Electromagnetic Induction JEE Main PYQ - 1

Total Time: 1 Hour **Total Marks:** 100

Instructions

Instructions

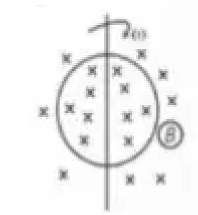
1. Test will auto submit when the Time is up.
2. The Test comprises of multiple choice questions (MCQ) with one or more correct answers.
3. The clock in the top right corner will display the remaining time available for you to complete the examination.

Navigating & Answering a Question

1. The answer will be saved automatically upon clicking on an option amongst the given choices of answer.
2. To deselect your chosen answer, click on the clear response button.
3. The marking scheme will be displayed for each question on the top right corner of the test window.

Electromagnetic Induction

1. A circular coil is rotating in a magnetic field of magnitude 0.25T with angular speed 6 rpm about its diameter. At $t = 0$, the coilâ€™s configuration is as shown. If the induced emf after the coil is rotated by an angle of 30Â° is 1.6 mV, find the radius of the coil (in cm). $(\pi^2 = 10)$ (+4, -1)



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2. **A small ring is given some velocity along the axis of a solenoid and it remains coaxial with solenoid. Current in solenoid is $i = 10\sin(\omega t)$; $\omega = 1000$ rad/s. Number of turns per unit length is 500/m. Radius of ring is 1 cm and its resistance is 10Ω. Find RMS value of induced current in the ring :** **(+4, -1)**

a. $\sqrt{2} \times 10^{-5}$ A

b. 3×10^{-4} A

c. $\sqrt{2} \times 10^{-4}$ A

d. 5×10^{-6} A

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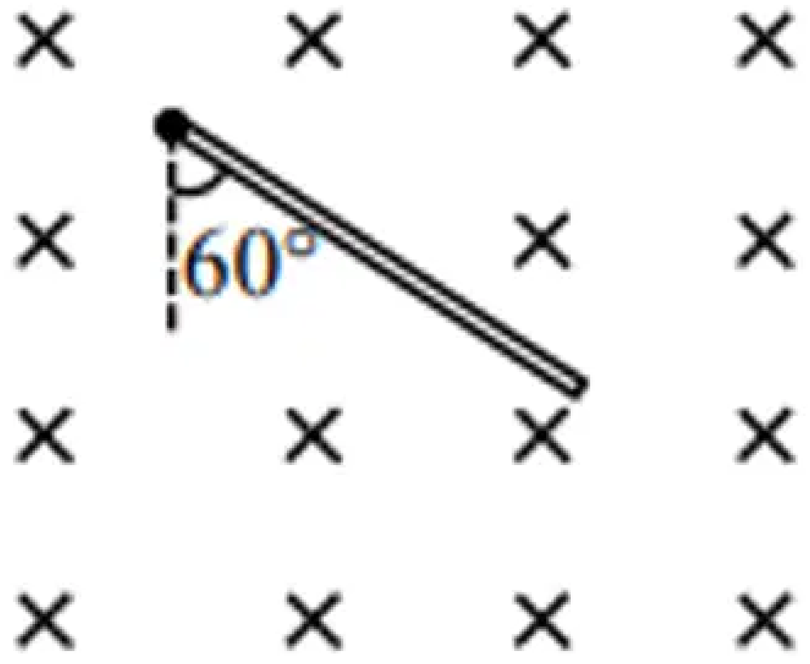
3. **A rod of mass m and length ℓ is released from the position shown with its upper end hinged in a uniform horizontal magnetic field B. Find the maximum induced emf in the rod:** **(+4, -1)**



a. $B\ell\sqrt{\frac{3g\ell}{8}}$

b. $B\ell\sqrt{\frac{g\ell}{8}}$

c. $B\ell\sqrt{\frac{7g\ell}{8}}$

d. $B\ell\sqrt{\frac{5g\ell}{8}}$

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4. A rod of mass m and length l falls from rest in a region of uniform horizontal magnetic field B. Find the emf induced in the rod after falling through a distance x: (+4, -1)

a. $B\sqrt{gx}$

b. $B\sqrt{5gx}$

c. $B\sqrt{2gx}$

d. $B\sqrt{3gx}$

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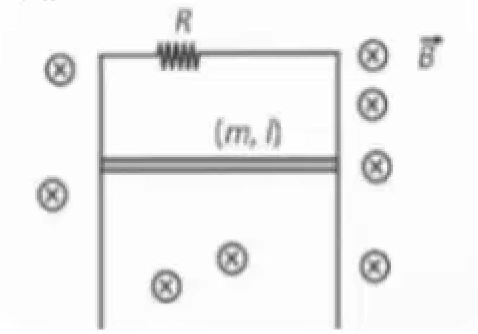
5. A conducting rod of mass m and length l is moving on an infinite pair of conducting rails as shown. Conducting rails are connected to a resistance R at one end. Motion is in the vertical plane and horizontal magnetic field in the region is B. Find the terminal speed of the rod. (+4, -1)



a. $V_0 = \frac{3mgR}{2B^2l^2}$

b. $V_0 = \frac{mgR}{2B^2l^2}$

c. $V_0 = \frac{mgR}{B^2l^2}$

d. $V_0 = \frac{2mgR}{B^2l^2}$

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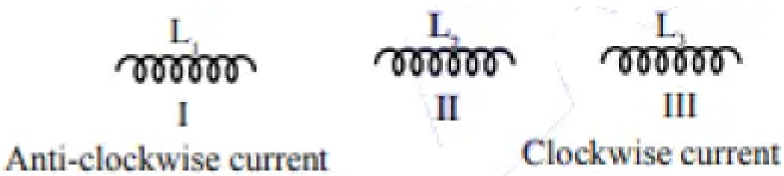
6. As shown, three coils are given. The first and the last coils carry equal currents. Choose the correct option for the second inductor so that it has clockwise current. (+4, -1)



a. Move L_1 towards L_2 and L_3 away from L_2.

b. Move L_1 away from L_2 and L_3 away from L_2.

c. Move L_1 towards L_2 and L_3 towards L_2.

d. Move L_1 away from L_2 and L_3 towards L_2.

