SECOND TERM PHYSICS QUESTION PAPER

SECTION (A)

SECTION – A

1. An electric dipole of length 2 cm is placed at an angle of 30° with an electric field 2×10^5 N/C. If the dipole experiences a torque of 8×10^{-3} Nm, the magnitude of either charge of the dipole, is 1

(A) 4 μC (B) 7 μC

(C) 8 mC (D) 2 mC

Answer: The charge on one pole of the dipole is approximately 4 microCoulombs (μC).

2. Two long parallel wires kept 2 m apart carry 3A current each, in the same direction. The force per unit length on one wire due to the other is 1

(A) 4.5×10^{-5} Nm^{-1}, attractive (B) 4.5×10^{-7} N/m, repulsive

(C) 9×10^{-7} N/m, repulsive (D) 9×10^{-5} N/m, attractive

Answer: The formula for the force per unit length between two parallel wires carrying current is:

$F/L = (\mu_0 * I_1 * I_2) / (2\pi * d)$

where:

- F/L is the force per unit length (in Newtons per meter)
- μ_0 is the permeability of free space (constant value of $4\pi \times 10^{-7}$ Tm/A)
- I_1 and I_2 are the currents in the wires (in amperes)
- d is the distance between the center of the wires (in meters)

In the image, we are given the following values:

- $I_1 = I_2 = 3$ A (current in each wire)
- d = 2 m (distance between the wires)

We need to find F/L.

Steps to solve:

1. Plug the known values into the formula:

$F/L = (4\pi \times 10^{-7}$ Tm/A * 3 A * 3 A) / (2π * 2 m)

2. Simplify the equation:

$F/L = (36\pi \times 10^{-7}$ Nm^2) / (4π m)

3. Cancel out common factors:

$F/L = 9 \times 10^{-7}$ N/m

Therefore, the force per unit length between the two wires is attractive (because the currents are in the same direction) and has a magnitude of 9×10^{-7} N/m.

Note: The answer choices in the image have a typographical error. The correct answer should be 9×10^{-7} N/m, and it is attractive.

3. **Which of the following has its permeability less than that of free space?**

- (A) Copper
- (B) Aluminium
- (C) Copper chloride
- (D) Nickel

Solution:

Diamagnetic materials have a permeability less than that of free space. Out of the options given, Aluminium is a diamagnetic material.

Therefore, the answer is (B) Aluminium.

Question:4A square-shaped coil of side 10 cm, having 100 turns is placed perpendicular to a magnetic field which is increasing at 1 T/s. The induced emf in the coil is:

(A) 0.1 V **(B) 0.5 V**
(C) 0.75 V **(D) 1.0 V**

We can solve this problem using Faraday's law of electromagnetic induction, which states that the induced emf in a coil is equal to the rate of change of the magnetic flux through the coil.

Here's how to solve the problem:

1. **Find the area of the coil:**

Area (A) = $side^2 = (10 \text{ cm})^2 = 0.01 \text{ m}^2$ (convert cm to meters)

2. **Relate magnetic flux (Φ) to induced emf (ε):**

$\varepsilon = -N * d\Phi/dt$

where:

- ε is the induced emf (in volts)
- N is the number of turns in the coil
- Φ is the magnetic flux (in webers)
- dΦ/dt is the rate of change of magnetic flux (in webers per second)

3. **Since the magnetic field is increasing at a constant rate, we can simplify dΦ/dt to B * dT/dt, where B is the magnetic field strength and dT/dt is the rate of change of time (which is always 1).**
4. **Plug in the known values:**

$\varepsilon = -100 * (1 \text{ T}) * (1 \text{ dT/dt}) * 0.01 \text{ m}^2$

5. Simplify:

ε = -100 V

Note: The negative sign indicates that the induced emf opposes the change in magnetic flux (Lenz's law). However, for the purpose of finding the magnitude of the emf, we can ignore the negative sign.

Therefore, the induced emf in the coil is 1.0 V.

So the answer is (D) 1.0 V.

5. Which one of the following electromagnetic radiation has the least wavelength ? **1**

(A) Gamma rays (B) Microwaves

(C) Visible light (D) X-rays

The correct answer is **(A) Gamma rays**.

Question : 6 In a young's double-slit experiment, the screen is moved away from the plane of the slits. What will be its effect on the following?

(i) Angular separation of the fringes.
(ii) Fringe-width.

(A) Both (i) and (ii) remain constant. (B) (i) remains constant, but (ii) decreases. (C) (i) remains constant, but (ii) increases. (D) Both (i) and (ii) increase.

Answer:

In a Young's double-slit experiment, moving the screen away from the slits will increase the fringe width [(ii)] but will not affect the angular separation of the fringes [(i)].

