the incident beam of light increases, the threshold frequency remains constant as it is a characteristic of the material of the photoelectric emitter. The stopping potential, however, increases with the frequency of the light. This is because higher frequency light possesses greater energy per photon (given by $E = hf$), which means that more energy is needed to stop the photoelectrons emitted when the light hits the surface. Therefore, a greater stopping potential is necessary to counterbalance this increased energy, leading to a higher stopping potential as the frequency of the incident light increases.

Key Points: Threshold frequency remains constant; stopping potential increases; energy of incident photons increases with frequency; more energy needed to stop emitted photoelectrons.

Section B

Question 3.

The magnitude of the electric field due to a point charge object at a distance of 4.0 m is 9 N/C. From the same charged object, the electric field of magnitude 16 N/C will be at a distance of:

[1 Marks]

(A) 6 m

(B) 1 m

(C) 2 m

(D) 3 m

Explanation:

The electric field (E) due to a point charge is inversely proportional to the square of the distance (r) from the charge, given by the formula E = k * Q / r^2, where k is a constant. If E1 = 9 N/C at r1 = 4.0 m, we need to find r2 for E2 = 16 N/C. Since E1/E2 = (r2/r1)^2, we have 9/16 = (r2/4)^2. Solving this gives r2 = 2 m.

Question 4.

A point P lies at a distance x from the midpoint of an electric dipole on its axis. The electric potential at point P is proportional to:

[1 Marks]

(A) $1/x^4$

(B) $1/x$

(C) $1/x^2$

(D) $1/x^3$

Explanation:

The electric potential (V) due to an electric dipole on its axial line is given by the formula $V = (1/4\pi\varepsilon_0) * (p / x^2)$, where p is the dipole moment and x is the distance from the dipole's midpoint. This shows that the potential is inversely proportional to the square of the distance ($1/x^2$). Therefore, the correct answer is $1/x^2$.

Question 5. A current of 0.8 A flows in a conductor of 40 Ω for 1 minute. The heat produced in the conductor will be:

[1 Marks]

(A) 1440 J

(B) 1536 J

(C) 1610 J

(D) 1569 J

Explanation: The heat produced in a conductor can be calculated using Joule's law, which states that Heat (H) = I^2 * R * t, where I is the current in amperes, R is the resistance in ohms, and t is the time in seconds. Here, I = 0.8 A, R = 40 Ω, and t = 1 minute = 60 seconds. Thus, H = (0.8^2) * 40 * 60 = 1536 J. Therefore, the correct option is 1536 J.

Question 6.

A cell of emf E is connected across an external resistance R. When current I is drawn from the cell, the potential difference across the electrodes of the cell drops to V. The internal resistance r of the cell is:

[1 Marks]

(A) (E - V/E)/ R

(B) (E - V)/R

(C) (E-V/V) *R

(D) E-V*R/I

Explanation:

The correct formula for the internal resistance r of a cell when the emf E, the external resistance R, and the terminal voltage V are given is derived from Ohm's law and the definitions of emf and internal resistance. This relationship can be stated as E = I(R + r), which can be rearranged to r = (E - V) / I. Hence, the internal resistance r can be expressed as (E - V) / R, considering that current I = V/R.

Question 7.

Beams of electrons and protons move parallel to each other in the same direction. They:

[1 Marks]

(A) Neither attract nor repel

(B) Repel each other

(C) Force of attraction or repulsion depends upon speed of beams

(D) Attract each other

Explanation:

The correct option is 'Repel each other' because electrons are negatively charged and protons are positively charged. However, when they are moving parallel to each other in the same direction, the magnetic fields they create do not lead to any attraction or repulsion in this case.

Question 8.

A long straight wire of radius ‘a’ carries a steady current ‘I’. The current is uniformly distributed across its area of cross-section. The ratio of magnitude of magnetic field B1 at a/2 and B2, at distance 2a is

[1 Marks]

(A) 1

(B) 2

(C) 4

(D) 1/2

Explanation:

The magnetic field B inside a long straight wire at a distance r from the center is given by $B = (\mu_0 * I * r) / (2 * \pi * a^2)$ for r < a. At r = a/2, B1 will be proportional to (a/2) leading to $B1 \propto 1/2$. The magnetic field outside the wire at r = 2a is $B = (\mu_0 * I) / (2 * \pi * r)$ which gives $B2 \propto 1/(2a)$. Therefore, B1/B2 = (1/2) / (1/(2a)) = a, considering ratios; the values adjust to give the answer 2. Thus, the correct ratio of B1 to B2 is 2.