7. A rod of mass m and length L is released on a rail placed in a uniform magnetic field B as shown. The circuit has resistance R. What will be the terminal velocity of the rod? v (+4, -1)

a. $\frac{mgR}{B^2L^2}$

b. $\frac{mgR}{B^2\ell^2}$

c. $\frac{mgR}{B\ell^2}$

d. $\frac{mg}{B^2\ell^2R}$

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8. In a series R–L circuit, the voltage of the battery is $10\ \mathrm{V}$. Resistance and inductance are $10\ \Omega$ and $10\ \mathrm{mH}$ respectively. Find the energy stored in the inductor when the current reaches $\frac{1}{e}$ times its maximum value. (+4, -1)

a. $0.67\ \mathrm{mJ}$

b. $1.33\ \mathrm{mJ}$

c. $0.33\ \mathrm{mJ}$

d. $0.50\ \mathrm{mJ}$

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9. If ϵ_0 denotes the permittivity of free space and Φ_E is the flux of the electric field through the area bounded by the closed surface, then the dimension of $\epsilon_0 \frac{d\Phi_E}{dt}$ are that of: (+4, -1)

a. Electric field

b. Electric potential

c. Electric charge

d. Electric current

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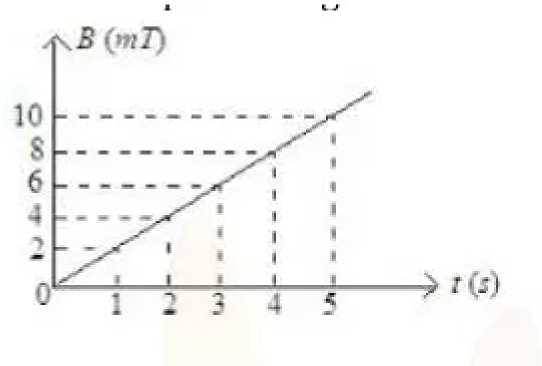
10. The magnetic field B crossing normally a square metallic plate of area $4\,\mathrm{m}^2$ is changing with time as shown in the figure. The magnitude of induced emf in the plate during $t = 2\,\mathrm{s}$ to $t = 4\,\mathrm{s}$ is _______ mV. **(+4, -1)**



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11. The current sensitivity of moving coil galvanometer is increased by 25%.This increase is achieved only by changing in the number of turns of coils and area of cross section of the wire while keeping the resistance of galvanometer coil constant. The percentage change in the voltage sensitivity will be : **(+4, -1)**

a. +25%

b. -25%

c. -50%

d. Zero

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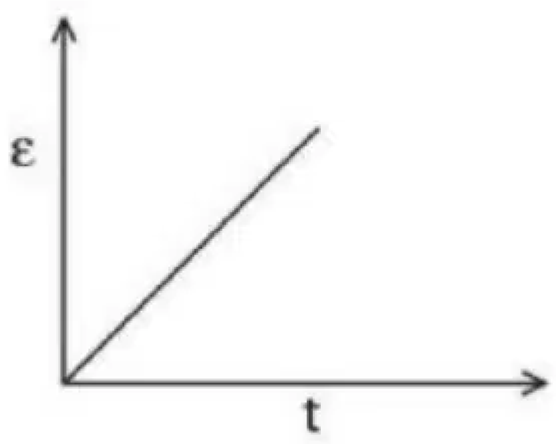
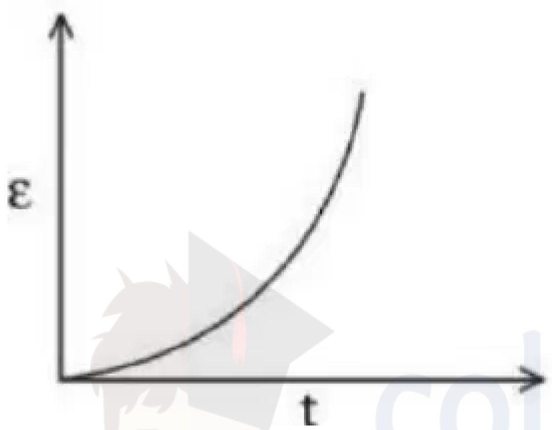
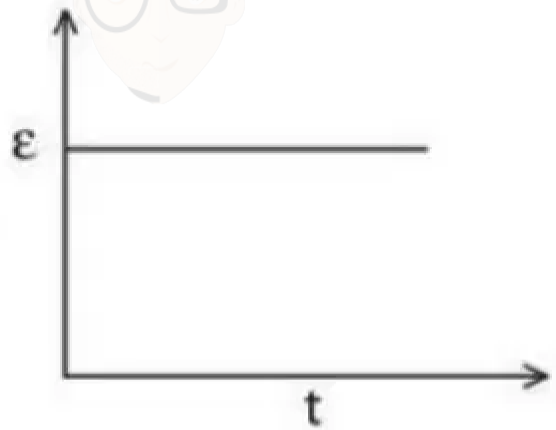
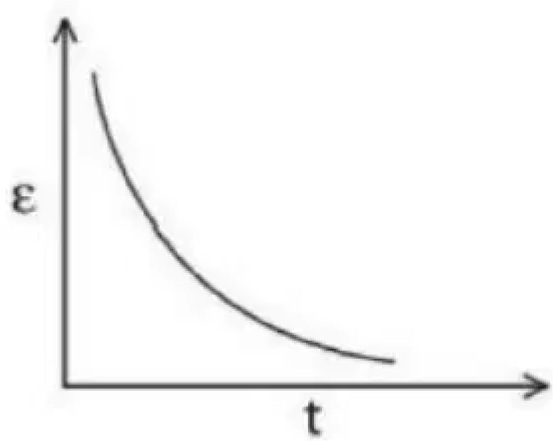
12. A rectangular metallic loop is moving out of a uniform magnetic field region to a field-free region with a constant speed. When the loop is partially inside the magnetic field, the plot of the magnitude of the induced emf (ε) with time (t) is given by: \includegraphics[width=1\linewidth]{3.png} **(+4, -1)**

a. 

b. 

c. 

d. 

13. Consider a long straight wire of a circular cross-section (radius a) carrying a steady current I. The current is uniformly distributed across this cross-section. The distances from the center of the wire's cross-section at which the magnetic field (inside the wire, outside the wire) is half of the maximum possible magnetic field, anywhere due to the wire, will be: (+4, -1)

a. $\frac{a}{2}, 3a$

b. $\frac{a}{4}, 2a$

c. $\frac{a}{2}, 2a$

d. $\frac{a}{4}, \frac{3a}{2}$

14. Consider I_1 and I_2 are the currents flowing simultaneously in two nearby coils 1 and 2, respectively. If L_1 = self-inductance of coil 1, M_{12} = mutual inductance of coil 1 with respect to coil 2, then the value of induced emf in coil 1 will be: (+4, -1)

a. $e_1 = -L_1 \frac{dI_1}{dt} + M_{12} \frac{dI_2}{dt}$

b. $e_1 = -L_1 \frac{dI_1}{dt} + M_{12} \frac{dI_1}{dt}$

c. $e_1 = -L_1 \frac{dI_1}{dt} - M_{12} \frac{dI_2}{dt}$

d. $e_1 = -L_1 \frac{dI_1}{dt} + M_{12} \frac{dI_1}{dt}$

15. A coil of area A and N turns is rotating with angular velocity ω in a uniform magnetic field $\vec{B}$ about an axis perpendicular to $\vec{B}$ Magnetic flux φ and induced emf ε across it, at an instant when $\vec{B}$ is parallel to the plane of the coil, are: (+4, -1)