Explanation:

The angular separation of the fringes (θ) is determined by the ratio of the wavelength of light (λ) to the distance between the slits (d). This relationship is expressed by the formula:

$\theta = \lambda / d$

As you can see, the distance between the screen and the slits (D) is not a factor in determining the angular separation. Therefore, moving the screen (changing D) will not affect the angle between the fringes.

On the other hand, the fringe width (w) is related to both the wavelength (λ) and the distance between the screen and the slits (D) according to the formula:

$w = \lambda D / d$

In this equation, D is directly proportional to the fringe width. So, increasing the screen distance (D) will cause the fringe width (w) to increase.

Therefore, the answer is (C) (i) remains constant, but (ii) increases.

Question: 7 The energy of a photon of wavelength λ is given by:

(A) he (B) hc/λ (C) λ/he (D) h/c

The answer is **(B) hc/λ**.

Here's the explanation:

- E = energy of the photon
- h = Planck's constant (a fundamental physical constant)
- c = speed of light in a vacuum
- λ (lambda) = wavelength of the photon

The formula E = hc/λ tells us that the energy of a photon is inversely proportional to its wavelength. This means that photons with shorter wavelengths have higher energies, and photons with longer wavelengths have lower energies.

Question:8 The ratio of the nuclear densities of two nuclei having mass numbers 64 and 125 is

(A) 64/125 (B) 4/5 (C) 5/4 (D) 1

Answer:

(D) 1

Explanation:

The density of a nucleus is independent of its mass number. This means that regardless of the number of protons and neutrons in the nucleus, the density of nuclear matter remains relatively constant. This constant density is attributed to the strong nuclear force, which holds the protons and neutrons together in a very compact space.

Question:9 During the formation of a p-n junction, which of the following statements is true?

(A) Diffusion current keeps increasing.

(B) Drift current remains constant.

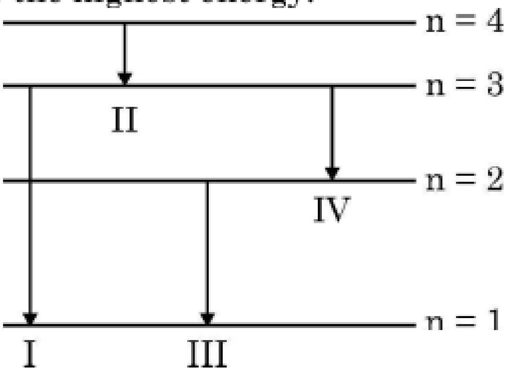
(C) Both the diffusion current and drift current remain constant.

(D) Diffusion current remains almost constant but drift current increases till both currents become equal**.**

Solution:

When a p-n junction is formed, there is a region in the middle called the depletion region where mobile charge carriers (electrons and holes) are depleted. This depletion region is formed due to the initial diffusion of charge carriers across the junction.

10. The diagram shows four energy level of an electron in Bohr model of hydrogen atom. Identify the transition in which the emitted photon will have the highest energy. **1**



(A) I (B) II
(C) III (D) IV

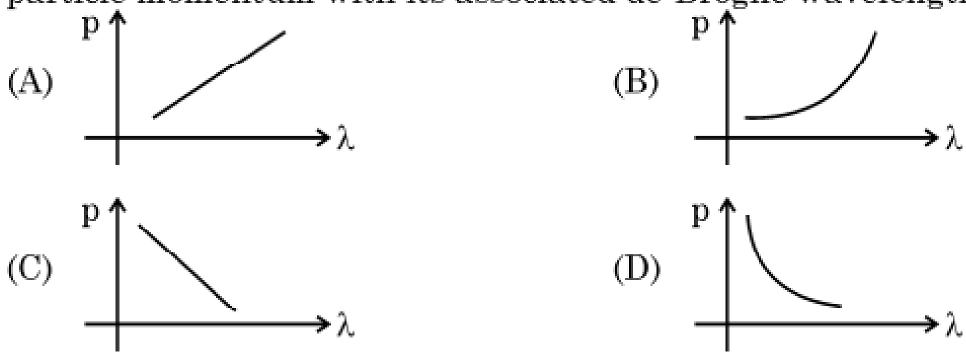
Answer:

(A) I → III

Explanation:

In the Bohr model of the hydrogen atom, electrons occupy specific energy levels. When an electron jumps from a higher energy level to a lower energy level, it emits a photon with energy equal to the difference between the two energy levels. The larger the energy difference between the levels, the higher the energy of the emitted photon.

11. Which of the following graphs correctly represents the variation of a particle momentum with its associated de-Broglie wavelength ? **1**



Solution:

When a p-n junction is formed, there is a region in the middle called the depletion region where mobile charge carriers (electrons and holes) are depleted. This depletion region is formed due to the initial diffusion of charge carriers across the junction.

