Electromagnetic Induction JEE Main PYQ - 2

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 rectangular loop of sides 12 cm and 5 cm, with its sides parallel to the x-axis and y-axis respectively, moves with a velocity of 5 cm/s in the positive x-axis direction, in a space containing a variable magnetic field in the positive z direction. (+4, -1)
The field has a gradient of 10^{-3} T/cm along the negative x direction, and it is decreasing with time at the rate of 10^{-3} T/s. If the resistance of the loop is 6 mΩ, the power dissipated by the loop as heat is ______ $\times 10^{-9}$ W.

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2. Two coils have mutual inductance 0.002 H. The current changes in the first coil according to the relation $i = i_0 \sin \omega t$, where $i_0 = 5\,\mathrm{A}$ and $\omega = 50\pi\,\mathrm{rad/s}$. The maximum value of emf in the second coil is $\frac{\pi}{\alpha}$. The value of α is ______. (+4, -1)

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3. A rectangular loop of length 2.5 m and width 2 m is placed at 60° to a magnetic field of 4 T. The loop is removed from the field in 10 sec. The average emf induced in the loop during this time is: (+4, -1)

a. -2V

b. $+2V$

c. $+1V$

d. − 1V

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4. A power transmission line feeds input power at 2.3 kV to a step down transformer with its primary winding having 3000 turns. The output power is delivered at 230 V by the transformer. The current in the primary of the transformer is 5A and its efficiency is 90%. The winding of transformer is made of copper. The output current of transformer is_____A. (+4, -1)

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5. A horizontal straight wire 5 m long, extending from east to west, is falling freely at a right angle to the horizontal component of Earth's magnetic field $0.60 \times 10^{-4}\,\mathrm{Wb/m^2}$. The instantaneous value of emf induced in the wire when its velocity is $10\,\mathrm{m/s}$ is _______ $\times 10^{-3}\,\mathrm{V}$. (+4, -1)

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6. A square loop of side $10\,\mathrm{cm}$ and resistance $0.7\,\Omega$ is placed vertically in the east-west plane. A uniform magnetic field of $0.20\,\mathrm{T}$ is set up across the plane in the northeast direction. The magnetic field is decreased to zero in $1\,\mathrm{s}$ at a steady (+4, -1)

rate. Then, the magnitude of the induced emf is $\sqrt{x} \times 10^{-3}\,\text{V}$. The value of x is _____.

7. Primary side of a transformer is connected to 230 V, 50 Hz supply. Turns ratio of primary to secondary winding is 10 : 1. Load resistance connected to secondary side is 46 Ω. The power consumed in it is : **(+4, -1)**

a. 12.5 W

b. 10.0 W

c. 11.5 W

d. 12.0 W

8. A ceiling fan having 3 blades of length 80 cm each is rotating with an angular velocity of 1200 rpm. The magnetic field of earth in that region is 0.5 G and the angle of dip is 30°. The emf induced across the blades is $N\pi \times 10^{-5}\,\text{V}$. The value of N is _____. **(+4, -1)**

9. A solenoid of 10 turns cross section area 36 cm^2 and of resistance 10 mΩ is placed in a magnetic field which is varying at a constant rate of 0.5 T/sec. Find power of heat dissipation. **(+4, -1)**

a. 1.8 W

b. 3.8 W

c. 3.24 W

d. 7.6 W

10. An insulated copper wire of 100 turns is wrapped around a wooden cylindrical core of the cross- sectional area 24 cm^2. The two ends of the wire are connected to a resistor. The total resistance in the circuit is 129. If an externally applied uniform magnetic field in the core along its axis changes from 1.5 T in one direction to 1.5 T in the opposite direction, the charge flowing through a point in the circuit during the change of magnetic field will be ________mC. **(+4, -1)**

11. A coil has an inductance of 2H and resistance of 4W, A 10V is applied across the coil. The energy stored in the magnetic field after the current has built up to its equilibrium value will be ____ × 10^{−2} J. (+4, -1)

12. The induced emf can be produced in a coil by (+4, -1)
A. moving the coil with uniform speed inside uniform magnetic field
B. moving the coil with non uniform speed inside uniform magnetic field
C. rotating the coil inside the uniform magnetic field
D. changing the area of the coil inside the uniform magnetic field
Choose the correct answer from the options given below :