a. $\phi = AB, \varepsilon = 0$

b. $\phi = 0, \varepsilon = 0$

c. $\phi = 0, \varepsilon = NAB\omega$

d. $\varphi = 0, \quad \varepsilon = NAB\omega$

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16. If B is magnetic field and μ_0 is permeability of free space, then the dimensions of $\frac{B}{\mu_0}$ is: (+4, -1)

a. $\mathrm{MT}^{-2}A^{-1}$

b. $\mathrm{L}^{-1}A$

c. $\mathrm{LT}^{-2}A^{-1}$

d. $\mathrm{ML}^{2}T^{-2}A^{-1}$

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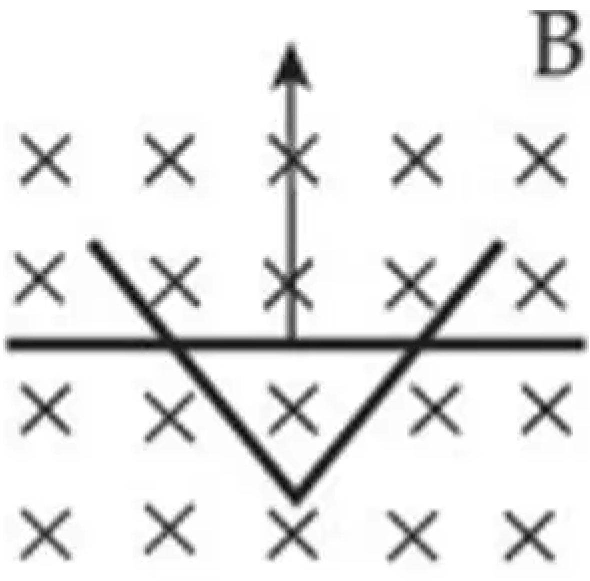
17. A conducting bar moves on two conducting rails as shown in the figure. A constant magnetic field B exists into the page. The bar starts to move from the vertex at time $t = 0$ with a constant velocity. If the induced EMF is $E \propto t^n$, then the value of n is _________________________. (+4, -1)



18. A uniform magnetic field of 0.4 T acts perpendicular to a circular copper disc 20 cm in radius. The disc is having a uniform angular velocity of 10π rad/s about an axis through its center and perpendicular to the disc. What is the potential difference developed between the axis of the disc and the rim? ($\pi = 3.14$) (+4, -1)

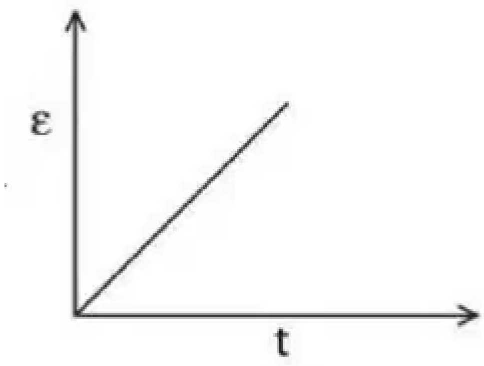
a. 0.5024 V

b. 0.2512 V

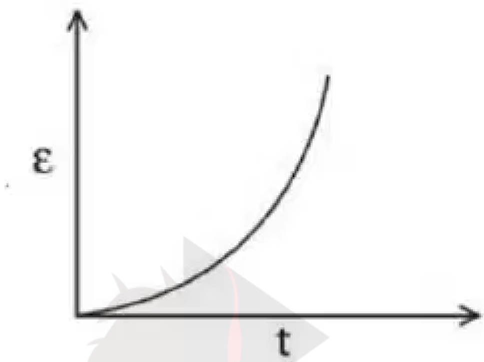
c. 0.0628 V

d. 0.1256 V

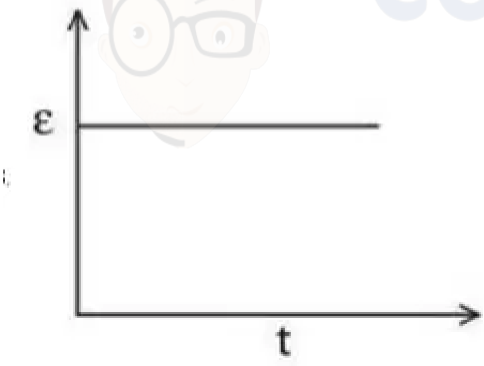
19. A rectangular metallic loop is moving out of a uniform magnetic field region to a field-free region with a constant speed. When the loop is partially inside the magnetic field, the plot of the magnitude of the induced emf (ε) with time (t) is given by: (+4, -1)



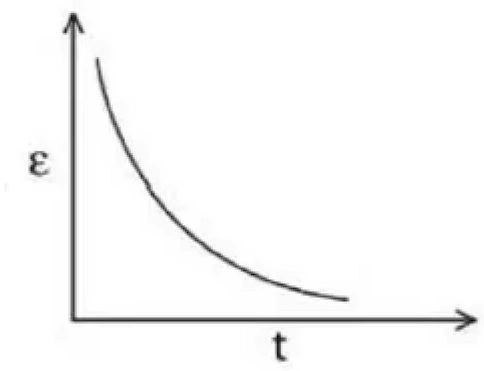
a.



b.



c.



d.

20. A coil of 200 turns and area $0.20\,\mathrm{m}^2$ is rotated at half a revolution per second and is placed in a uniform magnetic field of $0.01\,\mathrm{T}$ perpendicular to the axis of rotation of the coil. The maximum voltage generated in the coil is **(+4, -1)**

$$\frac{2\pi}{\beta}\ \text{volt.}$$

The value of β is:

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21. A transformer has an efficiency of 80% andworks at 10 V and 4 kW. If the secondary voltage is 240 V, then the current in the secondary coil is : **(+4, -1)**

a. 1.59 A

b. 13.33 A

c. 1.33 A

d. 15.1 A

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22. A rod of length 60 cm rotates with a uniform angular velocity $20\,\mathrm{rad\,s^{-1}}$ about its perpendicular bisector, in a uniform magnetic field $0.5\,\mathrm{T}$. The direction of the magnetic field is parallel to the axis of rotation. The potential difference between the two ends of the rod is _____ V. **(+4, -1)**