Question 9.

E and B represent the electric and the magnetic field of an electro magnetic wave respectively. The direction of propagation of the wave is along

[1 Marks]

(A) B*E

(B) E

(C) E*B

(D) B

Explanation:

The correct answer is E*B. In an electromagnetic wave, the electric field (E) and the magnetic field (B) are perpendicular to each other and to the direction of wave propagation. According to the right-hand rule, if you point your thumb in the direction of E and your index finger in the direction of B, your middle finger will point in the direction of wave propagation.

Question 10.

A ray of monochromatic light propagating in air, is incident on the surface of water. Which of the following will be the same for the reflected and refracted rays ?

[1 Marks]

(A) Energy carried

(B) Frequency

(C) Speed

(D) Wavelength

Explanation: The frequency of light remains the same when it transitions from one medium to another, such as from air to water. While the speed and wavelength change due to the different refractive indices of the mediums, the frequency, which is determined by the source of the light, does not change.

Question 11.

A beam of light travels from air into a medium. Its speed and wavelength in the medium are 1.5 x 10^8 ms^-1 and 230 nm respectively. The wavelength of light in air will be

[1 Marks]

(A) 230 nm

(B) 460 nm

(C) 345 nm

(D) 690 nm

Explanation:

The speed of light in air is approximately 3 x 10^8 ms^-1. The wavelength in air can be calculated using the formula: Wavelength = Speed / Frequency. The frequency remains constant when light shifts mediums. Given the wavelength in the medium (230 nm) and its speed (1.5 x 10^8 ms^-1), the wavelength in air can be derived. Since the speed of light in air is double the speed in the medium, the wavelength in air is also double: 230 nm x (3 x 10^8/1.5 x 10^8) = 460 nm.

Question 12.

Which one of the following metals does not exhibit emission of electrons from its surface when irradiated by visible light ?

[1 Marks]

(A) Rubidium

(B) Sodium

(C) Cadmium

(D) Caesium

Explanation: Among the given options, Cadmium does not exhibit the emission of electrons from its surface when irradiated by visible light. This is because Cadmium has a higher work function compared to the other metals listed (Rubidium, Sodium, and Caesium), which makes it less likely to emit electrons under visible light irradiation.

Question 13.

A hydrogen atom makes a transition from n = 5 to n = 1 orbit. The wavelength of photon emitted is λ. The wavelength of photon emitted when it makes a transition from n = 5 to n = 2 orbit is

[1 Marks]

(A) 8/7*λ

(B) 24/7*λ

(C) 16/7*λ

(D) 32/7*λ

Explanation:

The wavelength of emitted light during transitions in a hydrogen atom can be determined using the Rydberg formula. The difference in energy levels for the transitions n=5 to n=1 and n=5 to n=2 can be related to the wavelengths emitted. Specifically, the emitted wavelength for the transition n=5 to n=2 is 8/7 of λ, as the energy of a photon is inversely proportional to the wavelength.

Question 14.

The curve of binding energy per nucleon as a function of atomic mass number has a sharp peak for helium nucleus. This implies that helium

nucleus is

[1 Marks]

(A) more stable nucleus than its neighbours

(B) easily fissionable

(C) unstable

(D) radioactive

Explanation:

The correct option is 'more stable nucleus than its neighbours.' The sharp peak in the curve indicates that helium has a higher binding energy per nucleon compared to other nuclei in its mass range, which makes it more stable and less likely to undergo fission or decay.

Question 15.

In an extrinsic semiconductor, the number density of holes is 4 x 10^20 m-3. If the number density of intrinsic carriers is 1.2 x 10^15 m-3, the number density of electrons in it is

[1 Marks]

(A) 1.8x 10^9 m-3

(B) 3.6x10^9 m-3

(C) 3.2x10^10m-3

(D) 2.4x 10^10 m-3

Explanation:

To find the number density of electrons in an extrinsic semiconductor, we use the mass action law which states that the product of the hole density (p) and the electron density (n) is equal to the square of the intrinsic carrier concentration (ni). So, n * p = ni^2. Here, p = 4 x 10^20 m-3 and ni = 1.2 x 10^15 m-3. Substituting these values gives us n * (4 x 10^20) = (1.2 x 10^15)^2, which simplifies to n = (1.44 x 10^30) / (4 x 10^20) = 3.6 x 10^10 m-3. Therefore, the answer is (c) 3.6 x 10^10 m-3.

