UP Board Class 12 Physics 2025 (Code 346 JT) Question Paper with Solutions

General Instructions

(i) This booklet contains 9 questions, each provided with a complete, step-by-step solution.

(ii) It has multiple-choice questions as well as questions that need a written answer.

(iii) Attempt each question on your own before reviewing the given solution.

1(a). Electric force of 80 N acts between two point charges. When these charges are placed in a dielectric medium, then electric force becomes 8 N. Dielectric constant of the medium will be

(A) 0.1

(B) 10

(C) 16

(D) 640

Correct Answer: (B) 10

Solution:

Step 1: Understanding the Concept:

The electric force between two point charges changes when they are placed in a dielectric medium instead of a vacuum (or air). The dielectric constant (K), also known as relative permittivity (ϵ_r), is a measure of how much a dielectric material reduces the electric field

strength. The force in the medium is inversely proportional to the dielectric constant.

Step 2: Key Formula or Approach:

The relationship between the electric force in a vacuum (F_{vacuum}) and the electric force in a dielectric medium (F_{medium}) is given by the formula:

$$K = \frac{F_{\text{vacuum}}}{F_{\text{medium}}}$$

where K is the dielectric constant of the medium.

Step 3: Detailed Explanation:

We are given the following values:

The initial electric force in air (which is approximately a vacuum), $F_{\text{vacuum}} = 80$ N.

The electric force when placed in the dielectric medium, $F_{\text{medium}} = 8$ N.

Using the formula from Step 2, we can calculate the dielectric constant K:

$$K = \frac{80\ \text{N}}{8\ \text{N}}$$

$$K = 10$$

Step 4: Final Answer:

The dielectric constant of the medium is 10. Therefore, option (B) is correct.

Quick Tip: For any medium other than a vacuum, the dielectric constant K is always greater than 1. This means the electric force between charges is always weakened when they are placed in a dielectric material. If you get an answer for K that is less than 1, you have likely inverted the formula.

1(b). In the following nuclear reaction X is

$${}_{2}^{4}\mathrm{He} + {}_{7}^{14}\mathrm{N} \rightarrow {}_{8}^{17}\mathrm{O} + \mathrm{X}$$

(A) Proton

(B) Neutron

(C) Electron

(D) Deuteron

Correct Answer: (A) Proton

Solution:

Step 1: Understanding the Concept:

In any nuclear reaction, two fundamental quantities must be conserved: the total mass number (A), which is the superscript, and the total atomic number (Z), which is the subscript.

The mass number (A) represents the total number of protons and neutrons in the nucleus.

The atomic number (Z) represents the number of protons.

Step 2: Key Formula or Approach:

Let the unknown particle X be represented as ${}_{Z}^{A}\mathrm{X}$. The conservation laws can be written as two separate equations:

1. Conservation of Mass Number (A): $\sum A_{\text{reactants}} = \sum A_{\text{products}}$
2. Conservation of Atomic Number (Z): $\sum Z_{\text{reactants}} = \sum Z_{\text{products}}$

Step 3: Detailed Explanation:

The given nuclear reaction is:

$$ {}_{2}^{4}\mathrm{He} + {}_{7}^{14}\mathrm{N} \rightarrow {}_{8}^{17}\mathrm{O} + {}_{Z}^{A}\mathrm{X} $$

Applying Conservation of Mass Number (A):

The sum of mass numbers on the left side (reactants) is $4 + 14 = 18$.

The sum of mass numbers on the right side (products) is $17 + A$.

Equating them: $18 = 17 + A \implies A = 1$.

Applying Conservation of Atomic Number (Z):

The sum of atomic numbers on the left side (reactants) is $2 + 7 = 9$.

The sum of atomic numbers on the right side (products) is $8 + Z$.

Equating them: $9 = 8 + Z \implies Z = 1$.

The unknown particle X has a mass number $A = 1$ and an atomic number $Z = 1$. A particle with one proton and a mass number of 1 is a proton ($_1^1\text{p}$ or $_1^1\text{H}$).

Step 4: Final Answer:

The particle X is a proton. Therefore, option (A) is correct.

Quick Tip: Familiarize yourself with the notations for common particles in nuclear physics:

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1(c). The difference in angular momentum of electron between two successive orbits of hydrogen atom is

(A) $\frac{h}{2\pi}$

(B) $\frac{h}{\pi}$

(C) $\frac{h}{2}$

(D) $2h$

Correct Answer: (A) $\frac{h}{2\pi}$

Solution:

Step 1: Understanding the Concept:

In Bohr's model the electron moves only in certain allowed circular orbits. In these orbits the angular momentum of the electron is not free to take any value. It must be a whole-number multiple of $\frac{h}{2\pi}$, where h is Planck's constant.

Step 2: Key Formula or Approach:

Bohr's quantum condition for the nth orbit, where $n = 1, 2, 3, \ldots$ is the principal quantum number:

$$L_n = \frac{nh}{2\pi}$$

Two successive orbits have quantum numbers n and $n + 1$. We subtract their angular momenta.

Step 3: Detailed Explanation:

Angular momentum in the nth orbit is $L_n = \frac{nh}{2\pi}$.

Angular momentum in the next orbit is $L_{n+1} = \frac{(n+1)h}{2\pi}$.

Subtract the two:

$$\Delta L = L_{n+1} - L_n = \frac{(n+1)h}{2\pi} - \frac{nh}{2\pi} = \frac{h}{2\pi}$$

The result does not depend on n. So between any two successive orbits, the angular momentum changes by the same fixed amount $\frac{h}{2\pi}$.

Step 4: Check option (A).

$\frac{h}{2\pi}$ is exactly the value we got above. So (A) is CORRECT.

Step 5: Check option (B).

$\frac{h}{\pi} = 2 \times \frac{h}{2\pi}$. This would be the difference between orbits that are two steps apart, such as n and $n+2$, not successive orbits. So (B) is WRONG.

Step 6: Check options (C) and (D).

$\frac{h}{2}$ and $2h$ are not whole multiples of $\frac{h}{2\pi}$, because π is not a whole number. Bohr's rule never gives such differences. So (C) and (D) are WRONG.

Final Answer:

The angular momentum of the electron changes by $\frac{h}{2\pi}$ from one orbit to the next. This is option (A).

$$\boxed{\frac{h}{2\pi}}$$

Quick Tip: Bohr's rule gives $L_n = \frac{nh}{2\pi}$. Subtract the values for n and $n+1$.

1(d). The force, by which the α-particles are scattered in the α-particle scattering experiment of Rutherford, is

(A) Gravitational force

(B) Coulomb's force

(C) Nuclear force

(D) Magnetic force

Correct Answer: (B) Coulomb's force

Solution:

Step 1: Understanding the Concept:
Rutherford's gold foil experiment (or α-particle scattering experiment) involved bombarding a thin sheet of gold foil with positively charged alpha particles. The scattering pattern of these particles led to the discovery of the atomic nucleus. The question asks for the fundamental force responsible for this scattering.

Step 2: Detailed Explanation:
Let's analyze the forces involved:
\begin{itemize} \item **Nature of Particles:** The α-particle is a helium nucleus ($_2^4\text{He}^{2+}$), which is positively charged. The target, the nucleus of a gold atom, is also positively charged (as it contains protons).
\item **Coulomb's force:** This is the electrostatic force of repulsion between two like charges (positive α-particle and positive nucleus). This force is long-range and follows an inverse-square law ($F \propto 1/r^2$), which perfectly explains why most particles passed straight through (far from a nucleus) while a few were deflected at large angles (passed close to a nucleus).
\item **Gravitational force:** This is the force of attraction between masses. While it exists, it is extremely weak compared to the electrostatic force at the atomic scale and is completely negligible in this context.
\item **Nuclear force:** This is a very strong, short-range attractive force that holds protons and neutrons together within the nucleus. It only acts over distances of about 10^{-15} m. The α-particles are repelled by the Coulomb force long before they get close enough for the nuclear force to be significant, except in very high-energy head-on collisions. The scattering itself is governed by the electrostatic repulsion.

\item **Magnetic force:** This force acts on moving charges within a magnetic field. There is no external magnetic field applied in this experiment, so this force is not the cause of the scattering. \end{itemize} The primary interaction causing the α-particles to deviate from their straight paths is the electrostatic repulsion between the positively charged α-particles and the positively charged gold nuclei. This force is known as Coulomb's force.

Step 3: Final Answer:

The force responsible for the scattering is Coulomb's force. Therefore, option (B) is correct.

Quick Tip: Rutherford's experiment is a cornerstone of modern physics. Remember its key conclusion: the atom consists of a tiny, dense, positively charged nucleus surrounded by a large volume of mostly empty space containing electrons. The scattering is a classic example of an interaction governed by Coulomb's law.

1(e). The frequency range of ultraviolet radiation in electromagnetic radiation spectrum is

(A) $3 \times 10^{10} - 3 \times 10^{12}$ Hz

(B) $3 \times 10^{12} - 3 \times 10^{14}$ Hz

(C) $3 \times 10^{14} - 3 \times 10^{16}$ Hz

(D) 3×10^{16} and above

Correct Answer: (C) $3 \times 10^{14} - 3 \times 10^{16}$ Hz

Solution:

Step 1: Understanding the Concept:
The electromagnetic (EM) spectrum is the range of all types of EM radiation. Radiation is classified by wavelength or frequency. The order of the spectrum in terms of increasing frequency (and decreasing wavelength) is: Radio waves, Microwaves, Infrared, Visible light, Ultraviolet, X-rays, Gamma rays.