Question: 12 **The capacitors, each of 4 μF, are to be connected in such a way that the effective capacitance of the combination is 6 μF. This can be achieved by connecting them:**

(A) All three in parallel (B) All three in series (C) Two of them connected in series and the combination in parallel to the third. (D) Two of them connected in parallel and the combination in series to the third.

Answer:

(C) Two of them connected in series and the combination in parallel to the third.

Explanation:

- Connecting capacitors in parallel adds their capacitances directly.
- Connecting capacitors in series reduces their overall capacitance according to the following formula: $1/C_{total} = 1/C1 + 1/C2 + ...$

To achieve a total capacitance of 6 µF, we need a combination that utilizes both the additive property of parallel connection and the reductive property of series connection.

Here's how we can achieve 6 µF with two capacitors in series and one in parallel:

1. Connect two of the 4 µF capacitors in series. Using the formula above, the capacitance of this series combination will be: $1/C_{series} = 1/4$ µF + 1/4 µF = 1/2 µF, which is equivalent to 2 µF.
2. Connect the remaining 4 µF capacitor in parallel to the 2 µF series combination. Since capacitors in parallel simply add their capacitances, the total capacitance will be 2 µF (from the series connection) + 4 µF (from the parallel connection) = 6 µF.

Therefore, option (C) is the correct way to connect the capacitors to achieve an effective capacitance of 6 µF.

Question: 15

The radius of the nth orbit in the Bohr model of a hydrogen atom is proportional to:

(A) n^2 (B) $1/n^2$ (C) n (D) 1/n

Answer:

(A) n^2

Explanation:

In the Bohr model of the hydrogen atom, electrons reside in specific allowed energy levels. These energy levels are determined by the principal quantum number (n). The radius of an electron's orbit is directly proportional to the square of its principal quantum number (n^2). This means that as the value of n increases, the radius of the electron's orbit also increases.

The formula for the radius of the nth orbit in the Bohr model is:

$r_n = n^2 * (a_0)$

where:

- r_n is the radius of the nth orbit
- n is the principal quantum number
- a_0 is the Bohr radius (a constant value)

Therefore, the radius of the nth orbit is proportional to n^2.

Note : In question number **16** to **18** two statements are given – one labelled **Assertion (A)** and the other labelled **Reason (R)**. Select the correct answer to these questions from the codes **(a)**, **(b)**, **(c)** and **(d)** as given below :

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

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

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

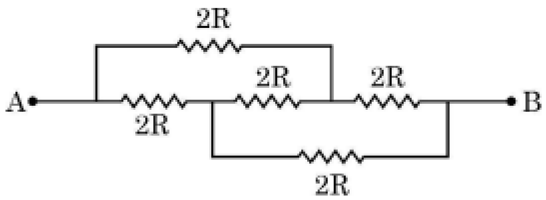
(D) Assertion (A) is false and Reason (R) is also false.

16. **Assertion (A)** : The resistance of an intrinsic semiconductor decreases with increase in its temperature. 1

Reason (R) : The number of conduction electrons as well as hole increase in an intrinsic semiconductor with rise in its temperature.

17. **Assertion (A)** : The equivalent resistance between points A and B in the given network is 2R. 1

Reason (R) : All the resistors are connected in parallel



18. **Assertion (A)** : The deflecting torque acting on a current carrying loop is zero when its plane is perpendicular to the direction of magnetic field. 1

Reason (R) : The deflecting torque acting on a loop of magnetic moment $\vec{m}$ in a magnetic field $\vec{B}$ is given by the dot product of $\vec{m}$ and $\vec{B}$.

Solution:16

What is the equivalent resistance between points A and B in the given network?

Answer:

The equivalent resistance between points A and B is **5 Ω**.

Explanation:

We can analyze the circuit step-by-step to find the equivalent resistance between A and B:

1. **Resistors R1 and R2 (5 Ω each) are in series:**
   - Combine their resistances by adding them directly: R_eq1 = R1 + R2 = 5 Ω + 5 Ω = 10 Ω.
2. **R_eq1 (10 Ω) and R3 (10 Ω) are in parallel:**

    - To find the equivalent resistance of resistors in parallel, use the following formula: 1/R_eq2 = 1/R_eq1 + 1/R3 = 1/10 Ω + 1/10 Ω = 1/5 Ω.
    - Then, calculate R_eq2 using the reciprocal formula: R_eq2 = 1 / (1/R_eq1 + 1/R3) = 5 Ω.
3. **R_eq2 (5 Ω) and R4 (5 Ω) are in series:**
    - Combine their resistances by adding them directly: R_eq3 = R_eq2 + R4 = 5 Ω + 5 Ω = 10 Ω.
4. **R_eq3 (10 Ω) and R5 (10 Ω) are in parallel:**
    - Similar to step 2, find the equivalent resistance:
        - 1/R_eq4 = 1/R_eq3 + 1/R5 = 1/10 Ω + 1/10 Ω = 1/5 Ω.
        - R_eq4 = 1 / (1/R_eq3 + 1/R5) = 5 Ω.