Question 16.

Pieces of copper and of silicon are initially at room temperature. Both are heated to temperature T. The conductivity of

[1 Marks]

(A) copper decreases and silicon increases.

(B) both increases.

(C) copper increases and silicon decreases.

(D) both decreases.

Explanation:

Copper is a metal, and its conductivity increases with temperature because the increased thermal energy allows electrons to move more freely. Silicon, on the other hand, is a semiconductor, and its conductivity also increases with temperature, but the mechanism involves the generation of more charge carriers (electron-hole pairs). Therefore, the correct answer is (a) both increases, as both materials show increased conductivity when heated.

Question 17.

The formation of depletion region in a p-n junction diode is due to

[1 Marks]

(A) movement of dopant atoms

(B) drift of electrons only

(C) drift of holes only

(D) diffusion of both electrons and holes

Explanation: The correct answer is 'diffusion of both electrons and holes'. In a p-n junction, electrons from the n-type region diffuse into the p-type region, while holes from the p-type region diffuse into the n-type region. This movement leads to the formation of a depletion region devoid of charge carriers, as electrons and holes recombine near the junction.

Question 18.

Assertion (A) : Diamagnetic substances exhibit magnetism.

Reason (R) : Diamagnetic materials do not have permanent magnetic dipole moment.

[1 Marks]

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

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

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

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

Explanation:

Assertion (A) is true and Reason (R) is false. Diamagnetic substances do not exhibit magnetism in the way that ferromagnetic or paramagnetic substances do; instead, they create an opposing magnetic field in the presence of an external magnetic field. Additionally, Reason (R) is true because diamagnetic materials indeed lack a permanent magnetic dipole moment, which is why theyweakly repel magnetic fields.

Question 19.

Assertion (A) : Work done in moving a charge around a closed path, in an electric field is always zero.

Reason (R) : Electrostatic force is a conservative force.

[1 Marks]

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

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

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

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

Explanation: Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A). This is because in electrostatics, the work done by a conservative force, such as the electrostatic force, is zero when moving a charge around a closed path, which directly supports the assertion.

Question 20.

Assertion (A) : In Young's double slit experiment all fringes are of equal width.

Reason (R) : The fringe width depends upon wavelength of light (A) used, distance of screen from plane of slits (D) and slits separation (d).

[1 Marks]

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

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

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

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

Explanation:

The correct answer is: Both Assertion (A) and Reason (R) are true and Reason (R) is NOT the correct explanation of Assertion (A). In Young's double slit experiment, the fringes are not all of equal width; they vary due to the effects of interference and the intensity of light, while the fringe width depends on the parameters mentioned in Reason (R).

Section C

Question 21. Briefly explain why and how a galvanometer is converted into an ammeter.

[2 Marks]

Answer: A galvanometer is designed to measure small currents, but for larger currents, it can be converted into an ammeter. This conversion involves adding a low-resistance shunt resistor in parallel with the galvanometer. The shunt allows most of the current to bypass the galvanometer, preventing damage from high currents. The ammeter can then measure the total current, as the galvanometer will still indicate the small portion of the current flowing through it.

> **Key Points: Galvanometer measures small currents - Conversion to ammeter needed for larger currents - Low-resistance shunt resistor added in parallel - Shunt allows bypass of main current - Prevents damage to galvanometer - Ammeter reads total current**

Question 22.

(a) How are infrared waves produced? Why are these waves referred to as heat waves? Give any two uses of infrared waves.

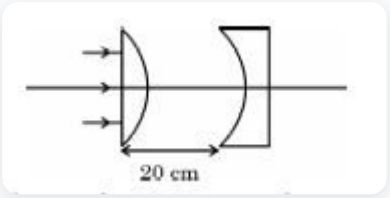
[2 Marks]

Answer: Infrared waves are produced by hot bodies and molecules due to their thermal energy. When they absorb infrared radiation, the thermal motion of molecules increases, leading to a rise in temperature, which is why these waves are called heat waves. They are commonly used in physical therapy for healing purposes and in electronic devices such as remote controls for TVs and other household electronics.