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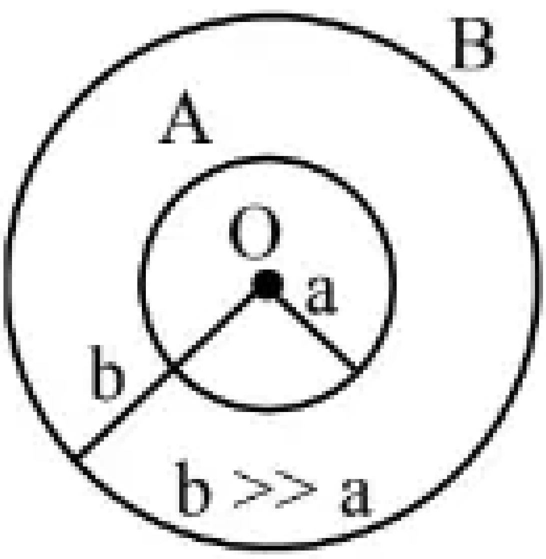
23. Two conducting circular loops A and B are placed in the same plane with their centres coinciding as shown in figure. The mutual inductance between them is: **(+4, -1)**



a. $\frac{\mu_0 \pi a^2}{2b}$

b. $\frac{\mu_0}{2\pi} \cdot \frac{b^2}{a}$

c. $\frac{\mu_0 \pi b^2}{2a}$

d. $\frac{\mu_0}{2\pi} \cdot \frac{a^2}{b}$

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24. A small square loop of wire of side ℓ is placed inside a large square loop of wire of side L ($L = \ell^2$). The loops are coplanar and their centers coincide.The value of the mutual inductance of the system is $\sqrt{x} \times 10^{-7}\,\mathrm{H}$, where $x =$ _____. **(+4, -1)**

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25. A coil is placed perpendicular to a magnetic field of 5000 T. When the field is changed to 3000 T in 2s, an induced emf of 22 V is produced in the coil. If the diameter of the coil is 0.02 m, then the number of turns in the coil is : **(+4, -1)**

a. 7

b. 70

c. 35

d. 140

Answers

1. Answer: 8 - 8

Explanation:

Step 1: Formula for induced emf.
The induced emf ϵ in a coil rotating in a magnetic field is given by:

$$\epsilon = NAB\omega \sin\theta,$$

where: - N is the number of turns (assumed to be 1 for this case), - A is the area of the coil ($A = \pi R^2$), - B is the magnetic field strength, - ω is the angular speed (in radians per second), - θ is the angle of rotation. **Step 2: Convert angular speed to radians per second.**
Given that the angular speed is 6 rpm, we convert it to radians per second:

$$\omega = \frac{6 \times 2\pi}{60} = \frac{\pi}{5} \text{ rad/s}.$$

Step 3: Calculate the radius.
Substitute the known values into the induced emf formula:

$$1.6 \times 10^{-3} = \pi R^2 \times 0.25 \times \frac{\pi}{5} \times \sin 30^\circ.$$

Since $\sin 30^\circ = \frac{1}{2}$, we solve for R and find $R = 8\,\text{cm}$. **Final Answer:**

$$\boxed{8\,\text{cm}}.$$

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2. Answer: c

Explanation:

Step 1: Understanding the Question:
We have a ring placed coaxially inside a solenoid. The solenoid has a time-varying current, which creates a time-varying magnetic field. This changing magnetic field, in turn, creates a changing magnetic flux through the ring, inducing an electromotive force (EMF) and a current in the ring according to Faraday's law of induction. We need to find the RMS value of this induced current.

Step 2: Key Formula or Approach:

1. **Magnetic Field in a Solenoid:** $B = \mu_0 n i$, where n is the number of turns per unit length.
2. **Magnetic Flux:** $\Phi = B \cdot A$, where A is the area of the ring.
3. **Faraday's Law of Induction:** $\mathcal{E} = -\frac{d\Phi}{dt}$.
4. **Ohm's Law:** Induced current $I_{ind} = \frac{\mathcal{E}}{R}$.
5. **RMS Value:** For a sinusoidal current $I = I_0 \cos(\omega t)$, the RMS value is $I_{rms} = \frac{I_0}{\sqrt{2}}$.

Step 3: Detailed Explanation:

Part A: Magnetic Flux through the Ring

The magnetic field inside the solenoid is $B = \mu_0 n i = \mu_0 n(10\sin(\omega t))$. This field is uniform inside the solenoid and parallel to the axis.

The area of the ring is $A = \pi r^2$.

The magnetic flux through the ring is $\Phi = B \cdot A = \mu_0 n(10\sin(\omega t))(\pi r^2)$.

Part B: Induced EMF

$$\mathcal{E} = -\frac{d\Phi}{dt} = -\frac{d}{dt}\left[10\pi r^2 \mu_0 n \sin(\omega t)\right]$$

$$\mathcal{E} = -10\pi r^2 \mu_0 n \frac{d}{dt}(\sin(\omega t)) = -10\pi r^2 \mu_0 n\omega \cos(\omega t)$$

The peak value (amplitude) of the induced EMF is $\mathcal{E}_0 = 10\pi r^2 \mu_0 n\omega$.

Part C: Induced Current and its RMS Value

The induced current is $I_{ind} = \frac{\mathcal{E}}{R} = -\frac{10\pi r^2 \mu_0 n\omega}{R}\cos(\omega t)$.

The peak value of the induced current is $I_0 = \frac{10\pi r^2 \mu_0 n\omega}{R}$.

The RMS value of the induced current is $I_{rms} = \frac{I_0}{\sqrt{2}} = \frac{10\pi r^2 \mu_0 n\omega}{\sqrt{2}R}$.

Part D: Calculation

Substitute the given values (in SI units):

- $r = 1 \text{ cm} = 0.01 \text{ m}$
- $\mu_0 = 4\pi \times 10^{-7}$ T·m/A
- $n = 500$ m^{-1}
- $\omega = 1000$ rad/s
- $R = 10\ \Omega$

$$I_{rms} = \frac{10\pi(0.01)^2(4\pi \times 10^{-7})(500)(1000)}{\sqrt{2} \times 10}$$

$$I_{rms} = \frac{\pi(10^{-4})(4\pi \times 10^{-7})(500)(1000)}{\sqrt{2}}$$

$$I_{rms} = \frac{4\pi^2 \times (10^{-4} \times 10^{-7} \times 5 \times 10^2 \times 10^3)}{\sqrt{2}} = \frac{20\pi^2 \times 10^{-6}}{\sqrt{2}}$$

Using the approximation $\pi^2 \approx 10$:

$$I_{rms} \approx \frac{20 \times 10 \times 10^{-6}}{\sqrt{2}} = \frac{200 \times 10^{-6}}{\sqrt{2}} = \frac{2 \times 10^{-4}}{\sqrt{2}} = \sqrt{2} \times 10^{-4}\ \text{A}$$

Step 4: Final Answer:
The RMS value of the induced current in the ring is $\sqrt{2} \times 10^{-4}$ A.