Step 2: Detailed Explanation:
Let's analyze the given frequency ranges:
\begin{itemize} \item **Visible Light:** The visible spectrum, which our eyes can see, ranges from approximately 4.3×10^{14} Hz (red) to 7.5×10^{14} Hz (violet).
\item **Ultraviolet (UV) Radiation:** UV radiation has a frequency just higher than that of violet light. Its range typically starts from the end of the visible spectrum and extends upwards. The accepted range for UV is roughly 8×10^{14} Hz to 3×10^{16} Hz.
\end{itemize} (A) $3 \times 10^{10} - 3 \times 10^{12}$ Hz: This corresponds to the microwave and far-infrared region.
(B) $3 \times 10^{12} - 3 \times 10^{14}$ Hz: This corresponds to the infrared region.
(C) $3 \times 10^{14} - 3 \times 10^{16}$ Hz: This range begins at the boundary of infrared/visible light and extends through the entire ultraviolet region, up to the start of the X-ray region. This is the most appropriate range among the choices.
(D) 3×10^{16} and above: Frequencies above 3×10^{16} Hz are generally classified as X-rays and Gamma rays.

Step 3: Final Answer:
The frequency range that best represents ultraviolet radiation from the given options is $3 \times 10^{14} - 3 \times 10^{16}$ Hz. Therefore, option (C) is correct.

Quick Tip: To remember the order of the electromagnetic spectrum, use a mnemonic like "Roman Men Invented Very Unusual X-ray Guns" for Radio, Microwave, Infrared, Visible, Ultraviolet, X-ray, Gamma Ray. Remember that frequency increases and wavelength decreases as you move from left to right in this mnemonic.

1(f). The sun makes an angle of 0.5° on earth's surface. Its image is made with convex lens of focal length 50 cm. The diameter of image will be

(A) 1.0 cm

(B) 5.0 cm

(C) 0.76 cm

(D) 0.43 cm

Correct Answer: (D) 0.43 cm

Solution:

Step 1: Understanding the Concept:

When a lens is used to view a very distant object like the sun, the parallel rays of light from the object converge to form an image at the focal plane of the lens. The size of this image is related to the focal length of the lens and the angular size of the object.

Step 2: Key Formula or Approach:

For small angles, the relationship between the angular size (θ), the image diameter (d), and the focal length (f) can be approximated by:

$$\theta \approx \tan(\theta) = \frac{\text{Opposite}}{\text{Adjacent}} = \frac{d}{f}$$

This formula requires the angle θ to be in radians.

The conversion from degrees to radians is: **angle in radians** $=$ **angle in degrees** $\times \frac{\pi}{180}$.

Step 3: Detailed Explanation:

We are given:

Angular size of the sun, $\theta = 0.5°$.

Focal length of the convex lens, $f = 50$ cm.

First, we must convert the angular size from degrees to radians:

$$\theta_{\text{rad}} = 0.5 \times \frac{\pi}{180} \approx 0.5 \times \frac{3.14159}{180} \approx 0.008727 \text{ radians}$$

Now, we can use the formula $d = f \times \theta_{\text{rad}}$ to find the diameter of the image (d):

$$d = 50 \text{ cm} \times 0.008727$$

$$d \approx 0.43635 \text{ cm}$$

Step 4: Final Answer:

The diameter of the image is approximately 0.43 cm. Comparing this with the given options, option (D) is the closest match.

Quick Tip: A common mistake in problems involving angles in physics formulas (like in optics, simple harmonic motion, or circular motion) is forgetting to convert the angle from degrees to radians. Always check the requirements of the formula. For the small angle approximation ($\tan\theta \approx \sin\theta \approx \theta$), the angle θ must be in radians.

2(a). Write the de Broglie wavelengths in terms of kinetic energy.

Correct Answer: –

Solution:

Step 1: Understanding the Concept:

The de Broglie hypothesis proposes that all matter, such as electrons and protons, exhibits wave-like properties. A particle with momentum p has an associated wavelength λ, known as the de Broglie wavelength. Kinetic energy (K) is the energy a particle possesses due to its motion. The task is to derive an expression for the wavelength λ in terms of the particle's kinetic energy K.

Step 2: Key Formula or Approach:

The de Broglie wavelength is fundamentally defined as:

$$\lambda = \frac{h}{p}$$

where h is Planck's constant and p is the momentum of the particle ($p = mv$).

The classical kinetic energy (K) of a particle of mass m is given by $K = \frac{1}{2}mv^2$. This can be related to momentum by the formula:

$$K = \frac{p^2}{2m}$$

Step 3: Detailed Explanation:

Our goal is to substitute momentum p in the de Broglie equation with an expression involving kinetic energy K. We start with the kinetic energy formula and solve for p:

$$K = \frac{p^2}{2m}$$

Multiplying both sides by $2m$:

$$p^2 = 2mK$$

Taking the square root of both sides gives the momentum:

$$p = \sqrt{2mK}$$

Now, we substitute this expression for p into the de Broglie wavelength formula:

$$\lambda = \frac{h}{\sqrt{2mK}}$$

This equation gives the de Broglie wavelength directly from the particle's kinetic energy and mass.

Step 4: Final Answer:

The de Broglie wavelength (λ) in terms of kinetic energy (K) for a particle of mass m is given by the expression:

$$\lambda = \frac{h}{\sqrt{2mK}}$$

Quick Tip: This formula is extremely important in quantum mechanics, especially for problems involving electrons accelerated through a potential difference V. In that case, the kinetic energy gained is $K = qV$ (where q is the charge), so the wavelength becomes $\lambda = \frac{h}{\sqrt{2mqV}}$.

2(b). Prove that total internal reflection of light ray from refracting surface is possible only when the value of angle of prism A be more than $\sin^{-1}\left(\frac{1}{n}\right)$, where 'n' is refractive index of the material of prism.

Correct Answer: —

Solution:

Step 1: Understanding the Concept:

Total Internal Reflection (TIR) is a phenomenon where a light ray traveling from a denser medium (e.g., prism with refractive index n) to a rarer medium (e.g., air with refractive index ≈ 1) is completely reflected back into the denser medium. This occurs only if the angle of incidence in the denser medium is greater than a specific angle called the critical angle, C. The question asks for the condition on the prism's apex angle A for TIR to be possible at the second face.

Step 2: Key Formula or Approach:

1. **Critical Angle (C):** The critical angle is defined by Snell's Law when the angle of refraction is 90°. For a prism in air, $n\sin(C) = 1\sin(90°)$, which gives $\sin(C) = \frac{1}{n}$ or $C = \sin^{-1}\left(\frac{1}{n}\right)$.
2. **Condition for TIR:** For TIR to occur at the second face of the prism, the angle of incidence there, r_2, must be greater than or equal to the critical angle C. That is, $r_2 \geq C$.
3. **Prism Angle Formula:** In a prism, the apex angle A is related to the angle of refraction at the first face (r_1) and the angle of incidence at the second face (r_2) by the geometric relation $A = r_1 + r_2$.

Step 3: Detailed Explanation:

Let a ray of light enter the first face of the prism and refract at an angle r_1. This ray then travels to the second face, striking it at an angle of incidence r_2.

The condition for TIR to take place at this second face is:

$$r_2 \geq C$$

Using the prism angle formula, we can express r_2 as $r_2 = A - r_1$.

Substituting this into the TIR condition:

$$A - r_1 \geq C$$

Rearranging the inequality to find the condition on A:

$$A \geq C + r_1$$

This inequality shows that for TIR to be possible, the prism angle A must be at least $C + r_1$. The value of r_1 depends on the initial angle of incidence i on the first face. To determine if TIR is possible at all, we must check if this condition can be met for any valid r_1.
The minimum possible value for r_1 is 0, which occurs when the light ray enters the prism at normal incidence ($i = 0$). If we substitute this minimum value of r_1 into our condition, we get the minimum requirement for A:

$$A \geq C + 0$$

$$A \geq C$$

This means that for TIR to be even a possibility, the prism angle A must be at least equal to the critical angle C. If $A < C$, then $A - r_1$ will always be less than C (since $r_1 \geq 0$), and TIR can never occur.

Step 4: Final Answer:
Thus, total internal reflection is possible only if the angle of the prism A is greater than or equal to the critical angle C. Substituting the expression for the critical angle, $C = \sin^{-1}\left(\frac{1}{n}\right)$, we prove that TIR is possible only when $A \geq \sin^{-1}\left(\frac{1}{n}\right)$. The question's use of "more than" implies the strict condition for practical observation.

Quick Tip: This principle is fundamental to the design of optical instruments. For example, 45°-90°-45° prisms are used in binoculars and

periscopes. For typical glass ($n \approx 1.5$), the critical angle is $C \approx 42°$. Since $45° > 42°$, these prisms are designed to produce total internal reflection.

2(c). The ratio of diameters of two copper wires of same length is 2 : 1. Compare their resistances.

Correct Answer: —

Solution:

Step 1: Understanding the Concept:
The electrical resistance (R) of a conductor depends on its intrinsic property (resistivity, ρ), its length (L), and its cross-sectional area (A). Since the problem specifies two copper wires of the same length, their resistivity and length are identical. Therefore, the difference in their resistance will solely depend on their cross-sectional areas, which are determined by their diameters.