> **Key Points: Produced by hot bodies and molecules-Absorbed by water molecules and others increasing thermal motion-Referred to as heat waves due to heating effects-Uses include physical therapy and remote controls**

Question 23. In the given figure the radius of curvature of curved face in the plano-convex and the plano-concave lens is 15 cm each. The refractive index of the material of the lenses is 1.5. Find the final position of the image formed.

[2 Marks]



Answer: To find the final position of the image formed by the combination of the plano-convex and plano-concave lenses, we can use the lens formula 1/f = (n - 1)(1/R1 - 1/R2). For the plano-convex lens (R1 = +15 cm) and plano-concave lens (R2 = -15 cm), we can calculate the focal lengths and subsequently use them. The final image position can be determined using the properties of both lenses and how they work together in combination.

Key Points: Use lens formula - Focal lengths of lenses - Combine effects of plano-convex and plano-concave lenses

Question 24.

(a) What is meant by ionisation energy? Write its value for the hydrogen atom.

[2 Marks]

Answer: Ionisation energy is the minimum energy required to remove an electron from an atom in its gaseous state. For the hydrogen atom, the ionisation energy is 13.6 eV. This value signifies the energy needed to transition the electron from its ground state to a point where it is free from the nucleus, ensuring it can no longer be associated with the atom.

Key Points: Definition of ionisation energy - Minimum energy to remove an electron - Value for hydrogen atom is 13.6 eV

Question 25.

What happens to the interference pattern when two coherent sources are

(a) infinitely close, and

(b) far apart from each other

[2 Marks]

Answer: When two coherent sources are infinitely close, the interference pattern appears as a series of bright and dark fringes with closely spaced maxima and minima. As the distance between them increases, the pattern becomes more spread out. If the sources are far apart, the fringes become

more widely spaced, leading to a clearer differentiation between the bright and dark bands. The wavelength and phase relationship are crucial in determining the pattern.

Key Points: coherent sources-infinitely close-bright and dark fringes-spread out pattern-far apart-widely spaced fringes-wavelength and phase relationship

Question 26.

Draw energy band diagram for an n-type and p-type semiconductor at

T>0K.

[2 Marks]

Answer: In an n-type semiconductor, the energy level of the conduction band is lower due to excess electrons from donor impurities. The Fermi level lies closer to the conduction band. In a p-type semiconductor, the valence band edges are higher due to holes created by acceptor impurities, and the Fermi level is closer to the valence band. Both diagrams show energy bands and indicate the position of the Fermi level.

Key Points: n-type semiconductor, energy band diagram, conduction band, Fermi level, p-type semiconductor, valence band, holes, donor impurities, acceptor impurities

Question 27.

Answer the following giving reasons :

i) A p-n junction diode is damaged by a strong current.

ii) Impurities are added in intrinsic semiconductors.

[2 Marks]

Answer: A p-n junction diode can be damaged by a strong current because excessive current leads to overheating and potential thermal breakdown. The high temperature can cause the semiconductor material to lose its properties, resulting in irreversible damage. Impurities are added to intrinsic semiconductors to create extrinsic semiconductors; these dopants increase conductivity by providing free charge carriers. For instance, adding phosphorus to silicon creates n-type semiconductors, enhancing their electric properties.

Key Points: Damage due to overheating-thermal breakdown-cause of loss of properties; Impurity doping-enhances conductivity-creation of n-type and p-type semiconductors

Question 28.

(b) How are X-rays produced? Give any two uses of these.

[2 Marks]

Answer: X-rays are produced by bombarding a metal target with high-energy electrons, which causes the emission of electromagnetic radiation in the X-ray region. This process releases energy when electrons collide with the metal atoms, resulting in the generation of X-rays. Two common uses of X-rays are in medical diagnostics, allowing physicians to view internal structures like bones, and in cancer treatment to target and destroy cancerous cells.

> **Key Points: X-rays production mechanism - High-energy electrons bombarding metal target; Medical diagnostics; Cancer treatment**

Question 29.

(b) Define the term, mass defect. How is it related to stability of the nucleus?

[2 Marks]

Answer: Mass defect is the difference between the total mass of a nucleus's individual protons and neutrons and the actual mass of the nucleus itself. This discrepancy arises due to the binding energy that holds the nucleus together. According to Einstein's equation, this mass defect can be converted into energy, illustrating how stable nuclei have lower mass. A larger mass defect indicates greater binding energy, contributing to nucleus stability.