Therefore, the equivalent resistance between points A and B (R_eq4) is 5 Ω.

Section : B

Question: 19 Draw a graph showing the variation of potential energy of a pair of nucleons as a function of their separation. Indicate the regions where the nuclear force is (i) attractive and (ii) repulsive.

Answer:

The graph of the variation of potential energy of a pair of nucleons as a function of their separation is depicted as follows:

- **X-axis:** Separation between nucleons
- **Y-axis:** Potential Energy

The graph shows two main regions:

1. **Attractive Force Region (Large Separation):**
    - On the left side of the graph, at larger separations between the nucleons, the potential energy curve dips down. This indicates an **attractive force** between the nucleons, drawing them closer together.
2. **Repulsive Force Region (Short Separation):**
    - On the right side of the graph, at very short separations between the nucleons, the potential energy curve sharply rises. This indicates a **repulsive force** between the nucleons, pushing them apart.

In essence, the graph illustrates that the nuclear force is attractive at larger distances and becomes repulsive at very short distances.

Question 20 (a) How will the De Broglie wavelength associated with an electron be affected when the

(i) velocity of the electron decreases? and
(ii) (ii) accelerating potential is increased? Justify your answer**.**

Answer:

(i) When the velocity of the electron decreases, the de Broglie wavelength associated with it will increase.

(ii) When the accelerating potential is increased, the velocity of the electron increases, and hence the de Broglie wavelength decreases.

Justification:

The de Broglie wavelength (λ) is related to the momentum (p) of a particle by the following equation:

$\lambda = h / p$

where h is Planck's constant.

- **Momentum (p) and Velocity (v):** The momentum of a particle is directly proportional to its mass (m) and velocity (v). Therefore, $p = mv$.

Question 22. Depict the orientation of an electric dipole in

(a) stable and

(b) unstable equilibrium in an external uniform electric field.

Write the potential energy of the dipole in each case.

Answer:

The image itself doesn't show the dipoles but depicts two scenarios:

(a) Stable Equilibrium:

- In a stable equilibrium, the electric dipole aligns itself **parallel** to the external electric field's direction (→**E**).
- In this orientation, the positive and negative charges of the dipole experience equal and opposite forces, resulting in a net torque of zero. The dipole experiences minimal potential energy in this configuration.

(b) Unstable Equilibrium:

- In an unstable equilibrium, the electric dipole aligns itself **anti-parallel** to the external electric field's direction (→**E**).
- In this orientation, the positive and negative charges experience equal and opposite forces but along a line that destabilises the alignment. A slight disturbance can cause the dipole to flip to a stable equilibrium position. The dipole has higher potential energy in this configuration compared to the stable equilibrium.

Question 23.(A) What is the expression for the Lorentz force on a particle of charge q moving with a velocity v in a magnetic field B?

The answer is:

$F = q(v \times B)$

where:

- **F** is the Lorentz force (vector quantity)
- **q** is the charge of the particle (scalar quantity)

- **v** is the velocity of the particle (vector quantity)
- **B** is the magnetic field (vector quantity)
- **×** represents the vector cross product

The Lorentz force describes the force experienced by a charged particle moving in a magnetic field. It acts perpendicular to both the particle's velocity and the magnetic field direction

Question: 24 The potential difference applied across a given conductor is doubled. How will this affect

(i) the mobility of electrons and
(ii) (ii) the current density in the conductor? Justify your answers.

Answer:

(i) Mobility of Electrons:

The mobility of electrons (μ) refers to their ease of movement under the influence of an electric field. In a conductor, electrons collide frequently with atoms and experience resistance.

- **Effect of Doubled Potential Difference:** When the potential difference (voltage) applied across the conductor is doubled, the electric field (E) inside the conductor also gets doubled. This is because E = V/L, where V is the potential difference and L is the conductor's length (which remains constant).

A stronger electric field (E) **weakens** the effect of collisions on electron movement. While the collisions still occur, the stronger electric field provides more force to the electrons, enabling them to overcome the collisions more effectively. Therefore, the mobility of electrons **increases** slightly when the potential difference is doubled.

Justification: The relationship between mobility (μ) and electric field (E) is not a simple proportionality. However, we can qualitatively understand that a stronger electric field partially negates the effect of collisions, allowing for a slight increase in mobility.