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3. Answer: a

Explanation:

Concept: Key ideas involved:
Conservation of mechanical energy for a rotating rod
Moment of inertia of a rod about one end: $I = \frac{1}{3}m\ell^2$
Motional emf induced in a rotating rod in a magnetic field The maximum emf is induced when the angular speed of the rod is maximum, i.e., when the rod passes through the vertical position.
Step 1: Loss of gravitational potential energy The centre of mass of the rod is at a distance $\frac{\ell}{2}$ from the hinge. Initial angle with vertical is 60°. Vertical fall of centre of mass:

$$h = \frac{\ell}{2}(1 - \cos 60^\circ) = \frac{\ell}{2}\left(1 - \frac{1}{2}\right) = \frac{\ell}{4}$$

Loss in potential energy:

$$\Delta U = mg\frac{\ell}{4}$$

Step 2: Rotational kinetic energy at lowest position

$$\frac{1}{2}I\omega^2 = mg\frac{\ell}{4}$$

Using $I = \frac{1}{3}m\ell^2$:

$$\frac{1}{2} \cdot \frac{1}{3}m\ell^2\omega^2 = mg\frac{\ell}{4}$$

$$\omega^2 = \frac{3g}{2\ell}$$

Step 3: Expression for induced emf For a rod rotating in a uniform magnetic field perpendicular to the plane of motion:

$$\mathcal{E}_{\text{max}} = \frac{1}{2}B\ell^2\omega$$

Substitute ω:

$$\mathcal{E}_{\text{max}} = \frac{1}{2}B\ell^2\sqrt{\frac{3g}{2\ell}} = B\ell\sqrt{\frac{3g\ell}{8}}$$

Step 4: Thus, the maximum induced emf is:

$$\boxed{B\ell\sqrt{\frac{3g\ell}{8}}}$$

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4. **Answer: c**

Explanation:

Concept: When a conductor of length l moves with velocity v perpendicular to a magnetic field B, the motional emf induced is:

$$\mathcal{E} = Blv$$

For a body falling freely from rest under gravity, the velocity after falling through a distance x is obtained using kinematics.
Step 1: Since the rod starts from rest and falls freely under gravity,

$$v^2 = u^2 + 2gx$$

Here $u = 0$, so

$$v = \sqrt{2gx}$$

Step 2: The rod is falling vertically while the magnetic field is horizontal, hence the velocity is perpendicular to the magnetic field. Therefore, the induced emf is:

$$\mathcal{E} = Blv$$

Step 3: Substitute the value of v:

$$\mathcal{E} = Bl\sqrt{2gx}$$

Since l is constant and absorbed in the given options, the emf varies as:

$$\boxed{\mathcal{E} = B\sqrt{2gx}}$$

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5. **Answer: c**

Explanation:

Step 1: Force due to magnetic field.
The force on the rod moving in a magnetic field is given by $F = BlvI$, where v is the velocity, l is the length of the rod, and I is the current. **Step 2: Induced current.**
The induced EMF ε is given by $\varepsilon = Blv$, and the current I is given by $I = \frac{\varepsilon}{R} = \frac{Blv}{R}$. **Step 3: Apply Newton's second law.**
At terminal speed, the magnetic force equals the gravitational force:

$$Blv\frac{Blv}{R} = mg$$

Solving for v, we get the terminal speed as:

$$V_0 = \frac{mgR}{B^2l^2}$$

Final Answer:

$$\boxed{\frac{mgR}{B^2l^2}}$$

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6. **Answer: a**

Explanation:

Concept:
The direction of induced current in a coil is determined by **Lenz's law**. According to Lenz's law: The induced current flows in such a direction that it opposes the change in magnetic flux producing it. Key ideas used:

Approaching coils increase magnetic flux
Receding coils decrease magnetic flux
The induced current always opposes the {change} in flux, not the flux itself
Step 1: Effect of coil L_1 on coil L_2. The current in L_1 is **anticlockwise**. If L_1 is moved **towards** L_2, the magnetic flux through L_2 due to L_1 increases. To oppose this increase, the induced current in L_2 must produce a magnetic field in the **opposite direction**, which corresponds to a **clockwise current**.
Step 2: Effect of coil L_3 on coil L_2. The current in L_3 is **clockwise**. If L_3 is moved **away** from L_2, the magnetic flux through L_2 due to L_3 decreases. To oppose the decrease in flux, the induced current in L_2 must try to maintain the original flux direction, again requiring a **clockwise current**.
Step 3: Combine both effects. Both actions:
Moving L_1 **towards** L_2
Moving L_3 **away** from L_2 produce induced currents in L_2 in the **same (clockwise) direction**. Hence, this combination ensures that the current in the second coil is clockwise.

$$\boxed{\text{Correct option is (1)}}$$

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7. Answer: b

Explanation:

Concept:
As the rod moves on the rails in a uniform magnetic field, an emf is induced due to change of magnetic flux. This induces a current in the closed circuit, which produces a magnetic force opposing the motion (Lenz's law). At **terminal velocity**, the magnetic retarding force balances the weight of the rod. Key relations:
Motional emf: $\varepsilon = B\ell v$
Current: $I = \dfrac{\varepsilon}{R}$
Magnetic force on rod: $F = BI\ell$
Step 1: Calculate the induced emf. If the rod moves with speed v,

$$\varepsilon = B\ell v$$

Step 2: Find the induced current.

$$I = \frac{\varepsilon}{R} = \frac{B\ell v}{R}$$

Step 3: Determine the magnetic force on the rod. The force on a current-carrying conductor in a magnetic field is:

$$F = BI\ell$$

Substitute I:

$$F = B\ell\left(\frac{B\ell v}{R}\right) = \frac{B^2\ell^2 v}{R}$$

This force acts upward, opposing the downward motion of the rod.
Step 4: Apply the condition for terminal velocity. At terminal velocity v_t, net force is zero:

$$mg = \frac{B^2\ell^2 v_t}{R}$$

Solve for v_t:

$$v_t = \frac{mgR}{B^2\ell^2}$$

$$\boxed{v_t = \frac{mgR}{B^2\ell^2}}$$

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8. Answer: a

Explanation:

Concept: In a series R–L circuit connected to a DC source:
Maximum (steady-state) current: $I_{\max} = \dfrac{V}{R}$
Energy stored in an inductor: $U = \dfrac{1}{2}LI^2$
Step 1: Find the maximum current in the circuit.

$$I_{\max} = \frac{V}{R} = \frac{10}{10} = 1 \text{ A}$$

Step 2: Find the current at the given instant.

$$I = \frac{1}{e} I_{\text{max}} = \frac{1}{e}\ \text{A}$$

Step 3: Write the expression for energy stored in the inductor.

$$U = \frac{1}{2} L I^2$$

Given:

$$L = 10\ \text{mH} = 0.01\ \text{H}$$

$$U = \frac{1}{2} \times 0.01 \times \left(\frac{1}{e}\right)^2$$

Step 4: Calculate the value.

$$U = 0.005 \times \frac{1}{e^2} \approx 0.005 \times 0.135 = 6.75 \times 10^{-4}\ \text{J}$$

$$U \approx 0.675\ \text{mJ}$$

$$U \approx 0.67\ \text{mJ}$$

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9. **Answer: d**

Explanation:

We are given that ϵ_0 is the permittivity of free space and Φ_E is the electric flux. The electric flux Φ_E is given by:

$$\Phi_E = \int_S \mathbf{E} \cdot d\mathbf{A}$$

where $\mathbf{E}$ is the electric field and $d\mathbf{A}$ is the area element. The dimension of ϵ_0 (the permittivity of free space) is:

$$[\epsilon_0] = \frac{\text{C}^2}{\text{N m}^2} = \frac{\text{C}^2}{\text{kg} \cdot \text{m}^3 \cdot \text{s}^2}$$

The electric flux Φ_E has the dimension of:

$$[\Phi_E] = \mathrm{C} \cdot \mathrm{m}^2$$

Now, we are interested in the dimension of $\epsilon_0 \frac{d\Phi_E}{dt}$. The dimension of $\frac{d\Phi_E}{dt}$ is the rate of change of electric flux, which has the dimension:

$$\left[\frac{d\Phi_E}{dt}\right] = \frac{\mathrm{C} \cdot \mathrm{m}^2}{\mathrm{s}}$$

Now, multiplying this by ϵ_0, we get:

$$\left[\epsilon_0 \frac{d\Phi_E}{dt}\right] = [\epsilon_0] \times \left[\frac{d\Phi_E}{dt}\right] = \frac{\mathrm{C}^2}{\mathrm{kg} \cdot \mathrm{m}^3 \cdot \mathrm{s}^2} \times \frac{\mathrm{C} \cdot \mathrm{m}^2}{\mathrm{s}}$$

Simplifying this:

$$\left[\epsilon_0 \frac{d\Phi_E}{dt}\right] = \frac{\mathrm{C}^3 \cdot \mathrm{m}^2}{\mathrm{kg} \cdot \mathrm{m}^3 \cdot \mathrm{s}^3} = \frac{\mathrm{C}}{\mathrm{s}}$$

This is the dimension of electric current (since electric current has the dimension $\frac{\mathrm{C}}{\mathrm{s}}$). Thus, the dimension of $\epsilon_0 \frac{d\Phi_E}{dt}$ is electric current.

---

10. **Answer: 8 - 8**

Explanation:

The induced emf in the plate is given by Faraday's Law of Induction:

$$\mathrm{emf} = -\frac{d\Phi}{dt}$$

Where Φ is the magnetic flux given by:

$$\Phi = B \times A$$

Here, $A = 4\,\mathrm{m}^2$, and $\frac{dB}{dt}$ is the slope of the B-time graph from $t = 2\,\mathrm{s}$ to $t = 4\,\mathrm{s}$. From the graph, the change in B is $B_2 - B_1 = 8 - 4 = 4\,\mathrm{T}$ and the change in time is $\Delta t = 4 - 2 = 2\,\mathrm{s}$. Now, the induced emf is:

$$\mathrm{emf} = \frac{dB}{dt} \times A = \frac{4\,\mathrm{T}}{2\,\mathrm{s}} \times 4\,\mathrm{m}^2 = 8\,\mathrm{V}$$

Thus, the magnitude of the induced emf is $8\,\mathrm{V}$.

---

11. **Answer: a**

Explanation:

Given:

$$\tau = mB$$

$$K_\theta = \frac{IA \cdot NB}{I \cdot \theta} = \frac{A \cdot N \cdot B}{K} \quad (1)$$

$$\left(\frac{\theta}{\theta_1}\right) = \frac{I_1}{I_2} = \frac{A \cdot N \cdot B}{K} \quad (2)$$

$$\Rightarrow \lambda = a \cdot N \quad (3)$$

$$V_\theta = I \cdot R = \text{Current Sensitivity} \quad (4)$$

$$\text{Voltage sensitivity} \propto \text{Current sensitivity}$$

Correct Answer: (A)

The formulae involve relationships for current and voltage sensitivities. Equation (1) gives the relationship between the magnetic field B and the area of the coil A. From Equation (2), we can deduce that voltage sensitivity is directly proportional to current sensitivity. This shows a clear relation where R remains constant.

---

12. **Answer: d**

Explanation:

Step 1: Understanding Faraday's Law. According to Faraday's Law of Electromagnetic Induction, the induced emf ε in a loop is given by:

$$\varepsilon = \left|\frac{d\Phi_B}{dt}\right|,$$

where Φ_B is the magnetic flux through the loop. **Step 2:** Expressing flux in terms of motion. Since the loop is moving with constant velocity v, the flux linkage Φ_B is proportional to the area of the loop inside the magnetic field:

$$\Phi_B = BLx,$$

where: - B is the magnetic field strength, - L is the width of the loop, - x is the portion of the loop still inside the field, given by $x = vt$. **Step 3:** Computing emf. Differentiating Φ_B with respect to time:

$$\varepsilon = BL\frac{dx}{dt} = BLv.$$

Since v is constant, the emf remains constant while the loop is partially inside the field. However, as the loop starts exiting, the effective area inside the field decreases linearly, causing ε to decrease linearly to zero. **Step 4:** Identifying the correct graph. - Since the emf starts at zero, increases linearly while exiting, and reaches a peak before going to zero once the loop is fully out of the field, the correct choice is:

$$\boxed{1} \text{ (Linearly increasing graph)}$$

---

13. Answer: c

Explanation:

To solve for the distances from the center of the wire's cross-section at which the magnetic field is half of its maximum value, we first consider the magnetic field behavior for different sections of the wire.

Inside the Wire $(r \leq a)$**:**

The magnetic field B at any point inside the wire is given by:

$$B = \frac{\mu_0 I r}{2\pi a^2}$$

where μ_0 is the permeability of free space, I is the total current, r is the radial distance from the center, and a is the wire's radius.

The maximum magnetic field inside the wire occurs at the surface, $r = a$:

$$B_{\text{max, inside}} = \frac{\mu_0 I a}{2\pi a^2} = \frac{\mu_0 I}{2\pi a}$$

Half of this maximum value is:

$$\frac{B_{\text{max, inside}}}{2} = \frac{\mu_0 I}{4\pi a}$$

Setting the general expression for B equal to half the maximum:

$$\frac{\mu_0 I r}{2\pi a^2} = \frac{\mu_0 I}{4\pi a}$$

Simplifying, we find:

$$r = \frac{a}{2}$$

Outside the Wire $(r > a)$**:**

The magnetic field B at any point outside the wire is given by:

$$B = \frac{\mu_0 I}{2\pi r}$$

The maximum magnetic field outside is on the surface $r = a$:

$$B_{\text{max, outside}} = \frac{\mu_0 I}{2\pi a}$$

Half of this maximum is:

$$\frac{B_{\text{max, outside}}}{2} = \frac{\mu_0 I}{4\pi a}$$

Equating the general expression for B outside to half the maximum:

$$\frac{\mu_0 I}{2\pi r} = \frac{\mu_0 I}{4\pi a}$$

Simplifying, we find:

$$r = 2a$$

Therefore, the distances from the center where the magnetic field is half its maximum are $\frac{a}{2}$ inside the wire and $2a$ outside the wire.