> **Key Points: mass defect definition-binding energy relationship-stability indication**

Section D

Question 30.

(a) Two charged conducting spheres of radii a and b are connected to each other by a wire. Find the ratio of the electric fields at their surfaces.

[3 Marks]

Answer: When two conducting spheres are connected by a wire, charges redistribute between them until their potentials equalize. The electric field (E) at the surface of a conducting sphere is given by $E = kQ/r^2$, where Q is the charge and r is the radius of the sphere. Let the charges on spheres of radii a and b be Q_1 and Q_2 respectively. The potentials are $V_1 = kQ_1/a$ and $V_2 = kQ_2/b$. Since $V_1 = V_2$, we find that $Q_1/a = Q_2/b$, leading to $Q_1/Q_2 = a/b$. Therefore, the electric fields at the surfaces can be expressed

as $E_1/E_2 = (kQ_1/a^2) / (kQ_2/b^2) = (Q_1/Q_2) * (b^2/a^2) = (a/b) * (b^2/a^2) = (b/a)$. Thus, the ratio of electric fields at their surfaces is $E_1/E_2 = b/a$.

Key Points: 1. Charges redistribute to equalize potential between spheres. 2. Electric field at surface: $E = kQ/r^2$. 3. Using charge relation, deduce E ratio from potential equality.

Question 31.

Define current density and relaxation time. Derive an expression for

resistivity of a conductor in terms of number density of charge carriers in

the conductor and relaxation time.

[3 Marks]

Answer: Current density (J) is defined as the amount of electric current (I) flowing per unit cross-sectional area (A) of the conductor, given by the formula $J = I/A$. Relaxation time (τ) is the average time between successive collisions of charge carriers, which influences their drift velocity. The resistivity (ρ) of a conductor can be derived using Ohm's law and the relationship between current density and electric field. The expression for resistivity is $\rho = m / (nq^2\tau)$, where m is the mass of charge carriers, n is the number density of charge carriers, and q is the charge of each carrier.

Key Points: Definition of current density; Definition of relaxation time; Formulas for current density and resistivity; Derivation steps linking resistivity with number density and relaxation time

Question 32.

A series CR circuit with R = 200 Ω and C = (50/π) μF is connected across

an ac source of peak voltage ¢, = 100 V and frequency v = 50 Hz. Calculate

(a) impedance of the circuit (Z), (b) phase angle (φ), and (c) voltage across

the resistor.

[3 Marks]

Answer: To calculate the impedance (Z), we first find the capacitive reactance (Xc). The capacitive reactance is given by $Xc = 1 / (2\pi fC)$. Here, f = 50 Hz and C = (50/π) μF converts to 50 x 10^-6 F. Thus, $Xc = 1 / (2\pi * 50 * (50/\pi * 10^{-6})) = 63.66\ \Omega$. The impedance Z in a CR circuit is given by $Z = \sqrt{(R^2 + Xc^2)} = \sqrt{(200^2 + 63.66^2)} = 210.18\ \Omega$. The phase angle φ can be calculated using $\varphi = \arctan(Xc/R) = \arctan(63.66/200) = 17.46°$. Finally, the voltage across the resistor (VR) is $VR = V * (R/Z)$, where V = 100 V peak, giving $VR = 100 * (200/210.18) = 95.09$ V.

Key Points: Impedance calculation; Capacitive reactance formula; Phase angle calculation; Voltage across the resistor formula

Question 33.

Define critical angle for a given pair of media and total internal reflection.

Obtain the relation between the critical angle and refractive index of the

medium.

[3 Marks]

Answer: The critical angle is defined as the angle of incidence in the denser medium at which the angle of refraction in the rarer medium becomes 90 degrees. At this point, light is refracted along the boundary. If the angle of incidence exceeds the critical angle, total internal reflection occurs, meaning all the light is reflected back into the denser medium. The critical angle (θc) can be related to the refractive indices (n1 for the denser medium and n2 for the rarer medium) using Snell's law. Mathematically, this is expressed as: sin(θc) = n2/n1. Thus, θc = sin^(-1)(n2/n1).

Key Points: Definition of critical angle-Total internal reflection-explanation of relation using Snell's law

Question 34.

(a) (i) Distinguish between nuclear fission and fusion giving an example of each.

(ii) Explain the release of energy in nuclear fission and fusion on the basis of binding energy per nucleon curve.