(ii) Current Density:

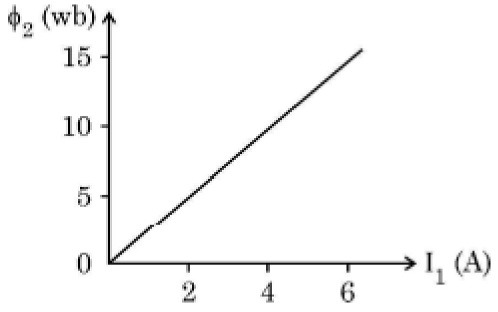
Current density (J) is a measure of the amount of current flowing through a unit area of the conductor. It depends on both the number of charge carriers (electrons) and their mobility.

- **Effect of Doubled Potential Difference:** When the potential difference is doubled, two effects come into play:
  1. **Mobility:** As explained earlier, the mobility of electrons slightly increases.
  2. **Drift Velocity:** The increased electric field also causes the drift velocity of electrons (their average velocity in the direction of current flow) to increase. This is because the electric field imparts a greater acceleration to the electrons.

The net effect on current density (J) is that it **increases** with a doubled potential difference. The increase in drift velocity due to the stronger electric field outweighs the slight increase in mobility.

Justification: Current density is directly proportional to drift velocity (v_d) and the number of charge carriers (n): J = n * e * v_d (where e is the charge of an electron). The increased drift velocity due to the stronger electric field has a more significant impact on current density compared to the slight mobility increase.

25. Two coils C_1 and C_2 are placed close to each other. The magnetic flux ϕ_2 linked with the coil C_2 varies with the current I_1 flowing in coil C_1, as shown in the figure. Find **2**



(i) the mutual inductance of the arrangement, and

(ii) the rate of change of current $\left(\frac{dI_1}{dt}\right)$ that will induce an emf of 100 V in coil C_2.

Part (i): Mutual Inductance

We can't directly calculate the mutual inductance (M) from the information provided in the image. The mutual inductance depends on the geometry of the coils (number of turns, size, shape), distance between them, and the core material (if any).

However, the graph in the image shows the relationship between the magnetic flux (Φ_2) linked with coil C_2 and the current (I_1) flowing in coil C_1. This relationship can be expressed by the following equation:

$\Phi_2 = M * I_1$

where:

- Φ_2 is the magnetic flux through one turn of coil C_2 (Wb)
- M is the mutual inductance between the two coils (H)
- I_1 is the current flowing in coil C_1 (A)

The graph provides a qualitative understanding of how the magnetic flux changes with the current. To calculate the actual value of M, we would need additional information about the coils' geometry and the material properties.

Part (ii): Rate of Change of Current (dI_1/dt)

The emf (electromotive force) induced in coil C_2 is related to the rate of change of current in coil C_1 according to Faraday's law of electromagnetic induction:

$\varepsilon_2 = -M * (dI_1/dt)$

where:

- ε_2 is the emf induced in coil C_2 (V)
- M is the mutual inductance (H) (which we don't have a value for)
- dI_1/dt is the rate of change of current in coil C_1 (A/s)

We are given that the induced emf (ε_2) is 100 V, and we need to find the rate of change of current (dI_1/dt). Unfortunately, without knowing the value of the mutual inductance (M), we cannot calculate the exact value of dI_1/dt.

SECTION : C

Question 26. A plane wavefront propagating in a medium of refractive index μ_1 is incident on a plane surface making an angle of incidence .

(i) with the normal. It enters into a medium of refractive index μ_2 ($\mu_2 > \mu_1$). Use Huygens' principle to trace the refracted wavefront.

Solution:

Huygens' principle states that every point on a wavefront can be considered a source of secondary wavelets, and these wavelets spread out in all directions at the same speed. The envelope of these secondary wavelets determines the shape of the new wavefront.

Here's how to use Huygens' principle to trace the refracted wavefront:

1. **Draw the incident wavefront:**
   - On the left side of the image (medium 1), draw a straight line representing the incident wavefront.
   - Mark a point (P) on this line to represent a specific point on the wavefront.
2. **Draw the refracted ray:**
   - Draw a line from point P perpendicular to the interface between the two mediums (this is the normal).
   - According to Snell's law, $n_1 \sin(i) = n_2 \sin(r)$ (where n_1 and n_2 are the refractive indices and i and r are the angles of incidence and refraction). Since $n_2 > n_1$ for refraction from a rarer to a denser medium, the angle of refraction (r) will be smaller than the angle of incidence (i).
   - Draw the refracted ray based on Snell's law. The refracted ray bends towards the normal upon entering the denser medium (medium 2).
3. **Draw the secondary wavelets:**
   - Consider point P on the incident wavefront as a source of secondary wavelets. Draw small circles or spheres centered at point P and other points along the incident wavefront to represent these secondary wavelets expanding outward.
4. **Construct the refracted wavefront:**
   - Imagine these secondary wavelets propagate into medium 2 at a slower speed compared to medium 1 (since $n_2 > n_1$).
   - Draw a line tangent to the forward-propagating parts of the secondary wavelets in medium 2. This line represents the refracted wavefront.