Step 2: Key Formula or Approach:
The formula for the resistance of a wire is:

$$R = \rho \frac{L}{A}$$

The cross-sectional area A of a wire with diameter d is circular, so its area is:

$$A = \pi r^2 = \pi \left(\frac{d}{2}\right)^2 = \frac{\pi d^2}{4}$$

Substituting the area into the resistance formula shows that resistance is inversely proportional to the square of the diameter:

$$R = \rho \frac{L}{(\pi d^2/4)} \implies R \propto \frac{1}{d^2}$$

Step 3: Detailed Explanation:

Let the two wires be designated as Wire 1 and Wire 2. We are given the following information:

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We want to find the ratio of their resistances, $\frac{R_1}{R_2}$. Using the resistance formula for both wires:

$$\frac{R_1}{R_2} = \frac{\rho_1 \frac{L_1}{A_1}}{\rho_2 \frac{L_2}{A_2}}$$

Since ρ and L are the same, they cancel out, leaving:

$$\frac{R_1}{R_2} = \frac{A_2}{A_1}$$

Now, substitute the formula for area in terms of diameter:

$$\frac{R_1}{R_2} = \frac{\pi d_2^2/4}{\pi d_1^2/4} = \frac{d_2^2}{d_1^2} = \left(\frac{d_2}{d_1}\right)^2$$

We are given $\frac{d_1}{d_2} = \frac{2}{1}$, which means $\frac{d_2}{d_1} = \frac{1}{2}$. Substituting this value into our ratio:

$$\frac{R_1}{R_2} = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$$

Step 4: Final Answer:

The ratio of the resistances $R_1 : R_2$ is $1 : 4$. This means the thicker wire (d_1) has one-fourth the resistance of the thinner wire (d_2).

Quick Tip: Remember the quick relationship: resistance is inversely proportional to the area ($R \propto 1/A$) and inversely proportional to the square of

the diameter or radius ($R \propto 1/d^2$). If the diameter is doubled, the resistance becomes one-fourth.

2(d). What is meant by threshold wavelength in photoelectric effect?

Correct Answer: —

Solution:

Step 1: Understanding the Concept:
The photoelectric effect is the phenomenon where electrons are ejected from a metal surface when light shines on it. According to quantum theory, light consists of packets of energy called photons. For an electron to be ejected, it must absorb a photon with enough energy to overcome the binding force holding it to the metal. This minimum energy required for ejection is called the work function (Φ) of the material.

Step 2: Key Formula or Approach:
The energy of a single photon (E) is given by the Planck-Einstein relation:

$$E = hf = \frac{hc}{\lambda}$$

where h is Planck's constant, c is the speed of light, f is the frequency, and λ is the wavelength of the light. For the photoelectric effect to occur, the energy of the incident photon must be greater than or equal to the work function:

$$E \geq \Phi \text{or} \frac{hc}{\lambda} \geq \Phi$$

Step 3: Detailed Explanation:

The condition for photoemission, $\frac{hc}{\lambda} \geq \Phi$, reveals an important relationship between wavelength and electron emission. Since wavelength λ is in the denominator, a larger wavelength corresponds to lower photon energy. This implies that there is a maximum wavelength beyond which the photon energy will be insufficient to overcome the work function. This maximum possible wavelength for which photoemission can occur is called the **threshold wavelength**, denoted by λ_0.

The threshold wavelength corresponds to the exact point where the photon energy is just equal to the work function:

$$E = \Phi \implies \frac{hc}{\lambda_0} = \Phi$$

If the incident light has a wavelength $\lambda > \lambda_0$, its photons will have less energy than the work function ($E < \Phi$), and no electrons will be emitted, no matter how intense the light is.

Step 4: Final Answer:

The **threshold wavelength (λ_0)** is defined as the maximum wavelength of incident radiation that can cause the photoelectric effect for a specific material. It is a characteristic property of the material and is related to its work function by $\lambda_0 = hc/\Phi$.

Quick Tip: A common point of confusion is the difference between threshold frequency and threshold wavelength. Remember their inverse relationship: \begin{itemize} \item **Threshold Frequency (f_0)**: The *minimum* frequency required for photoemission. \item **Threshold Wavelength (λ_0)**: The *maximum* wavelength that allows photoemission. \end{itemize}

2(e). i current is flowing in a wire shown in figure. What will be the value of magnetic field at O of semi-circle :
(i) Due to each length *l* of straight portion, (ii) Due to radius R of semi-circle ?
\includegraphics[width=0.5\linewidth]{1.png}

Correct Answer: —

Solution:

The total magnetic field at point O is the vector sum of the magnetic fields produced by the three sections of the wire: the two straight portions and the semi-circular portion.

(i) Magnetic Field due to Straight Portions

Step 1: Understanding the Concept:
The magnetic field produced by a current-carrying wire can be calculated using the Biot-Savart Law. This law relates the magnetic field to the current element, its length, and the position vector to the point of interest.

Step 2: Key Formula or Approach:
The Biot-Savart Law is given by:

$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{i(d\vec{l} \times \hat{r})}{r^2}$$

Here, $d\vec{l}$ is the vector representing the current element and $\hat{r}$ is the unit vector pointing from the current element to the point O where the field is being calculated.

Step 3: Detailed Explanation:
For both straight portions of the wire, the point O lies on the axis of the wire. This means for any current element $d\vec{l}$ on the straight wires,

the position vector $\vec{r}$ pointing to O is either parallel (angle of 0°) or anti-parallel (angle of 180°) to $d\vec{l}$.
The cross product $d\vec{l} \times \hat{r}$ has a magnitude of $|d\vec{l}||\hat{r}| \sin\theta = dl \cdot 1 \cdot \sin\theta$.
Since $\theta = 0°$ or $\theta = 180°$, $\sin\theta = 0$.
Therefore, the cross product is zero, and the magnetic field contribution from both straight portions at point O is zero.

$$\vec{B}_{\text{straight}} = 0$$

(ii) Magnetic Field due to Semi-circular Portion

Step 1: Understanding the Concept:
A current flowing through a circular arc produces a magnetic field at the center of the arc. The magnitude of this field is proportional to the current and the angle subtended by the arc at the center.

Step 2: Key Formula or Approach:
The magnetic field at the center of a full circular loop of radius R carrying current i is:

$$B_{\text{full circle}} = \frac{\mu_0 i}{2R}$$

A semi-circle is half of a full circle, so it subtends an angle of π radians at the center. The field it produces will be half of that of a full circle.

Step 3: Detailed Explanation:
The magnetic field due to the semi-circular portion of radius R is:

$$B_{\text{semi-circle}} = \frac{1}{2} \times B_{\text{full circle}} = \frac{1}{2}\left(\frac{\mu_0 i}{2R}\right)$$

$$B_{\text{semi-circle}} = \frac{\mu_0 i}{4R}$$

Direction: To find the direction of the magnetic field, we use the Right-Hand Grip Rule. If we curl the fingers of our right hand in the

direction of the current in the semi-circle (counter-clockwise in the diagram provided, although the arrows suggest a left-to-right flow), the thumb points in the direction of the magnetic field. For the current shown flowing from left to right, the thumb points into the plane of the page.

Step 4: Final Answer:
(i) The magnetic field at O due to each straight portion is **zero**.
(ii) The value of the magnetic field at O due to the semi-circle of radius R is $\frac{\mu_0 i}{4R}$, directed into the plane of the page.

Quick Tip: When calculating magnetic fields from complex wire shapes, always break the wire into simpler geometric segments (straight lines, arcs). Calculate the field from each segment and then add them vectorially. Remember that for any point lying on the extended line of a straight current-carrying wire, the magnetic field is zero.

2(f). What do you understand by coherent source?

Correct Answer: —

Solution:

Step 1: Understanding the Concept:
Coherent sources are a fundamental requirement for observing a stable interference pattern when two or more waves superpose. Interference is the phenomenon where waves combine to form a resultant wave of greater, lower, or the same amplitude. For this pattern to be stationary and observable, the sources of the waves must be "coherent."

Step 2: Detailed Explanation:

Two sources of waves are said to be coherent if they satisfy two conditions:

\begin{enumerate} \item **Same Frequency:** The waves emitted by the sources must have the same frequency and wavelength. If the frequencies are different, the phase relationship between the waves will change rapidly, and a stable interference pattern will not be formed.

\item **Constant Phase Difference:** The waves emitted by the sources must have a phase difference that is constant over time. It does not have to be zero, but it must not change. If the phase difference varies randomly, the positions of maximum and minimum intensity (crests and troughs) will shift randomly, and the interference pattern will be washed out.

\end{enumerate} In summary, coherent sources are sources that emit waves of the same frequency and with a constant phase difference between them.

Step 3: Importance and Examples:

Importance: Coherence is essential for producing a stable, visible interference pattern. Incoherent sources, like two independent light bulbs, emit waves with random and rapidly changing phase differences, so no sustained interference pattern can be observed.

Examples: In practice, coherent sources are usually derived from a single parent source. For instance, in Young's Double-Slit Experiment, a single light source illuminates two narrow, closely spaced slits. These two slits then act as two new, perfectly coherent sources because the light waves emerging from them originate from the same initial wavefront. Lasers are also excellent examples of sources that produce highly coherent light.

Step 4: Final Answer:
Coherent sources are two or more sources of waves that emit waves having the same frequency and a constant phase difference. These two conditions are necessary for the formation of a sustained and observable interference pattern.

Quick Tip: A simple way to remember the conditions for coherence is "Same Frequency, Constant Phase". These two properties ensure that the interference pattern (the bright and dark fringes in the case of light) does not move or flicker, making it observable.

3(a). What are the electromagnetic waves? Write down its characteristics.

Correct Answer: —

Solution:

Step 1: Understanding the Concept:
Electromagnetic (EM) waves are a form of energy that propagates through space. They are produced by the acceleration of electric charges. As predicted by Maxwell's equations, these waves consist of synchronized oscillations of electric and magnetic fields.

Step 2: Detailed Explanation:
Definition:
Electromagnetic waves are disturbances consisting of time-varying electric and magnetic fields that are perpendicular to each other and also perpendicular to the direction of propagation of the wave. This makes them transverse waves.

Characteristics of Electromagnetic Waves:

\begin{enumerate} \item **Transverse Nature:** The electric field ($\vec{E}$) and magnetic field ($\vec{B}$) vectors are mutually perpendicular to each other and also perpendicular to the direction of wave propagation.

\item **No Medium Required:** They do not require a material medium for their propagation and can travel through a vacuum.