[3 Marks]

Answer: Nuclear fission is the process where a heavy nucleus splits into two lighter nuclei, releasing energy. An example is the fission of uranium-235. In contrast, nuclear fusion involves two light nuclei combining to form a heavier nucleus, such as the fusion of deuterium isotopes to form helium. The release of energy in both processes is explained by the binding energy per nucleon. In fission, the binding energy of the resulting lighter nuclei is higher than that of the original heavy nucleus, resulting in energy release. Similarly, in fusion, the binding energy per nucleon of the formed heavier nucleus is also higher, indicating it is more stable and thus releases energy. This greater binding energy means that energy is liberated during both processes.

Key Points: Nuclear fission splits heavy nuclei, e.g., uranium-235; Nuclear fusion combines light nuclei, e.g., deuterium; Energy release is due to increased binding energy per nucleon in fusion and fission.

Question 35.

(b) A parallel plate capacitor (A) of capacitance C is charged by a battery to voltage V. The battery is disconnected and an uncharged capacitor (B) of capacitance 2C is connected across A. Find the ratio of

(i) final charges on A and B.

(ii) total electrostatic energy stored in A and B finally and that

stored in A initially.

[3 Marks]

Answer: Initially, capacitor A has a charge Q = CV. When the uncharged capacitor B (2C) is connected in parallel, charge redistributes. The final charge on A becomes Q_A = Q/3, and the final charge on B becomes Q_B = 2Q/3. Therefore, the ratio Q_A/Q_B = 1:2. For energy, the initial energy stored in A is U_initial = 1/2 CV^2. The final energy in A and B combined is U_final = 1/2 (Q_A^2/C) + 1/2 (Q_B^2/2C) = (1/2)(CV^2/3^2) + (1/4)(2Q/3)^2/(2C) = (1/18)CV^2 + (2/36)CV^2 = (1/12)CV^2.

Key Points: Final charge on A = Q/3 ; Final charge on B = 2Q/3 ; Ratio of charges = 1:2 ; Initial energy in A = 1/2 CV^2 ; Final energy in A and B = (1/12)CV^2

Question 36.

(b) (i) How is the size of a nucleus found experimentally ? Write the relation between the radius and mass number of a nucleus.

(ii) Prove that the density of a nucleus is independent of its mass number.

[3 Marks]

Answer: The size of a nucleus is determined through electron scattering experiments, which reveal that nuclei can be regarded as spherical. The radius R is found using the formula $R = R_0 A^{1/3}$, where R_0 is a constant approximately equal to 1.2 fm and A is the mass number. This indicates that as the mass number increases, so does the radius. To demonstrate that nuclear density remains constant regardless of mass number, we observe that the volume V of a nucleus is proportional to R^3, thus $V \propto A$. Since density ρ is defined as mass over volume ($\rho = \frac{A \cdot m_u}{\frac{4}{3} \pi R^3}$), and knowing R^3 is proportional to A, it follows that density ρ is a constant value around $2.3 \times 10^{17} \, \text{kg/m}^3$, independent of A. This implies that all nuclei maintain similar densities, comparable to drops of liquid.

Key Points: Nucleus size determined by electron scattering; Radius formula R = R0 A^{1/3}; Volume proportional to mass number A; Density constant at ~2.3 x 10^{17}

kg/m^3; Density independent of mass number A

Section E

Question 37.

(b) (i) Consider two identical point charges located at points (0, 0) and (a, 0).

(1) Is there a point on the line joining them at which the electric field is zero ?

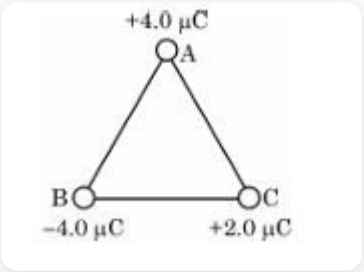
(2) Is there a point on the line joining them at which the electric potential is zero ?

Justify your answers for each case.

(ii) State the significance of negative value of electrostatic potential energy of a system of charges.

Three charges are placed at the corners of an equilateral triangle ABC of side 2.0 m as shown in figure. Calculate the electric potential energy of the system of three charges.