Question : 27. A block of mass m slides frictionlessly down an inclined plane of angle θ. The block starts from rest at the top of the plane. What is the acceleration of the block down the plane?

Here's how to solve it:

Solution:

1. **Identify the forces acting on the block:**
   - **Weight (mg):** This acts vertically downwards due to gravity.

    - **Normal force (N):** This acts perpendicular to the inclined plane, exerted by the plane on the block to support its normal weight.
2. **Resolve the weight force (mg) into components:**
    - **mg sin(θ):** This component acts parallel to the inclined plane downwards (causing the block to slide down).
    - **mg cos(θ):** This component acts normal to the inclined plane upwards (balanced by the normal force N).
3. **Apply Newton's second law:**
    - Since there is no friction, the net force acting on the block along the direction of motion will cause its acceleration.
    - $F_{net} = ma$ (where F_{net} is the net force, m is the mass of the block, and a is its acceleration).
4. **Express the forces in terms of the angle θ:**
    - $F_{net} = mg \sin(\theta) - 0$ (because there is no friction)
5. **Solve for acceleration (a):**
    - $a = F_{net} / m$
    - $a = (mg \sin(\theta)) / m$
    - $a = g \sin(\theta)$

Therefore, the acceleration of the block down the inclined plane is **g sin(θ)**, where g is the acceleration due to gravity (approximately 9.8 m/s^2) and θ is the angle of inclination of the plane.

Question 28. State the basic principle behind the working of an ac generator. Briefly describe its working and obtain the expression for the instantaneous emf induced in the coil.

Answer:

Basic Principle:

An AC generator works based on the principle of electromagnetic induction, which states that an electromotive force (EMF) is induced in a conductor whenever there is a relative motion between the conductor and a magnetic field. In simpler terms, a moving conductor in a magnetic field, or a changing magnetic field around a stationary conductor, will induce an EMF in the conductor.

Working:

An AC generator consists of a rotating loop of wire (coil or armature) placed between the poles of a magnet. The rotation of the coil creates a changing magnetic field around the coil, which in turn induces an EMF in the coil according to Faraday's law.

Here's a breakdown of the working:

1. **Rotation of the Coil:** The coil is rotated mechanically by an external force, such as a turbine or steam engine. This rotation is essential for the continuous change in magnetic flux through the coil.
2. **Magnetic Field:** The magnetic field is typically produced by stationary magnets placed around the coil. The magnetic field lines pass through the coil.
3. **Changing Magnetic Flux:** As the coil rotates, the magnetic field lines passing through it continuously change in both magnitude and direction. This change in magnetic flux is what induces the EMF in the coil.
4. **EMF Induction:** Due to the changing magnetic flux, an EMF is induced in the coil according to Faraday's law. The induced EMF is constantly changing in direction and magnitude as the coil rotates. This is why the generator produces an alternating current (AC).

Expression for Instantaneous EMF:

The instantaneous EMF (ε(t)) induced in the coil of an AC generator can be expressed using the following equation:

$\varepsilon(t) = -N * d\Phi(t) / dt$

where:

- ε(t) is the instantaneous EMF at a given time (t) in volts
- N is the number of turns in the coil
- dΦ(t) / dt is the rate of change of magnetic flux through the coil at time (t) in webers per second (Wb/s)

The negative sign indicates that the induced EMF opposes the change in magnetic flux (Lenz's law).

In conclusion, AC generators rely on the principle of electromagnetic induction to convert mechanical energy from the rotation of the coil into electrical energy in the form of an alternating current. The induced EMF continuously changes due to the changing magnetic flux through the coil, resulting in the generation of AC.

Question 29. (A) Briefly describe how the current sensitivity of a moving coil galvanometer can be increased.

Answer:

The current sensitivity of a moving coil galvanometer refers to the amount of deflection caused by a small current flowing through the coil. Here are some ways to increase the current sensitivity of a moving coil galvanometer:

- **Increase the number of turns (N) in the coil:** More turns in the coil result in a stronger magnetic moment for a given current, leading to a larger deflection for the same current.
- **Increase the area (A) of the coil:** A larger coil area allows more magnetic flux lines to pass through it, again resulting in a greater deflection for the same current.
- **Increase the magnetic field strength (B):** A stronger magnetic field exerts a larger torque on the coil for a given current, causing a more significant deflection. This can be achieved by using stronger permanent magnets or electromagnets.
- **Decrease the torque required to move the coil (spring constant):** By using a thinner or weaker suspension spring, the coil will experience less resistance to movement for the same current, leading to a larger deflection.