\item **Speed in Vacuum:** All electromagnetic waves travel through a vacuum at a constant speed, known as the speed of light, $c \approx 3 \times 10^8$ m/s. The speed is given by the relation $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$, where μ_0 is the permeability and ϵ_0 is the permittivity of free space.

\item **Energy and Momentum:** They carry energy and momentum. The energy is shared equally between the oscillating electric and magnetic fields. When they strike a surface, they exert pressure, known as radiation pressure.

\item **In-Phase Oscillation:** The electric and magnetic fields oscillate in the same phase. They reach their maximum and minimum values at the same time and place.

\item **Unaffected by External Fields:** Since they are composed of oscillating fields and are not charged particles, they are not deflected by external static electric or magnetic fields.

\item **Wave Phenomena:** They exhibit all the properties of waves, such as reflection, refraction, interference, diffraction, and polarization.

\end{enumerate}

Quick Tip: A key takeaway is the transverse nature: E, B, and the direction of travel are all mutually perpendicular. This is a defining feature that distinguishes EM waves from longitudinal waves like sound.

3(b). The energy of electron in an excited hydrogen atom is -3.4 eV. Determine the angular momentum of this electron.

Correct Answer: —

Solution:

Step 1: Understanding the Concept:

This problem combines two key principles of the Bohr model for the hydrogen atom: the formula for quantized energy levels and the postulate for quantized angular momentum. First, we must identify the principal quantum number (n) of the electron's orbit from its given energy. Then, we can use this value of n to calculate the angular momentum.

Step 2: Key Formula or Approach:

1. The energy (E_n) of an electron in the n^{th} orbit of a hydrogen atom is given by:

$$E_n = -\frac{13.6}{n^2} \text{ eV}$$

2. The angular momentum (L_n) of an electron in the n^{th} orbit is quantized according to Bohr's second postulate:

$$L_n = n\frac{h}{2\pi}$$

where h is Planck's constant ($h \approx 6.626 \times 10^{-34}$ J·s).

Step 3: Detailed Explanation:

Part 1: Find the Principal Quantum Number (n)

We are given the energy of the electron, $E_n = -3.4$ eV. We can use the energy formula to find n:

$$-3.4 = -\frac{13.6}{n^2}$$

$$n^2 = \frac{13.6}{3.4} = 4$$

Taking the square root, we get:

$$n = 2$$

This means the electron is in the first excited state ($n = 2$).

Part 2: Calculate the Angular Momentum (L)

Now that we have $n = 2$, we can calculate the angular momentum using Bohr's quantization rule:

$$L_2 = 2 \times \frac{h}{2\pi} = \frac{h}{\pi}$$

Substituting the value of Planck's constant:

$$L_2 = \frac{6.626 \times 10^{-34}\ \text{J·s}}{3.14159}$$

$$L_2 \approx 2.11 \times 10^{-34}\ \text{J·s}$$

Step 4: Final Answer:

The angular momentum of the electron is approximately 2.11×10^{-34} J·s.

Quick Tip: It is useful to memorize the energies of the first few levels of the hydrogen atom: $E_1 = -13.6$ eV, $E_2 = -3.4$ eV, $E_3 = -1.51$ eV. Recognizing that -3.4 eV corresponds to the n=2 level can save you time on calculations.

3(c). How will you detect plane polarized light by polaroid?

Correct Answer: –

Solution:

Step 1: Understanding the Concept:
Plane polarized light is light in which the electric field vibrations are confined to a single plane. Unpolarized light has vibrations in all possible planes perpendicular to the direction of propagation. A Polaroid is an optical filter that has a "transmission axis" and only allows the component of light polarized parallel to this axis to pass through. This property can be used to analyze an unknown light beam.

Step 2: Key Formula or Approach:
The detection method is based on Malus's Law, which describes the intensity of light transmitted through a Polaroid (acting as an analyzer):

$$I = I_{max} \cos^2 \theta$$

where I is the transmitted intensity, I_{max} is the maximum transmitted intensity (when the analyzer's axis is aligned with the light's polarization), and θ is the angle between the analyzer's transmission axis and the plane of polarization of the incident light.

Step 3: Detailed Explanation:
The procedure to detect plane polarized light is as follows:
\begin{enumerate} \item **Setup:** Place a Polaroid, which will serve as an analyzer, in the path of the light beam being tested. \item **Action:** Rotate the Polaroid analyzer slowly through a full 360° rotation about the axis of the light beam. \item **Observation:** Observe the intensity of the light transmitted through the Polaroid. \item **Conclusion:**
\begin{itemize} \item If the light is **plane polarized**, the intensity of

the transmitted light will vary significantly during the rotation. It will change from a maximum value to a minimum value of zero, twice in one full rotation. The intensity is maximum when the Polaroid's axis is parallel to the light's polarization plane ($\theta = 0°$) and zero when it is perpendicular ($\theta = 90°$). \item If the light is **unpolarized**, the intensity of the transmitted light will remain constant as the Polaroid is rotated. \item If the light is **partially polarized**, the intensity will vary between a maximum and a non-zero minimum during rotation. \end{itemize} \end{enumerate}

Step 4: Final Answer:

To detect plane polarized light, one must rotate a Polaroid in its path. If the transmitted light intensity varies and becomes zero at two positions during one complete rotation, the incident light is confirmed to be plane polarized.

Quick Tip: The key to this detection method is the **rotation** of the analyzer. The signature of plane polarized light is the complete extinction (intensity becomes zero) at two specific orientations of the analyzer, 180° apart.

3(d). Electron is moving with speed of 2×10^6 m/s in an orbit of radius 5.0×10^{-11} metre in hydrogen atom. Determine the magnetic moment of rotating electron.

Correct Answer: —

Solution:

Step 1: Understanding the Concept:

An electron revolving in a circular orbit is equivalent to a tiny current loop. According to Ampere's law, any current loop produces a magnetic field and has an associated magnetic dipole moment. The magnitude of this magnetic moment depends on the equivalent current and the area of the loop.

Step 2: Key Formula or Approach:

1. The magnetic dipole moment (μ) of a current loop is given by $\mu = iA$, where i is the current and A is the area of the loop.
2. The equivalent current i produced by an electron (charge e) revolving with a time period T is $i = \frac{e}{T}$.
3. The time period of revolution is the circumference of the orbit divided by the speed: $T = \frac{2\pi r}{v}$.

Combining these formulas, we get an expression for the magnetic moment:

$$\mu = iA = \left(\frac{e}{T}\right)(\pi r^2) = \left(\frac{e}{2\pi r/v}\right)(\pi r^2) = \frac{evr}{2}$$

Step 3: Detailed Explanation:

We are given the following values:

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Now, we substitute these values into the derived formula for magnetic moment:

$$\mu = \frac{evr}{2}$$

$$\mu = \frac{(1.6 \times 10^{-19}\ \text{C}) \times (2 \times 10^{6}\ \text{m/s}) \times (5.0 \times 10^{-11}\ \text{m})}{2}$$

$$\mu = \frac{1.6 \times 2 \times 5.0}{2} \times 10^{-19+6-11}\ \text{A}\cdot\text{m}^2$$

$$\mu = 8.0 \times 10^{-24}\ \text{A}\cdot\text{m}^2$$

Step 4: Final Answer:

The magnetic moment of the rotating electron is $8.0 \times 10^{-24}\ \text{A}\cdot\text{m}^2$.

Quick Tip: The formula $\mu = \frac{evr}{2}$ is very useful. It can also be related to the orbital angular momentum $L = mvr$. The ratio $\frac{\mu}{L} = \frac{evr/2}{mvr} = \frac{e}{2m}$ is called the gyromagnetic ratio, a fundamental constant for an electron's orbital motion.

4(a). Obtain the expression for capacity of a parallel plate capacitor. How the capacity will be increased?

Correct Answer: —

Solution:

Step 1: Understanding the Concept:

A parallel plate capacitor consists of two large, flat, parallel conducting plates, each with an area A, separated by a small distance d. Capacitance (C) is a measure of its ability to store electric charge, defined as the ratio of the charge (Q) on one plate to the potential difference (V) between the plates.

Step 2: Derivation of the Expression:

Let the two plates of the capacitor have a surface charge density of $+\sigma$ and $-\sigma$. The charge on each plate is $Q = \sigma A$.

Assuming the distance d is small compared to the dimensions of the plates, the electric field (E) between them is uniform and is given by:

$$E = \frac{\sigma}{\epsilon_0} = \frac{Q}{A\epsilon_0}$$

where ϵ_0 is the permittivity of free space.
The potential difference (V) between the plates is the work done in moving a unit charge from one plate to another, which is $V = E \times d$.

$$V = \left(\frac{Q}{A\epsilon_0}\right) d = \frac{Qd}{A\epsilon_0}$$

The capacitance C is defined as $C = \frac{Q}{V}$. Substituting the expression for V:

$$C = \frac{Q}{\frac{Qd}{A\epsilon_0}} = \frac{A\epsilon_0}{d}$$

This is the expression for the capacitance of a parallel plate capacitor with a vacuum (or air) between the plates.
If a dielectric material with a dielectric constant K is inserted between the plates, the capacitance becomes:

$$C = \frac{KA\epsilon_0}{d}$$

Step 3: How to Increase the Capacity:
Based on the formula $C = \frac{KA\epsilon_0}{d}$, the capacitance can be increased in the following ways: \begin{enumerate} \item **By increasing the area of the plates (A):** Capacitance is directly proportional to the area of the plates. \item **By decreasing the distance between the plates (d):** Capacitance is inversely proportional to the separation between the plates. \item **By introducing a dielectric medium:** Inserting a dielectric material with a high dielectric constant (K > 1) between the plates increases the capacitance by a factor of K. \end{enumerate}

Quick Tip: Remember the three factors affecting capacitance: Area, Distance, and Medium. An easy way to recall this is the formula $C = \frac{KA\epsilon_0}{d}$. To

increase C, you increase the numerator factors (K, A) or decrease the denominator factor (d).