---

14. Answer: b

Explanation:

To determine the value of the induced electromotive force (emf) in coil 1 when currents are flowing in two nearby coils, we need to consider both self-induction and mutual induction effects. The self-induced emf in coil 1, due to its own current, is given by:

$e_{self} = -L_1 \frac{dI_1}{dt}$

where:

- L_1 is the self-inductance of coil 1.

- $\frac{dI_1}{dt}$ is the rate of change of current in coil 1.

Additionally, the mutual induced emf in coil 1, due to the current in coil 2, is expressed as:

$$e_{mutual} = M_{12}\frac{dI_2}{dt}$$

where:

- M_{12} is the mutual inductance between coil 1 and coil 2.
- $\frac{dI_2}{dt}$ is the rate of change of current in coil 2.

The total induced emf in coil 1, considering both self-induction and mutual induction, is:

$$e_1 = e_{self} + e_{mutual}$$

Substituting the expressions for e_{self} and e_{mutual}, we get:

$$e_1 = -L_1\frac{dI_1}{dt} + M_{12}\frac{dI_2}{dt}$$

---

15. **Answer: d**

Explanation:

To solve this problem, we need to understand the concept of electromagnetic induction in a rotating coil in a magnetic field.

Given:

- A coil with area A and N turns, rotating with angular velocity ω in a uniform magnetic field $\vec{B}$.
- The axis of rotation is perpendicular to the magnetic field $\vec{B}$.
- We are asked to find the magnetic flux φ and the induced electromotive force (emf) ε when $\vec{B}$ is parallel to the plane of the coil.

Key Concepts:

- Magnetic flux (φ) through a coil is given by the formula: $\varphi = B \cdot A \cdot \cos\theta$, where θ is the angle between the magnetic field $\vec{B}$ and the normal to the plane of the coil.

- Induced emf (ε) is given by Faraday's law of electromagnetic induction: $\varepsilon = -N\frac{d\varphi}{dt}$.

Analysis:

- When the magnetic field $\vec{B}$ is parallel to the plane of the coil, the angle $\theta = 90^\circ$, thus: $\cos\theta = 0$.
- Consequently, the magnetic flux is: $\varphi = B \cdot A \cdot \cos 90^\circ = 0$.

Calculating the induced emf (ε):

- Since the coil is rotating, the angle θ will change with time, affecting the rate of change of flux.
- The expression for the emf, using that the coil rotates with angular velocity ω, becomes: $\varepsilon = NAB\omega \cdot \sin(\omega t)$.
- At the specified instant, $\theta = 90^\circ$, which leads to $\cos\theta = 0$, so the rate of change of flux is maximal, thereby inducing the maximum emf: $\varepsilon = NAB\omega$.

Conclusion:

- At the instant when $\vec{B}$ is parallel to the plane of the coil, the magnetic flux is zero (since the magnetic field lines are parallel to the coil and not passing through it).
- The maximum emf is induced due to the change in flux related to the rotation of the coil, resulting in $\varepsilon = NAB\omega$.

Thus, the correct answer is: $\varphi = 0, \quad \varepsilon = NAB\omega$.

---

16. Answer: b

Explanation:

To find the dimensions of the expression $\frac{B}{\mu_0}$, where B is the magnetic field and μ_0 is the permeability of free space, we must first consider their fundamental dimensional formulas:

The magnetic field B has the dimensions given by: $[B] = \mathrm{MT}^{-2}A^{-1}$

The permeability of free space μ_0 has the dimensions: $[\mu_0] = \mathrm{MLT}^{-2}A^{-2}$

Now, calculate $\frac{B}{\mu_0}$:

$\frac{B}{\mu_0} = \frac{\mathrm{MT}^{-2}A^{-1}}{\mathrm{MLT}^{-2}A^{-2}}$

This simplifies to:

$\frac{B}{\mu_0} = \frac{\mathrm{M}^{1-1}\mathrm{T}^{-2+2}\mathrm{A}^{-1+2}}{\mathrm{L}^1}$

Resulting dimensions are: $\mathrm{L}^{-1}\mathrm{A}^1$

Therefore, the dimensions of $\frac{B}{\mu_0}$ are $\mathrm{L}^{-1}A$.

---

17. Answer: 2 - 2

Explanation:

The induced EMF in a moving conductor is given by:

$$E = B\frac{dA}{dt}$$

The area enclosed by the rails at any time t is:

$$A = \frac{1}{2}l^2$$

Since the length of the moving bar is proportional to time t, we assume:

$$l = vt$$

Then:

$$A = \frac{1}{2}(vt)^2 = \frac{1}{2}v^2t^2$$

Differentiating with respect to t:

$$\frac{dA}{dt} = v^2t$$

Thus, the induced EMF is:

$$E = Bv^2t$$

Comparing with $E \propto t^n$, we get $n = 2$.

---

18. **Answer: d**

Explanation:

The induced potential difference V in a rotating conducting disc is given by:

$$V = \frac{1}{2} B\omega R^2$$

where: - $B = 0.4$ T (magnetic field strength), - $\omega = 10\pi$ rad/s (angular velocity), - $R = 20$ cm $= 0.2$ m (radius of the disc). Substituting the values:

$$V = \frac{1}{2} \times 0.4 \times 10\pi \times (0.2)^2$$

$$V = \frac{1}{2} \times 0.4 \times 10\pi \times 0.04$$

$$V = \frac{1}{2} \times 0.4 \times 0.4\pi$$

$$V = \frac{1}{2} \times 0.16\pi$$

$$V = 0.08\pi$$

Since $\pi = 3.14$, we calculate:

$$V = 0.08 \times 3.14 = 0.2512\,\mathrm{V}$$

Thus, the correct answer is (2) 0.2512 V.

---

19. **Answer: a**

Explanation:

Step 1: Understanding Faraday's Law. According to Faraday's Law of Electromagnetic Induction, the induced emf ε in a loop is given by:

$$\varepsilon = \left| \frac{d\Phi_B}{dt} \right|,$$

where Φ_B is the magnetic flux through the loop.

Step 2: Expressing flux in terms of motion. Since the loop is moving with constant velocity v, the flux linkage Φ_B is proportional to the area of the loop inside the magnetic field:

$$\Phi_B = BLx,$$

where: - B is the magnetic field strength, - L is the width of the loop, - x is the portion of the loop still inside the field, given by $x = vt$.

Step 3: Computing emf. Differentiating Φ_B with respect to time:

$$\varepsilon = BL\frac{dx}{dt} = BLv.$$

Since v is constant, the emf remains constant while the loop is partially inside the field. However, as the loop starts exiting, the effective area inside the field decreases linearly, causing ε to decrease linearly to zero.