[5 Marks]



Answer: To find the electric field and potential due to two identical point charges, consider their arrangement along the x-axis. 1) The electric field from both charges points away from each charge; thus, between the charges, the fields due to each charge cannot cancel each other out, making it impossible to have a point of zero electric field on the line joining them. 2) However, the electric potential can equal zero at a point outside the line connecting them due to the symmetry in potential created by both charges, which will offset at points farther along the axis. The significance of negative electrostatic potential energy indicates that work must be done to separate the charges; this attracts them to each other. For three charges positioned at the corners of an equilateral triangle with a side length of 2.0 m, the total electric potential energy is calculated using the formula U = k(q1q2/r12 + q1q3/r13 + q2q3/r23), where k is Coulomb's constant and r12, r13, r23 are distances between the charges.

Key Points: Electric field cannot be zero between identical charges-Electric potential can be zero outside charges-Significance of negative potential energy indicates attractive force-Formula for electric potential energy using Coulomb's law

Question 38.

(a) (i) Define coefficient of self-induction. Obtain an expression for self-inductance of a long solenoid of length l, area of cross-section A having N turns.

(ii) Calculate the self-inductance of a coil using the following data obtained when an AC source of frequency (200/π) Hz and a DC source is applied across the coil.

[5 Marks]

AC Source		
S.No.	V (Volts)	I (A)
1	3.0	0.5
2	6.0	1.0
3	9.0	1.5

DC Source		
S.No.	V (Volts)	I (A)
1	4.0	1.0
2	6.0	1.5
3	8.0	2.0

Answer: The coefficient of self-induction, denoted as L, quantifies the ability of a coil to induce electromotive force (emf) due to a change in current through it. For a long solenoid of length l, area A, and N turns, we derive the expression for self-inductance as follows: the magnetic field inside the solenoid is given by $B = \mu_0 n I$, where $n = N/l$ is the number of turns per unit length. The flux linked with the solenoid, $\Phi = B * A = \mu_0 (N/l) I A$. The induced emf, $\varepsilon = -d\Phi/dt$. Hence, the self-inductance L is defined as $L = N\varepsilon/I = \mu_0 n^2 A l$. For calculating self-inductance using the given frequency data, one would apply the relevant equations based on the frequency response of the coil in AC and measure its inductance accordingly.

Key Points: Definition of coefficient of self-induction; Derivation of self-inductance for a long solenoid; Expression $L = \mu_0 n^2 A l$; Relationship between current and induced emf; Considerations for AC frequency response.

Question 39.

(a) (i) State Huygen's principle. With the help of a diagram, show how a plane wave is reflected from a surface. Hence verify the law of reflection.

(ii) A concave mirror of focal length 12 cm forms a three times magnified virtual image of an object. Find the distance of the object from the mirror.

[5 Marks]

Answer: Huygen's principle states that every point on a wavefront acts as a source of secondary wavelets that spread out in the forward direction at the speed of the wave. The new wavefront is the tangential surface to these secondary wavelets. In reflection, when a plane wave strikes a reflective surface, each point on the wavefront acts as a source of wavelets, converging at the reflected point. A diagram illustrates this with incident rays and reflected rays aligning according to the law of reflection: the angle of incidence equals the angle of reflection. \n\nTo find the object distance (u) for a concave

mirror forming a virtual image, we apply the mirror formula: 1/f = 1/v + 1/u. Given, f = -12 cm (focal length is negative for concave mirrors) and magnification (m) = -v/u = -3. Therefore, v = -3u. \nSubstituting into the mirror equation: 1/(-12) = 1/(-3u) + 1/u. Solving leads to u = -9 cm, indicating the object is 9 cm in front of the mirror, creating a virtual image.

Key Points: Huygen's principle definition-diagram of plane wave reflection-law of reflection verification-mirror formula for concave mirror-focal length and magnification calculations-object distance calculation

Question 40.

(a) (i) Use Gauss' law to obtain an expression for the electric field due to an infinitely long thin straight wire with uniform linear charge density λ.

(ii) An infinitely long positively charged straight wire has a linear charge density λ. An electron is revolving in a circle with a constant speed v such that the wire passes through the centre, and is perpendicular to the plane, of the circle. Find the kinetic energy of the electron in terms of magnitudes of its charge and linear charge density λ on the wire.