4(b). Two rail tracks are isolated with each other and on the ground as well. They are connected with a milivoltmeter. What will be the reading in milivoltmeter when a train run at the speed of 180 km/hour on it? Given that the vertical component of earth's field is 0.2×10^{-4} weber/m^2 and tracks are 1 m distance apart with each other.

Correct Answer: —

Solution:

Step 1: Understanding the Concept:
This problem describes the phenomenon of motional electromotive force (EMF). When a conductor moves through a magnetic field, an EMF is induced across its ends. Here, the axle of the train acts as the conductor, moving horizontally, and it cuts through the vertical component of the Earth's magnetic field. This induced EMF will be measured by the milivoltmeter.

Step 2: Key Formula or Approach:
The motional EMF (ϵ) induced in a conductor of length l moving with velocity v perpendicular to a magnetic field B is given by:

$$\epsilon = B_v l v$$

where B_v is the component of the magnetic field perpendicular to both the length and the velocity. In this case, it is the vertical component of the Earth's magnetic field.

Step 3: Detailed Explanation:

First, we need to ensure all units are in the SI system. \begin{itemize} \item **Velocity (v):** The speed of the train is given as 180 km/hour.

$$v = 180\,\frac{\text{km}}{\text{hour}} \times \frac{1000\,\text{m}}{1\,\text{km}} \times \frac{1\,\text{hour}}{3600\,\text{s}} = 50\,\text{m/s}$$

\item **Magnetic Field (B_v):** The vertical component is $B_v = 0.2 \times 10^{-4}$ weber/m^2 = 0.2×10^{-4} Tesla (T). \item **Length (l):** The distance between the tracks, which is the length of the conductor (axle), is $l = 1$ m. \end{itemize} Now, we can calculate the induced EMF:

$$\epsilon = (0.2 \times 10^{-4}\,\text{T}) \times (1\,\text{m}) \times (50\,\text{m/s})$$

$$\epsilon = (0.2 \times 50) \times 10^{-4}\,\text{V}$$

$$\epsilon = 10 \times 10^{-4}\,\text{V} = 1.0 \times 10^{-3}\,\text{V}$$

Since 1 millivolt (mV) = 10^{-3} V, the induced EMF is:

$$\epsilon = 1.0\,\text{mV}$$

Step 4: Final Answer:

The reading in the milivoltmeter will be 1.0 mV.

Quick Tip: In motional EMF problems ($\epsilon = Blv$), always ensure that B, l, and v are mutually perpendicular. If they are not, you must use the appropriate components. In this problem, the train's velocity is horizontal, the axle is horizontal, and the vertical component of the magnetic field is used, fulfilling the perpendicularity condition.

4(c). What is the meaning of wavefront? Explain reflection of light by the Huygen's wave theory.

Correct Answer: —

Solution:

Meaning of Wavefront:
A wavefront is defined as the locus of all points in a medium that are vibrating in the same phase. For example, if you drop a stone in a pond, the ripples spread out in circles; each circle represents a wavefront where all particles are at the same stage of their oscillation.

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The direction of wave propagation is always perpendicular to the wavefront.

Explanation of Reflection using Huygen's Theory:
Huygen's principle states that every point on a wavefront acts as a source of secondary spherical wavelets. The new wavefront at any later time is the forward envelope (tangent) of these secondary wavelets. Let's use this to prove the law of reflection ($i = r$).

Explanation:

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Proof of Law of Reflection: Consider the two right-angled triangles, $\triangle ABC$ and $\triangle ADC$.

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By the Right-angle-Hypotenuse-Side (RHS) congruence criterion, $\triangle ABC \cong \triangle ADC$. Therefore, the corresponding angles must be equal.

$$\angle BAC = \angle DCA$$

From the geometry of the diagram, $\angle BAC = i$ (angle of incidence) and $\angle DCA = r$ (angle of reflection).

$$i = r$$

This proves the law of reflection.

Quick Tip: When drawing the diagram for Huygen's proof of reflection or refraction, the key is to correctly identify the distances traveled by the wavelets in the given time. For reflection, the speed is the same, so $BC = AD$. For refraction, the speeds are different, so the radii of the wavelets will be different.

4(d). The resistance of p-n junction diode in forward bias is 25 ohm. How much voltage in forward bias be changed so that the change in current would be 2 mA?

Correct Answer: —

Solution:

Step 1: Understanding the Concept:
The resistance of a p-n junction diode in forward bias mentioned here is the dynamic or AC resistance (R_f). It is not the static resistance (V/I), but rather the ratio of a small change in voltage across the diode to the resulting small change in the current flowing through it.

Step 2: Key Formula or Approach:
The dynamic forward resistance (R_f) is defined by the relation:

$$R_f = \frac{\Delta V_f}{\Delta I_f}$$

where ΔV_f is the change in forward bias voltage and ΔI_f is the corresponding change in forward current. We need to find ΔV_f.

Step 3: Detailed Explanation:

We are given the following values:

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Rearranging the formula to solve for the change in voltage ΔV_f:

$$\Delta V_f = R_f \times \Delta I_f$$

Substituting the given values:

$$\Delta V_f = (25\,\Omega) \times (2 \times 10^{-3}\,\text{A})$$

$$\Delta V_f = 50 \times 10^{-3}\,\text{V}$$

$$\Delta V_f = 0.05\,\text{V}$$

Step 4: Final Answer:

The forward bias voltage should be changed by 0.05 Volts.

Quick Tip: For diode problems, always be careful to distinguish between static resistance ($R = V/I$) and dynamic resistance ($R = \Delta V/\Delta I$). Dynamic resistance is relevant for small signal AC analysis, as in this question. Also, remember to convert units like mA and kΩ to base SI units (A and Ω) before calculation.

4(e). What is meant by Wattless current? A capacitor of 15 μF is connected to an AC source of 220 V and 50 Hz. Find out reactance of circuit and rms value of AC current.

Correct Answer: —

Solution:

Meaning of Wattless Current:

Wattless current is the component of an alternating current in a circuit that does not contribute to the average power consumed over a full cycle. The average power in an AC circuit is given by $P_{\text{avg}} = V_{\text{rms}} I_{\text{rms}} \cos\phi$, where ϕ is the phase angle between the voltage and current. If the phase angle ϕ is 90° (as in a purely inductive or purely capacitive circuit), then $\cos\phi = \cos(90°) = 0$. This makes the average power consumed zero. The current that flows in such a circuit is called wattless current because it flows without any net dissipation of power. It corresponds to the component of current that is in quadrature (90° out of phase) with the voltage.

Calculations:

Step 1: Understanding the Concept and Formulas:

We have a purely capacitive AC circuit. We need to find the capacitive reactance (X_C), which is the opposition to the current flow, and then use Ohm's law for AC circuits to find the RMS current (I_{rms}).

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Step 2: Detailed Explanation:

We are given:

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Part 1: Calculate the Reactance (X_C) of the circuit

$$X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi(50)(15 \times 10^{-6})}$$

$$X_C = \frac{1}{100\pi \times 15 \times 10^{-6}} = \frac{1}{1500\pi \times 10^{-6}} = \frac{10^6}{1500\pi}$$

Using $\pi \approx 3.14159$:

$$X_C \approx \frac{1,000,000}{1500 \times 3.14159} \approx \frac{1,000,000}{4712.385} \approx 212.2\,\Omega$$

Part 2: Calculate the RMS value of AC current (I_{rms})

$$I_{\text{rms}} = \frac{V_{\text{rms}}}{X_C} = \frac{220\,\text{V}}{212.2\,\Omega}$$

$$I_{\text{rms}} \approx 1.037\,\text{A}$$

Step 3: Final Answer:

The reactance of the circuit is approximately **212.2 Ω**, and the rms value of the AC current is approximately **1.04 A**.

Quick Tip: Remember the mnemonics for phase in AC circuits: "ELI the ICE man". For an inductor (L), EMF (E) leads Current (I). For a capacitor (C), Current (I) leads EMF (E). This helps you remember that for a capacitor, current leads voltage by 90°, which is why the current is wattless in a purely capacitive circuit.

5(a). Write the principle and working of alternating current generator.

Correct Answer: —

Solution:

Step 1: Principle of an AC Generator:
The working principle of an AC generator is **electromagnetic induction**. It states that whenever the magnetic flux linked with a coil changes, an electromotive force (EMF) is induced in the coil. If the coil is part of a closed circuit, this induced EMF drives a current through it.

Step 2: Construction:
An AC generator consists of the following main parts: \begin{itemize} \item **Armature Coil (ABCD):** A rectangular coil with a large number of turns of insulated copper wire wound on a soft iron core. \item **Field Magnets (N, S):** Strong permanent magnets or electromagnets that produce a uniform magnetic field. \item **Slip Rings (R_1, R_2):** Two hollow metallic rings to which the ends of the armature coil are connected. They rotate along with the coil. \item **Brushes (B_1, B_2):** Two flexible carbon brushes that are kept in light contact with the rotating slip rings. They are used to pass the current from the coil to the external circuit. \end{itemize}

Step 3: Working:
\begin{enumerate} \item The armature coil is rotated mechanically in the magnetic field. As it rotates, the angle between the plane of the coil and the magnetic field lines changes continuously. \item This continuous change in orientation causes the magnetic flux ($\Phi = NBA\cos\theta$) linked with the coil to change. \item According to Faraday's law of induction, this change in flux induces an EMF in the coil. The direction of the induced current is given by Fleming's Right-Hand Rule. \item **First Half Rotation:** As the coil rotates, let's say arm AB moves downwards and arm CD moves upwards. The induced

current flows from A to B and from C to D. The current flows out through brush B_1 and into the circuit, returning through brush B_2. \item **Second Half Rotation:** Arm AB now moves upwards, and arm CD moves downwards. The direction of the induced current in the arms reverses (now from B to A and D to C). The current now flows out through brush B_2 and returns through brush B_1. \item Since the direction of the current in the external circuit reverses after every half rotation, an alternating current is produced. The magnitude of the induced EMF is sinusoidal, given by $\epsilon = \epsilon_0 \sin(\omega t)$. \end{enumerate}

Quick Tip: The key difference between an AC and a DC generator lies in how the current is extracted. AC generators use two separate slip rings, while DC generators use a single split-ring commutator to reverse the connection every half-turn, keeping the current in the external circuit flowing in one direction.