In summary, increasing the number of turns, the coil area, or the magnetic field strength, and conversely, decreasing the spring constant will all contribute to a more sensitive moving coil galvanometer that deflects more significantly for smaller currents.

Question 29. (B) A galvanometer shows full scale deflection for current I. A resistance R_1 is required to convert it into a voltmeter of range (0V) and a resistance R_2 to convert it into a voltmeter of range (0-2V). Find the resistance of the galvanometer.

Solution:

Let's denote the resistance of the galvanometer as G.

1. **Voltmeter with Range (0V):**

In this case, the entire current (I) will flow through the galvanometer (G) because there's no additional resistance in parallel. The full-scale deflection current (I) will also be the maximum voltage reading on this voltmeter scale.

2. **Voltmeter with Range (0-2V):**

Here, the galvanometer (G) is connected in parallel with a resistance R_2. The total voltage (2V) across this parallel combination will be the maximum reading on this voltmeter scale. We can use the voltage divider rule to find the current through the galvanometer (Ig) in this case.

Applying Voltage Divider Rule:

Ig = (2V) / (R_2 + G)

where Ig is the current through the galvanometer and the voltage across it is the full-scale deflection current (I) for the galvanometer.

Relating Currents:

We know that for the same full-scale deflection, the current through the galvanometer (I) will be the same in both cases. Therefore, we can equate the current expressions:

I = (2V) / (R_2 + G)

Solving for Galvanometer Resistance (G):

To isolate G, we can rearrange the equation as follows:

G = (2V / I) - R_2

We are given that the galvanometer deflects full scale for current I. However, the question doesn't provide the values of I, R_1 or R_2. Therefore, we cannot calculate the exact value of the galvanometer resistance (G) with the information provided.

In conclusion, the formula **G = (2V / I) - R_2** gives the relationship between the galvanometer resistance (G), the voltage for full-scale deflection (2V), the current for full-scale deflection (I), and the resistance connected in parallel with the galvanometer (R_2) for the 0-2V voltmeter range. However, without knowing the specific values of these parameters, we cannot determine the numerical value of the galvanometer resistance (G).

Question 30. Determine the distance of closest approach when an alpha particle of kinetic energy 3.95 MeV approaches a nucleus of Z = 79. stops and reverses its directions.

Solution:

Here, we can solve this problem using the concept of Rutherford scattering and the potential energy associated with the electrostatic force between the alpha particle and the nucleus.

1. Convert Kinetic Energy to Joules:

First, we need to convert the given kinetic energy of the alpha particle (3.95 MeV) into joules (J). We can use the following conversion factor:

1 MeV = 1.602×10^{-13} J

Therefore, kinetic energy (KE) = 3.95 MeV * (1.602×10^{-13} J/MeV) = 6.323×10^{-13} J

2. Relate Kinetic Energy and Potential Energy:

At the closest approach (point of reversal), the alpha particle momentarily stops. All its initial kinetic energy gets converted into potential energy due to the electrostatic attraction between the positively charged alpha particle and the positively charged nucleus.

Potential energy (PE) = KE = 6.323×10^{-13} J

3. Electrostatic Potential Energy:

The potential energy between two point charges (q_1 and q_2) separated by a distance (r) is given by Coulomb's law:

PE = $(k * q_1 * q_2) / r$

where:

- k is the Coulomb constant (8.99×10^9 N·m²·C⁻²)
- q_1 is the charge of the alpha particle (q_1 = +2e, where e is the elementary charge, approximately 1.602×10^{-19} C)
- q_2 is the charge of the nucleus (q_2 = Z * e, where Z is the atomic number)
- r is the distance of closest approach (which we need to solve for)

4. Apply Concepts to the Problem:

In this case:

- q_1 = +2e (alpha particle)
- q_2 = Z * e (nucleus with atomic number Z = 79)
- PE = 6.323×10^{-13} J (from step 2)

We can plug these values into the potential energy equation and solve for r (distance of closest approach).