Step 4: Identifying the correct graph.
- Since the emf starts at zero, increases linearly while exiting, and reaches a peak before going to zero once the loop is fully out of the field, the correct choice is:

$$\boxed{1} \text{ (Linearly increasing graph)}$$

---

20. Answer: 5 - 5

Explanation:

To determine the value of β in the given problem, we apply the formula for the maximum voltage (emf) induced in a rotating coil: $E_{\max} = NAB\omega$. Here:

- $N = 200$ (number of turns)
- $A = 0.20\,\text{m}^2$ (area of the coil)
- $B = 0.01\,\text{T}$ (magnetic field strength)
- ω (angular speed in radians per second needs to be calculated)

The coil is rotated at half a revolution per second. The angular speed ω in radians per second is given by:
$\omega = 0.5 \times 2\pi = \pi\,\text{rad/s}$

Now, substituting these values into the formula for $E_{\max}$:
$E_{\max} = 200 \times 0.20 \times 0.01 \times \pi = 0.4\pi \text{ V}$

We are told $E_{\max} = \frac{2\pi}{\beta}$, so we equate and solve for β:
$0.4\pi = \frac{2\pi}{\beta}$

$\beta = \frac{2\pi}{0.4\pi} = \frac{2}{0.4} = 5$

Therefore, the value of β is 5.

---

21. **Answer: b**

Explanation:

To solve the problem regarding the transformer's efficiency and current in the secondary coil, we need to apply the basic principles of transformers and efficiency calculations.

Given:

- Efficiency (η) = 80% = 0.8
- Primary voltage (V_p) = 10 V
- Power (P_p) = 4 kW = 4000 W (since 1 kW = 1000 W)
- Secondary voltage (V_s) = 240 V

The efficiency formula related to transformers is given by:

$\eta = \frac{P_s}{P_p}$,

where P_s is the power in the secondary coil.

First, calculate the power in the secondary coil:

$P_s = \eta \times P_p = 0.8 \times 4000 \text{ W} = 3200 \text{ W}$

Next, we find the current in the secondary coil using the formula:

$P_s = V_s \times I_s$

where I_s is the current in the secondary coil.

Rearrange the formula to solve for I_s:

$I_s = \frac{P_s}{V_s} = \frac{3200\,\mathrm{W}}{240\,\mathrm{V}} = 13.33\,\mathrm{A}$

Thus, the current in the secondary coil is **13.33 A**.

Therefore, the correct answer is:

13.33 A

Justification for other options:

- **1.59 A, 1.33 A, 15.1 A:** These values do not satisfy the power and efficiency equations used in the transformer calculations under the given conditions.

Remember, the power and efficiency calculations should be consistent with the transformer's behavior and the given conditions of primary and secondary voltages.

---

22. **Answer: 0 - 0**

Explanation:

The given data:
Length of rod, $\ell = 60\,\mathrm{cm} = 0.6\,\mathrm{m}$, Angular velocity, $\omega = 20\,\mathrm{rad/s}$, Magnetic field, $B = 0.5\,\mathrm{T}$
.

The potential difference $V_O - V_A$ between the ends of a rod rotating in a magnetic field is given by:

$$V_O - V_A = \frac{B\omega\ell^2}{2}.$$

Substitute the values:

$$V_O - V_A = \frac{0.5 \times 20 \times (0.6)^2}{2} = \frac{0.5 \times 20 \times 0.36}{2}.$$

$$V_O - V_A = \frac{3.6}{2} = 1.8\,\mathrm{V}.$$

However, since the magnetic field is parallel to the axis of rotation, no emf is induced across the rod. Therefore,

$$V_A = V_B \implies V_A - V_B = 0.$$

Answer: $0\,\mathrm{V}$

---

23. Answer: a

Explanation:

The magnetic flux (ϕ) through loop B due to current in loop A is given by:

$$\phi = M \cdot i = B \cdot A$$

The mutual inductance is:

$$M = \frac{\mu_0 \pi a^2}{2b}$$

where a is the radius of loop A, b is the distance between the loops, and μ_0 is the permeability of free space.

---

24. Answer: 128 - 128

Explanation:

Step 1: Magnetic Field (MF) due to the larger square loop at the center

The magnetic field B at the center of a square loop is given by:

$$B = \frac{4\mu_0 I}{4\pi \left(\frac{L}{2}\right)} [\sin 45^\circ + \sin 45^\circ]$$

Simplifying the expression, we get:

$$B = \frac{2\sqrt{2}\mu_0 I}{\pi L}.$$

Step 2: Magnetic Flux (ϕ) in the smaller coil

The magnetic flux ϕ in the smaller coil is the product of the magnetic field B and the area of the coil $A = L^2$, which gives:

$$\phi = \frac{2\sqrt{2}\mu_0 I}{\pi L} \cdot L^2.$$

Simplifying, we have:

$$\phi = 2\sqrt{2}\frac{\mu_0 I}{\pi}L.$$

Step 3: Mutual Inductance (M)

The mutual inductance M is given by the ratio of flux ϕ to the current I:

$$M = \frac{\phi}{I} = 2\sqrt{2}\frac{\mu_0 I^2}{\pi L}.$$

Substituting the values, we get:

$$M = 2\sqrt{2} \times 4 \times 10^{-7}\,\mathrm{H} = \sqrt{128 \times 10^{-7}}\,\mathrm{H}.$$

Therefore, the value of x is:

$$x = 128.$$

---

25. Answer: b

Explanation:

To find the number of turns in the coil given the information about the change in the magnetic field, we can use Faraday's Law of Electromagnetic Induction, which states that the induced emf (ε) in a coil is proportional to the rate of change of magnetic flux through the coil. The formula is:

$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$

where:

- ε is the induced emf,
- N is the number of turns in the coil,
- $\Delta\Phi$ is the change in magnetic flux,

- Δt is the time duration of the change.

The magnetic flux Φ through the coil is given by:

$\Phi = B \cdot A$

where:

- B is the magnetic field,
- A is the area of the coil.

The area A of the coil can be calculated from its diameter. Given the diameter $d = 0.02\,\mathrm{m}$, the radius $r = \frac{d}{2} = 0.01\,\mathrm{m}$. Thus, the area is:

$A = \pi r^2 = \pi(0.01)^2 = 0.0001\pi\,\mathrm{m}^2$

The change in magnetic field ΔB is:

$\Delta B = B_{\text{final}} - B_{\text{initial}} = 3000\,\mathrm{T} - 5000\,\mathrm{T} = -2000\,\mathrm{T}$

The change in magnetic flux $\Delta\Phi$ is:

$\Delta\Phi = A \cdot \Delta B = 0.0001\pi \cdot (-2000) = -0.2\pi\,\mathrm{Wb}$

The time duration $\Delta t = 2\,\mathrm{s}$. Since the induced emf $\varepsilon = 22\,\mathrm{V}$, we can write:

$22 = -N \cdot \frac{-0.2\pi}{2}$

Solving for N:

$22 = N \cdot \frac{0.2\pi}{2}$

$22 = N \cdot 0.1\pi$

$N = \frac{22}{0.1\pi}$

Calculating the value:

$N \approx \frac{22}{0.314} \approx 70$

Thus, the number of turns in the coil is **70**.