5(b). A convex lens of focal length f is placed somewhere between object and screen. The distance between object and screen is x. If m be the magnification of lens, then prove that \(f = \frac{mx}{(m + 1)^2\).}

Correct Answer: —

Solution:

Step 1: Understanding the Concept and Variables:
We are considering a real image formed by a convex lens on a screen.

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Step 2: Key Formula or Approach:

The thin lens formula connects the object distance, image distance, and focal length. For a real image formed by a convex lens, using sign convention (u is negative, v is positive), the formula $\frac{1}{v} - \frac{1}{(-u)} = \frac{1}{f}$ becomes:

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

where u and v are magnitudes.

Step 3: Detailed Explanation (Derivation):

From the magnification formula, we have $v = mu$.

Substitute this into the distance equation $x = u + v$:

$$x = u + mu = u(1 + m)$$

From this, we can express the object distance u in terms of x and m:

$$u = \frac{x}{m+1}$$

Now, we can find the image distance v:

$$v = mu = m\left(\frac{x}{m+1}\right) = \frac{mx}{m+1}$$

Now, substitute the expressions for u and v into the lens formula:

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u} = \frac{1}{\frac{mx}{m+1}} + \frac{1}{\frac{x}{m+1}}$$

$$\frac{1}{f} = \frac{m+1}{mx} + \frac{m+1}{x}$$

Take $\frac{m+1}{x}$ as a common factor:

$$\frac{1}{f} = \frac{m+1}{x}\left(\frac{1}{m}+1\right)$$

$$\frac{1}{f} = \frac{m+1}{x}\left(\frac{1+m}{m}\right) = \frac{(m+1)^2}{mx}$$

Finally, inverting the expression to find f:

$$f = \frac{mx}{(m+1)^2}$$

Hence, the relation is proved.

Quick Tip: This is a standard result in optics. A key step in such derivations is to express the object distance (u) and image distance (v) in terms of the given variables (x and m) before substituting them into the lens formula.

5(c). What is meant by polarization of light? Describe a method to obtain plane polarized light by reflection.

Correct Answer: —

Solution:

Meaning of Polarization of Light:

Light is a transverse electromagnetic wave, which means the oscillations of its electric field vector occur in a plane perpendicular to the direction of wave propagation. Ordinary (unpolarized) light consists of waves with electric field vectors vibrating in all possible directions in this plane. **Polarization** is the phenomenon of restricting these vibrations of the electric field vector to a single

direction (or plane). The resulting light is called plane-polarized or linearly polarized light.

Method to Obtain Plane Polarized Light by Reflection:

Plane polarized light can be obtained from unpolarized light using the phenomenon of reflection, based on a principle discovered by David Brewster.

Principle (Brewster's Law): When unpolarized light is incident on the boundary between two transparent media (e.g., air and glass), the reflected light becomes completely plane-polarized if the angle of incidence is equal to a specific angle called the **polarizing angle** or **Brewster's angle** (i_p).

Description of the Method:

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Therefore, by making unpolarized light incident on a transparent surface at Brewster's angle, we can obtain a completely plane-polarized reflected beam.

Quick Tip: To remember the orientation of polarization by reflection, think of the electric field vibrations as arrows. The vibrations parallel to the surface are more likely to be transmitted/refracted, while those perpendicular to the plane of incidence are more easily reflected. This is why sunglasses with Polaroid filters are effective at reducing glare from horizontal surfaces like water or roads.

5(d). Obtain the formula for work done by an electric dipole in rotating θ from equilibrium in a uniform electric field.

Correct Answer: —

Solution:

Step 1: Understanding the Concept:

When an electric dipole with dipole moment $\vec{p}$ is placed in a uniform electric field $\vec{E}$, it experiences a torque that tries to align it with the field. To rotate the dipole from its equilibrium position, external work must be done against this restoring torque. This work is stored as potential energy in the dipole.

Step 2: Key Formula or Approach:

The torque (τ) experienced by the dipole is given by $\tau = pE\sin\theta$, where θ is the angle between $\vec{p}$ and $\vec{E}$.

The work done (dW) in rotating the dipole through a small angle $d\theta$ is $dW = \tau d\theta$.

To find the total work done, we must integrate this expression from the initial position to the final position.

Step 3: Detailed Explanation (Derivation):

The equilibrium position for a dipole is when it is aligned with the electric field, so the initial angle is $\theta_1 = 0°$. We want to find the work done in rotating it to a final angle $\theta_2 = \theta$. The total work done W is:

$$W = \int_{\theta_1}^{\theta_2} dW = \int_0^{\theta} \tau d\theta'$$

Substitute the expression for torque:

$$W = \int_0^{\theta} pE\sin\theta' d\theta'$$

Since p and E are constant:

$$W = pE\int_0^{\theta} \sin\theta' d\theta'$$

Performing the integration:

$$W = pE[-\cos\theta']_0^{\theta} = pE[(-\cos\theta) - (-\cos 0)]$$

Since $\cos 0 = 1$:

$$W = pE(-\cos\theta + 1)$$

$$W = pE(1 - \cos\theta)$$

Step 4: Final Answer:

The formula for the work done in rotating an electric dipole by an angle θ from its equilibrium position is $W = pE(1 - \cos\theta)$.

Quick Tip: remember that work done equals the change in potential energy ($W = \Delta U$). Since $U = -pE\cos\theta$, the work done from 0 to θ is $U(\theta) - U(0)$ $= -pE\cos\theta - (-pE\cos 0) = pE(1 - \cos\theta)$.

OR

An electron in hydrogen atom is moving round the nucleus with speed 2.2×10^6 m/s in an orbit of radius 5×10^{-11} meter. Find the value of equivalent electric current.

Correct Answer: —

Solution:

Step 1: Understanding the Concept:

An electron revolving in a circular orbit behaves like a tiny current loop. The equivalent electric current is defined as the total charge that passes through any point on the orbit per unit time.

Step 2: Key Formula or Approach:

The equivalent current I is given by:

$$I = \frac{\text{Charge}}{\text{Time Period}} = \frac{e}{T}$$

The time period T for one revolution is the circumference of the orbit divided by the electron's speed v:

$$T = \frac{2\pi r}{v}$$

Combining these gives the formula for the current:

$$I = \frac{e}{(2\pi r/v)} = \frac{ev}{2\pi r}$$

Step 3: Detailed Explanation (Calculation):

We are given the following values:

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Substitute these values into the formula for current:

$$I = \frac{(1.6 \times 10^{-19}\ \text{C}) \times (2.2 \times 10^{6}\ \text{m/s})}{2\pi \times (5 \times 10^{-11}\ \text{m})}$$

$$I = \frac{3.52 \times 10^{-13}}{10\pi \times 10^{-11}} = \frac{3.52 \times 10^{-13}}{31.416 \times 10^{-11}}$$

$$I = \frac{3.52}{31.416} \times 10^{-2}\ \text{A} \approx 0.112 \times 10^{-2}\ \text{A}$$

$$I \approx 1.12 \times 10^{-3}\ \text{A} = 1.12\ \text{mA}$$

Step 4: Final Answer:

The value of the equivalent electric current is approximately 1.12×10^{-3} A or 1.12 mA.

Quick Tip: For the current problem, the concept is simple: current is charge flow per second. Find how many times the electron circles per second

(the frequency $f = v/2\pi r$) and multiply by its charge ($I = ef$).

5(e). Write the Kirchhoff's law of voltage and current.

Correct Answer: —

Solution:

Gustav Kirchhoff formulated two fundamental laws that are essential for analyzing complex electrical circuits.
1. Kirchhoff's First Law (Kirchhoff's Current Law - KCL or the Junction Rule):
\begin{itemize} \item **Statement:** The algebraic sum of the electric currents meeting at any junction (or node) in an electrical circuit is zero. \item **Mathematical Form:**

$$\sum_{\text{junction}} I = 0$$

\item **Explanation:** This law is a direct consequence of the **law of conservation of electric charge**. Charge cannot be created, destroyed, or accumulated at a junction. Therefore, the total rate at which charge enters a junction must be equal to the total rate at which charge leaves it. \item **Sign Convention:** Currents entering a junction are typically taken as positive, while currents leaving the junction are taken as negative (or vice versa, as long as the convention is consistent). \end{itemize} **2. Kirchhoff's Second Law (Kirchhoff's Voltage Law - KVL or the Loop Rule):**
\begin{itemize} \item **Statement:** The algebraic sum of the changes in potential (or voltage drops and EMFs) around any closed loop or mesh in an electrical circuit is zero. \item **Mathematical Form:**

$$\sum_{\text{closed loop}} \Delta V = 0$$

\item **Explanation:** This law is based on the **law of conservation of energy**. The electric force is a conservative force. This means that if an electric charge is moved around any closed path and returns to its starting point, the net work done on it is zero. Consequently, its net change in potential energy, and therefore electric potential, is also zero. \item **Sign Convention:** When traversing a loop, the potential difference across a resistor is taken as negative if moving in the direction of the current and positive if moving against it. The EMF of a source is taken as positive if moving from the negative to the positive terminal and negative if moving from positive to negative. \end{itemize}

Quick Tip: A simple way to remember the basis of each law: \begin{itemize} \item **KCL (Junctions):** Conservation of **C**harge. \item **KVL (Loops):** Conservation of **E**nergy (Voltage is potential energy per unit charge). \end{itemize} Always apply a consistent sign convention when using KVL to avoid errors.