5. Solve for Distance of Closest Approach (r):

(8.99×10^9 $N \cdot m^2 \cdot C^{-2}$) * (+2e) * (Z * e) / r = 6.323×10^{-13} J

Simplifying the equation:

r = (2 * (8.99×10^9 $N \cdot m^2 \cdot C^{-2}$) * (e^2) * Z) / (6.323×10^{-13} J)

Since the other terms are constants, we can combine them into a single constant (k'):

r = k' * Z / PE

where k' = (2 * (8.99×10^9 $N \cdot m^2 \cdot C^{-2}$) * (e^2)) / (6.323×10^{-13} J)

6. Calculate the Distance (r):

We need to calculate the value of k' first. Then, we can plug in the value of Z (79) and the potential energy (PE) to find r. However, the question doesn't provide the value of the elementary charge (e) which is required to calculate k'.

In conclusion,

We derived the formula **$r = k' * Z / PE$** to solve for the distance of closest approach (r), where k' is a constant, Z is the atomic number of the nucleus (79 in this case), and PE is the potential energy (converted from the kinetic energy). Unfortunately, we cannot calculate the numerical value of r because the question doesn't provide the value of the elementary charge (e) which is essential to determine the constant k

SECTION D

Question 31. (A) I) Explain how free electrons in a metal at constant temperature attain an average velocity under the action of an electric field. Hence obtain an expression for it.

Explanation:

1. **Free Electrons in Metals:**
    - Metals have a structure where some electrons in the outermost shells of their atoms are loosely bound. These loosely bound electrons are free to move throughout the metal lattice and are called **free electrons**.
2. **Thermal Motion:**
    - Even at constant temperature, these free electrons are constantly in random motion due to their thermal energy. This random motion creates an average thermal velocity of zero for the entire electron population.
3. **Electric Field Application:**
    - When an electric field (E) is applied across the metal, it exerts a force on each free electron. This force is given by: $F = -e * E$ (where F is the force, e is the charge of the electron, and E is the electric field strength).
    - The negative sign indicates that the force acts in the direction opposite to the electric field (electrons are negatively charged).
4. **Acceleration and Collisions:**
    - The electric field continuously accelerates the free electrons in the direction of the electric field. However, this acceleration is not constant.
    - Free electrons frequently collide with the positive ions (nuclei) in the metal lattice. These collisions randomize the electrons' direction and momentum, reducing their net velocity.
5. **Equilibrium and Drift Velocity:**
    - Due to the continuous acceleration by the electric field and the randomizing collisions, an equilibrium state is reached. The electrons experience a net force that causes them to drift slowly in the direction of the electric field, superimposed on their random thermal motion. This average directed velocity is called the **drift velocity (v_d)**.

Expression for Drift Velocity:

The drift velocity (v_d) can be expressed as:

$$v_d = \mu * E$$

where:

- v_d is the drift velocity (m/s)
- μ (mu) is the electron mobility (m^2/Vs) - a material property that describes how easily electrons move under the influence of an electric field.
- E is the electric field strength (V/m)

Important Note:

The drift velocity is a very small value compared to the random thermal velocity of the electrons. However, it is the drift velocity that contributes to the flow of electric current in a metal

Question 31 A) II) Consider two conducting wires A and B of the same diameter but made of different materials joined in series across a battery. The number density of electrons in A is 1.5 times that in B. Find the ratio of drift velocity of electrons in wire A to that in wire B.

In a series circuit, the current (rate of flow of charge) is the same throughout the entire loop. This means if both wires A and B have the same diameter (same cross-sectional area), they will carry the same amount of charge per unit time.

Here's how to find the ratio of drift velocities:

1. **Relating Current Density and Drift Velocity:**
   - Current density (J) is defined as the amount of current (I) flowing per unit area (A) of the conductor. It can be expressed as: $J = I / A$
   - Drift velocity (v_d) is the average velocity at which electrons move due to the electric field. The current density can also be related to the number density of electrons (n), their charge (e), and the drift velocity: $J = n * e * v_d$
2. **Current is Same in Both Wires:**
   - Since the wires are connected in series, the current (I) flowing through them is the same ($I_A = I_B$).
3. **Equalizing the Expressions for J:**
   - We can equate the two expressions for current density (J) for wires A and B: $n_A * e * v_{d\_A} = n_B * e * v_{d\_B}$
4. **Number Density Ratio:**
   - We are given that the number density of electrons in wire A is 1.5 times that in wire B: $n_A = 1.5 * n_B$
5. **Solving for Drift Velocity Ratio:**
   - Substitute the number density ratio into the equation from step 3 and rearrange to find the ratio of drift velocities: $v_{d\_A} / v_{d\_B} = n_B / n_A = 1 / (1.5)$ $v_{d\_A} / v_{d\_B} = 2/3$

Therefore, the ratio of the drift velocity of electrons in wire A (v_{d_A}) to that in wire B (v_{d_B}) is **2:3**. This means the drift velocity of electrons in wire B will be 3/2 times higher than that in wire A to compensate for the lower number density of electrons and maintain the same current flow