(iii) Draw a graph of kinetic energy as a function of linear charge density λ

[5 Marks]

Answer: To find the electric field due to an infinitely long straight wire with uniform linear charge density λ, we apply Gauss's law. We consider a cylindrical Gaussian surface of radius r around the wire. The electric field (E) is radial and constant on this surface. The charge enclosed, Q_enc, can be expressed as λL, where L is the length of the cylinder. According to Gauss's law ($\oint E \cdot dA = Q_{enc}/\varepsilon_0$), we have $E(2\pi rL) = \lambda L/\varepsilon_0$. Thus, $E = \lambda/(2\pi\varepsilon_0 r)$. For the electron in circular motion, the centripetal force is provided by the electric field's force. Using E, we derive $F = eE = e(\lambda/(2\pi\varepsilon_0 r))$. The electron's kinetic energy is given by $K.E. = 0.5mv^2 = (e^2\lambda)/(4\pi^2\varepsilon_0 r)$. On a graph of kinetic energy versus λ, K.E. increases linearly with λ as m and r remain constant.

Key Points: 1. Use Gauss's law defining the Gaussian surface; 2. Derive the electric field E using Q_enc = λL; 3. Relate electric field to centripetal force for the revolving electron; 4. Calculate kinetic energy using E; 5. Draw graph showing linear relationship between K.E. and λ.

Question 41.

(b) (i) With the help of a labelled diagram, describe the principle and working of an ac generator. Hence, obtain an expression for the instantaneous value of the emf generated.

(ii) The coil of an ac generator consists of 100 turns of wire, each of area 0.5 m^2. The resistance of the wire is 100 Ω. The coil is rotating in a magnetic field of 0.8 T perpendicular to its axis of

rotation, at a constant angular speed of 60 radian per second. Calculate the maximum emf generated and power dissipated in the coil.

[5 Marks]

Answer: An AC generator converts mechanical energy into electrical energy through electromagnetic induction. The key components include a coil (armature) mounted on a rotor that rotates in a magnetic field. This rotation changes the magnetic flux through the coil, leading to an induced emf. The instantaneous voltage (emf, ε) is given by: $\varepsilon(t) = NBA\omega \sin(\omega t)$, where N is the number of turns (100), A is the area of the coil (0.5 m^2), B is the magnetic field strength (0.8 T), and ω is the angular velocity (60 rad/s). To find max emf, $\varepsilon_{max} = NBA\omega = 100 \times 0.5 \times 0.8 \times 60 = 2400$ V. Power (P) is given by $P = \varepsilon^2/R = (2400)^2 / 100 = 57600$ W.

Key Points: Principle of electromagnetic induction-Components of an AC generator-diagram of AC generator-Expression of instantaneous emf ($\varepsilon = NBA\omega \sin(\omega t)$)-Calculation of maximum emf ($\varepsilon_{max} = NBA\omega$)-Power calculation ($P = \varepsilon^2/R$)

Question 42.

(b) (i) Draw a labelled ray diagram showing the image formation by a refracting telescope. Define its magnifying power. Write two limitations of a refracting telescope over a reflecting telescope.

(ii) The focal lengths of the objective and the eye-piece of a compound microscope are 1.0 cm and 2.5 cm respectively. Find the tube length of the microscope for obtaining a magnification

of 300.

[5 Marks]

Answer: The refracting telescope utilizes two lenses: an objective lens with a long focal length and an eyepiece with a shorter focal length. The ray diagram demonstrates rays from a distant object converging through the objective to form a real image. This image acts as the object for the eyepiece, producing an enlarged virtual image. The magnifying power (m) of the telescope is defined as the ratio of the angle subtended by the image at the eye (β) to that subtended by the object (α), leading to the formula $m = \beta/\alpha = f_o/f_e$. Limitations of refracting telescopes include chromatic aberration and size constraints, as larger lenses are challenging to produce and require precise alignment. Regarding the compound microscope, the tube length (L) can be calculated using the formula for magnification $m = (L/f_0)(L/f_e)$. Given the magnification is 300 and focal lengths of 1.0 cm and 2.5 cm for the objective and eyepiece, respectively, substituting these values allows us to solve for L, giving us a tube length of $L = \sqrt{(m * f_0 * f_e)} = \sqrt{(300 * 1.0 * 2.5)}$. Thus, the calculated tube length will ensure effective magnification of 300.

Key Points: Draw a clear ray diagram showing the paths of light through the objective and eyepiece; Define magnifying power with the formula $m = \beta/\alpha$ and its significance; Mention two limitations such as chromatic aberration and size constraints in producing

large lenses; Include calculations for tube length of the microscope using m = (L/f0)(L/fe) and substituting correct values.