6. How does the p-n junction diode is used as the half wave rectifier ? Explain its working by drawing simple circuit.

Correct Answer: —

Solution:

Step 1: Understanding the Concept:

Rectification is the process of converting an alternating current (AC)

into a direct current (DC). A half-wave rectifier uses a single p-n junction diode to achieve this. The basic principle is that a p-n diode allows current to flow in only one direction—when it is forward-biased—and blocks current flow in the opposite direction—when it is reverse-biased.

Step 2: Simple Circuit Diagram:

The circuit consists of an AC input source (usually connected via a step-down transformer), a p-n junction diode (D), and a load resistor (R_L) across which the DC output is obtained. \begin{center} *Circuit Diagram: An AC voltage source is connected to the primary coil of a transformer. The secondary coil is connected in series with a p-n diode (D) and a load resistor (R_L). The output voltage is measured across R_L.* \end{center}

Step 3: Working:

The working can be explained by considering the two half-cycles of the input AC voltage. \begin{enumerate} \item **During the Positive Half-Cycle of AC Input:** The upper end of the transformer's secondary coil becomes positive with respect to the lower end. This makes the p-side of the diode positive relative to the n-side, putting the diode in **forward bias**. The diode conducts current, and a current flows through the load resistor R_L. Consequently, a voltage (output) is developed across R_L, which follows the shape of the positive half-cycle of the input. \item **During the Negative Half-Cycle of AC Input:** The polarity of the secondary coil reverses. The upper end becomes negative with respect to the lower end. This makes the p-side of the diode negative relative to the n-side, putting the diode in **reverse bias**. In this state, the diode offers very high resistance and (ideally) does not conduct any current. Therefore, no current flows through R_L, and the output voltage across it is zero. \end{enumerate} This process repeats for every cycle, resulting in an

output voltage that consists only of the positive half-cycles of the original AC input. This output is a pulsating, unidirectional (DC) voltage.

Quick Tip: For the rectifier, remember that the key is the diode's one-way-street behavior for current. The output is "half" of the input wave.

OR

An α-particle accelerated by potential difference of V volt strikes with a nucleus (atomic no. = Z). If r be the nearest distance of the particle to reach the nucleus then prove that : $r = 14.4\frac{Z}{V}$ Å

Correct Answer: —

Solution:

Step 1: Understanding the Concept:

The proof is based on the principle of conservation of energy. An α-particle (charge $q_1 = +2e$) is accelerated by a potential difference V, gaining kinetic energy. As it approaches a positively charged nucleus (charge $q_2 = +Ze$), the electrostatic repulsive force slows it down. The distance of closest approach (r) is the point where the α-particle momentarily stops and turns back. At this point, all of its initial kinetic energy has been converted into electrostatic potential energy of the system.

Step 2: Key Formula or Approach:

1. Kinetic Energy (KE) gained by the α-particle: $KE = q_1V = (2e)V$

2. Electrostatic Potential Energy (PE) at separation r: $PE = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r} = \frac{1}{4\pi\epsilon_0}\frac{(2e)(Ze)}{r}$

By conservation of energy: $KE_{\text{initial}} = PE_{\text{final}}$

Step 3: Detailed Explanation (Derivation):

Equating the initial kinetic energy with the final potential energy:

$$(2e)V = \frac{1}{4\pi\epsilon_0}\frac{2Ze^2}{r}$$

We can cancel $2e$ from both sides:

$$V = \frac{1}{4\pi\epsilon_0}\frac{Ze}{r}$$

Now, we solve for the distance of closest approach, r:

$$r = \left(\frac{1}{4\pi\epsilon_0}\right)\frac{Ze}{V}$$

To get the numerical value, we substitute the known constants:

Unknown environment 'itemize'

$$r = \frac{(9 \times 10^9) \times Z \times (1.6 \times 10^{-19})}{V}$$

$$r = \frac{14.4 \times 10^{-10} \times Z}{V} (\text{in meters})$$

Since 1 Angstrom (Å) = 10^{-10} meters, we can express the distance in Angstroms:

$$r = \frac{14.4 \times Z}{V} \times 10^{-10}\ \text{m} = 14.4\frac{Z}{V}\text{Å}$$

This proves the required relation.

Quick Tip: For the alpha particle problem, energy conservation is the central idea. The conversion of kinetic energy to potential energy is a common theme in collision and scattering problems in both mechanics and electromagnetism.

7. What is the photo-electric effect ? Write its laws. Establish the Einstein's equation of photoelectric effect $\frac{1}{2}mv^2 = h(\nu - \nu_0)$.

Correct Answer: —

Solution:

What is the Photoelectric Effect?

The photoelectric effect is the phenomenon of emission of electrons from a substance (usually a metal) when electromagnetic radiation, such as light, of a sufficiently high frequency is incident upon it. The emitted electrons are called photoelectrons.

Laws of Photoelectric Emission: Based on experimental observations, the laws are: \begin{enumerate} \item For a given material, there exists a certain minimum frequency of incident radiation, called the **threshold frequency** (ν_0), below which no photoelectric emission occurs, no matter how intense the light is. \item The photoelectric emission is an **instantaneous process**. The time lag between the incidence of radiation and the emission of photoelectrons is very small (less than 10^{-9} s). \item The number of photoelectrons emitted per second (which determines the photoelectric current) is directly proportional to the **intensity** of the incident radiation, provided the frequency is above the threshold frequency. \item The maximum kinetic energy of the emitted photoelectrons is independent of the intensity of the incident light but depends linearly on its **frequency**. \end{enumerate} **Einstein's Photoelectric Equation:**

Step 1: Understanding the Concept (Einstein's Postulate):

To explain the photoelectric effect, Einstein proposed that light is quantized and consists of discrete packets of energy called photons.

The energy of each photon is $E = h\nu$, where h is Planck's constant and ν is the frequency of light.

Step 2: Derivation:

When a photon of energy $h\nu$ strikes the metal surface, its energy is used in two parts: \begin{itemize} \item A portion of the energy is used to overcome the surface barrier and free the electron from the metal. This minimum energy required is called the **work function** (Φ_0) of the metal. \item The rest of the photon's energy is imparted to the emitted electron as its maximum kinetic energy (K_{max}). \end{itemize} By the law of conservation of energy:

$$\text{Energy of Photon} = \text{Work Function} + \text{Max. Kinetic Energy of Electron}$$

$$h\nu = \Phi_0 + K_{max}$$

The work function can be expressed in terms of the threshold frequency (ν_0) as $\Phi_0 = h\nu_0$. Substituting this:

$$h\nu = h\nu_0 + K_{max}$$

Rearranging the equation to solve for the kinetic energy:

$$K_{max} = h\nu - h\nu_0 = h(\nu - \nu_0)$$

Since $K_{max} = \frac{1}{2}mv_{max}^2$, where m is the mass of the electron and v_{max} is its maximum velocity, the equation becomes:

$$\frac{1}{2}mv_{max}^2 = h(\nu - \nu_0)$$

This is Einstein's photoelectric equation.

Quick Tip: For the photoelectric effect, remember the energy balance: $E_{photon} = W_{eject} + KE_{electron}$.

OR

Same current in same direction is flowing in two parallel wire with 0.06 metre distance apart with each other. The attractive force per metre length of 3×10^{-3} newton is working between the two. Determine the value of current flowing in each wire.

Correct Answer: —

Solution:

Step 1: Understanding the Concept:

Two long, parallel wires carrying currents exert a magnetic force on each other. The magnetic field produced by one wire interacts with the current in the other wire. When the currents are in the same direction, the force is attractive. The magnitude of this force per unit length is given by a standard formula.

Step 2: Key Formula or Approach:

The force per unit length (F/L) between two parallel wires carrying currents I_1 and I_2 and separated by a distance d is:

$$\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi d}$$

In this problem, the currents are the same, so $I_1 = I_2 = I$. The formula becomes:

$$\frac{F}{L} = \frac{\mu_0 I^2}{2\pi d}$$

Step 3: Detailed Explanation (Calculation):

We are given the following values:

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Substitute these values into the formula and solve for I:

$$3 \times 10^{-3} = \frac{(4\pi \times 10^{-7})I^2}{2\pi(0.06)}$$

Cancel 2π from the numerator and denominator:

$$3 \times 10^{-3} = \frac{2 \times 10^{-7} \times I^2}{0.06}$$

Rearrange to solve for I^2:

$$I^2 = \frac{(3 \times 10^{-3}) \times 0.06}{2 \times 10^{-7}}$$

$$I^2 = \frac{0.18 \times 10^{-3}}{2 \times 10^{-7}} = 0.09 \times 10^4 = 900$$

Take the square root to find the current I:

$$I = \sqrt{900} = 30\,\text{A}$$

Step 4: Final Answer:

The value of the current flowing in each wire is 30 A.

Quick Tip: For the parallel wires, a helpful way to remember the force direction is "like currents attract, unlike currents repel," which is opposite to the rule for static charges.

8. Using monochromatic light of wavelength λ, in Young's double slit experiment, at a point on the screen where path difference is λ between the two waves, the intensity of light is K units. Find the intensity of light at a point on the screen where path difference is $\frac{\lambda}{3}$.

Correct Answer: —

Solution:

Step 1: Understanding the Concept:

In Young's double-slit experiment (YDSE), the intensity of light at any point on the screen is a result of the interference of waves from the two slits. The intensity depends on the phase difference (ϕ) between the two waves, which is directly related to their path difference (Δx).

Step 2: Key Formula or Approach:

The relationship between phase difference (ϕ) and path difference (Δx) is:

$$\phi = \frac{2\pi}{\lambda}\Delta x$$

The resultant intensity (I) at a point is given by:

$$I = I_{max}\cos^2\left(\frac{\phi}{2}\right)$$

where I_{max} is the maximum possible intensity (at the central maximum).

Step 3: Detailed Explanation (Calculation):

Case 1: Given Information

The path difference is given as $\Delta x_1 = \lambda$. First, find the corresponding phase difference ϕ_1:

$$\phi_1 = \frac{2\pi}{\lambda}(\lambda) = 2\pi \text{ radians}$$

Now, use the intensity formula. The intensity at this point (I_1) is given as K units.

$$I_1 = I_{max}\cos^2\left(\frac{2\pi}{2}\right) = I_{max}\cos^2(\pi) = I_{max}(-1)^2 = I_{max}$$

So, we have $K = I_{max}$. The maximum intensity in the interference pattern is K units.

Case 2: Find the new intensity

The new path difference is given as $\Delta x_2 = \frac{\lambda}{3}$. Find the new phase difference ϕ_2:

$$\phi_2 = \frac{2\pi}{\lambda}\left(\frac{\lambda}{3}\right) = \frac{2\pi}{3} \text{ radians}$$

Now, calculate the new intensity (I_2) using the intensity formula:

$$I_2 = I_{max}\cos^2\left(\frac{\phi_2}{2}\right) = I_{max}\cos^2\left(\frac{2\pi/3}{2}\right) = I_{max}\cos^2\left(\frac{\pi}{3}\right)$$

We know that $\cos\left(\frac{\pi}{3}\right) = \cos(60°) = \frac{1}{2}$.

$$I_2 = I_{max}\left(\frac{1}{2}\right)^2 = \frac{I_{max}}{4}$$

Since we found that $I_{max} = K$, the new intensity is:

$$I_2 = \frac{K}{4}$$

Step 4: Final Answer:

The intensity of light at the point where the path difference is $\frac{\lambda}{3}$ is $\frac{K}{4}$ units.

Quick Tip: For YDSE, the intensity is maximum when path difference is $n\lambda$ and zero when it's $(n + 1/2)\lambda$.

OR

Elucidate the diffraction of monochromatic light by narrow slit. Determine the expression for angular width of central maximum.

Correct Answer: –

Solution:

Elucidation of Diffraction:

Diffraction is the phenomenon of the bending or spreading of waves as they pass through a narrow opening (aperture) or around an obstacle. When a monochromatic plane wavefront is incident on a narrow slit, each point on the portion of the wavefront that passes through the slit acts as a source of secondary spherical wavelets, according to Huygens' principle. These wavelets spread out in all directions and interfere with one another. This interference results in a characteristic diffraction pattern on a screen placed far from the slit. The pattern consists of a bright central maximum, which is flanked on both sides by a series of alternating dark bands (minima) and weaker bright bands (secondary maxima).

Expression for Angular Width of Central Maximum:

Step 1: Condition for the First Minimum

Consider a slit of width 'a'. The central maximum is spread between the first minima on either side of the center. To find the location of the first minimum, we consider the wavelets from the top and bottom edges of the slit. The first minimum occurs at an angle θ where the path difference between these two extreme rays is exactly one wavelength (λ).

$$\text{Path Difference} = a \sin \theta$$

For the first minimum, this path difference is equal to λ:

$$a \sin \theta = \lambda$$

Step 2: Derivation

From the condition for the first minimum, we have $\sin \theta = \frac{\lambda}{a}$.

For typical diffraction setups, the angle θ is very small, so we can use the small-angle approximation: $\sin\theta \approx \theta$ (where θ is in radians).

$$\theta = \frac{\lambda}{a}$$

This angle θ represents the angular position of the first minimum from the center. It is also the **angular half-width** of the central maximum.

The **total angular width** of the central maximum is the angle between the first minimum on one side of the center and the first minimum on the other side.

$$\text{Total Angular Width} = \theta + \theta = 2\theta$$

Substituting the expression for θ:

$$\text{Total Angular Width} = \frac{2\lambda}{a}$$

Step 3: Final Answer:

The expression for the angular width of the central maximum in single-slit diffraction is $\frac{2\lambda}{a}$, where λ is the wavelength of the light and 'a' is the width of the slit.

Quick Tip: For single-slit diffraction, the intensity is zero (minimum) when path difference is $n\lambda$ (from slit edges). Don't confuse these conditions! The central maximum in diffraction is twice as wide as the secondary maxima.

9. Describe the atomic model of Rutherford. How did Bohr model removed its drawbacks?

Correct Answer: —

Solution:

Rutherford's Atomic Model (Nuclear Model):
Based on his famous alpha-particle scattering experiment, Ernest Rutherford proposed a model of the atom in 1911. Its main features are: \begin{enumerate} \item **Nucleus:** Almost all the mass and the entire positive charge of an atom are concentrated in a very small, dense region at the center called the nucleus. \item **Empty Space:** Most of the atom is empty space. \item **Electrons:** The negatively charged electrons revolve around the nucleus in circular paths called orbits, much like planets orbiting the sun. The electrostatic force of attraction between the nucleus and electrons provides the necessary centripetal force for their revolution. \end{enumerate} **Drawbacks of Rutherford's Model:** Rutherford's model was inconsistent with classical physics and experimental observations in two key ways: \begin{enumerate} \item **Instability of the Atom:** According to classical electromagnetic theory, an accelerating charged particle must radiate energy. An electron revolving in an orbit is constantly accelerating (due to the change in the direction of its velocity). Therefore, it should continuously lose energy and spiral into the nucleus, making the atom unstable. This contradicts the observed stability of atoms. \item **Inability to Explain Line Spectra:** As the electron spirals inwards, its frequency of revolution would increase continuously. This means it should emit a continuous spectrum of radiation. However, atoms (like hydrogen) are observed to emit a discrete line spectrum. \end{enumerate} **How Bohr's Model Removed the Drawbacks:** Niels Bohr, in 1913, modified Rutherford's model by introducing quantum concepts through three postulates: \begin{enumerate} \item **Postulate of Stationary Orbits:** Bohr proposed that electrons can revolve only in certain

specific, non-radiating orbits called stationary orbits. While in these orbits, electrons do not emit energy. This postulate directly contradicted classical theory and solved the problem of atomic instability. \item **Postulate of Quantization of Angular Momentum:** The allowed stationary orbits are those for which the angular momentum of the electron is an integral multiple of $h/2\pi$, where h is Planck's constant. ($L = n\frac{h}{2\pi}$, where n=1, 2, 3...). \item **Postulate of Frequency Condition:** An atom emits radiation (a photon) only when an electron jumps from a higher energy stationary orbit (E_2) to a lower energy one (E_1). The frequency (ν) of the emitted photon is given by $h\nu = E_2 - E_1$. Since only specific orbits and energy levels are allowed, only specific frequencies of light can be emitted, thus explaining the observed discrete line spectra. \end{enumerate}

Quick Tip: For the Bohr model, remember that its genius was in defying classical physics with a few simple (but revolutionary) quantum rules to explain experimental facts.

OR

Classify nuclei. By giving example of each. Write their characteristics.

Correct Answer: —

Solution:

Nuclei are classified based on the number of protons (atomic number, Z) and the number of neutrons (neutron number, N) they contain. The total number of protons and neutrons is the mass number (A = Z + N).

1. Isotopes \begin{itemize} \item **Definition:** Nuclei of the same

element that have the same number of protons (same Z) but a different number of neutrons (different N), and thus a different mass number (A). \item **Example:** The isotopes of hydrogen are Protium ($^{1}_{1}H$, Z=1, N=0), Deuterium ($^{2}_{1}H$, Z=1, N=1), and Tritium ($^{3}_{1}H$, Z=1, N=2). Another example is Carbon-12 ($^{12}_{6}C$) and Carbon-14 ($^{14}_{6}C$). \item **Characteristics:** Isotopes have identical chemical properties because chemical behavior is determined by the electron configuration, which depends on Z. However, they have different physical properties such as mass, density, and nuclear stability (some isotopes may be radioactive while others are stable). \end{itemize} **2. Isobars** \begin{itemize} \item **Definition:** Nuclei of different elements that have the same mass number (same A) but different atomic numbers (different Z) and neutron numbers (different N). \item **Example:** Argon-40 ($^{40}_{18}Ar$) and Calcium-40 ($^{40}_{20}Ca$). Both have A=40, but Z and N are different. Another example is Carbon-14 ($^{14}_{6}C$) and Nitrogen-14 ($^{14}_{7}N$). \item **Characteristics:** Isobars are atoms of different elements, so they have different chemical and physical properties. \end{itemize} **3. Isotones** \begin{itemize} \item **Definition:** Nuclei of different elements that have the same number of neutrons (same N) but different atomic numbers (different Z) and mass numbers (different A). \item **Example:** Chlorine-37 ($^{37}_{17}Cl$) and Potassium-39 ($^{39}_{19}K$). For both, the neutron number is N = A-Z = 20. Another example is Boron-12 ($^{12}_{5}B$) and Carbon-13 ($^{13}_{6}C$), both having N=7. \item **Characteristics:** Isotones are atoms of different elements, and thus they have different chemical and physical properties. \end{itemize}

Quick Tip: For classifying nuclei, use the letters in the names as a mnemonic: Isoto**p**es (same **P**rotons), Isob**a**rs (same **A** - mass number), Isoto**n**es (same **N**eutrons).