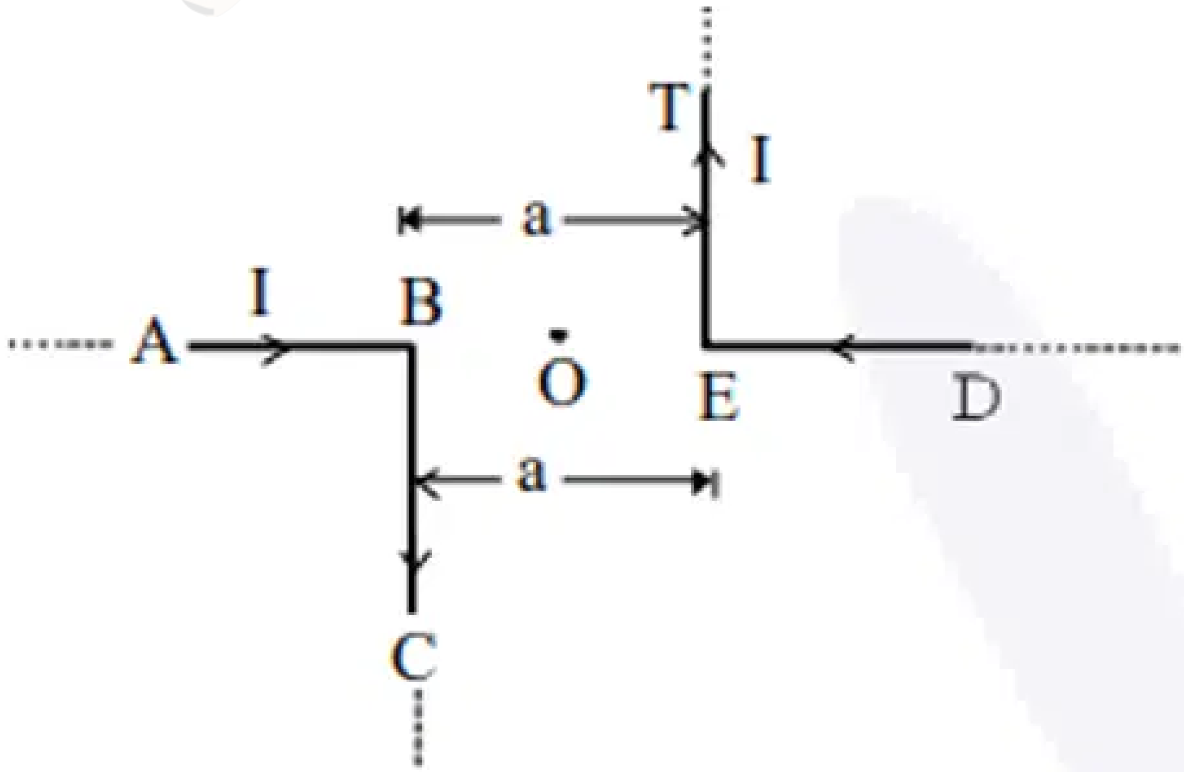
a. B and D only

b. C and D only

c. B and C only

d. A and C only

13. The magnitude of magnetic induction at the mid-point O due to the current arrangement shown in the figure is: (+4, -1)



a. 0

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

c. $\frac{\mu_0 I}{\pi a}$

d. $\frac{\mu_0 I}{4\pi a}$

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14. A block of mass 1 g is equilibrium with the help of a current carrying square loop which is partially lying in constant magnetic field (B) as shown. Resistance of the loop is 10 Ω. Find the voltage (V) (in volts) of the battery in the loop. **(+4, -1)**

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15. The electric current in a circular coil of four turns produces a magnetic induction 32 T at its centre. The coil is unwound and is rewound into a circular coil of single turn, the magnetic induction at the centre of the coil by the same current will be : **(+4, -1)**

a. 16 T

b. 2 T

c. 8 T

d. 4 T

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16. A square loop of area $25\ cm^2$ has a resistance of $10\ \Omega$. The loop is placed in uniform magnetic field of magnitude $40.0\ T$. The plane of loop is perpendicular to the magnetic field. The work done in pulling the loop out of the magnetic field slowly and uniformly in 1.0 sec, will be **(+4, -1)**

a. $1.0 \times 10^{-3} J$

b. $2.5 \times 10^{-3} J$

c. $5 \times 10^{-3} J$

d. $1.0 \times 10^{-4} J$

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17. A circular ring is placed in magnetic field of 0.4 T. Suddenly its radius starts shrinking at the rate of 1 mm/s. Find the induced emf in the ring at r = 2 cm. **(+4, -1)**

a. 16 πμV

b. 8 πμV

c. 16 πmV

d. 8 πmV

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18. A wire of length 314 cm carrying current of 14 A is bent to form a circle. The magnetic moment of the coil is _______ A–m^2. [Given $\pi = 3.14$] **(+4, -1)**

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19. A closely wounded circular coil of radius 5 cm produces a magnetic field of 37.68×10^{-4} T at its center. The current through the coil is _______ A. [Given, number of turns in the coil is 100 and $\pi = 3.14$] **(+4, -1)**

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20. A coil of inductance 1 H and resistance 100 Ω is connected to a battery of 6 V. Determine approximately : **(+4, -1)**
(a) The time elapsed before the current acquires half of its steady – state value.
(b) The energy stored in the magnetic field associated with the coil at an instant 15 ms after the circuit is switched on.
(Given $ln2 = 0.693$, $e^{-3/2}$ = 0.25)

a. t = 10 ms; U = 2 mJ

b. t = 10 ms; U = 1 mJ

c. t = 7 ms; U = 1 mJ

d. t = 7 ms; U = 2 mJ

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21. A coil is placed in a time varying magnetic field. If the number of turns in the coil were to be halved and the radius of wire doubled, the electrical power dissipated due to the current induced in the coil would be: **(+4, -1)**
(Assume the coil to be short circuited.)

a. Halved

b. Quadrupled

c. The same

d. Doubled

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22. In a meter bridge experiment, for measuring unknown resistance 'S', the null point is obtained at a distance 30 cm from the left side as shown at point D. If R is 5.6 kΩ, then the value of unknown resistance 'S' will be ___Ω. **(+4, -1)**

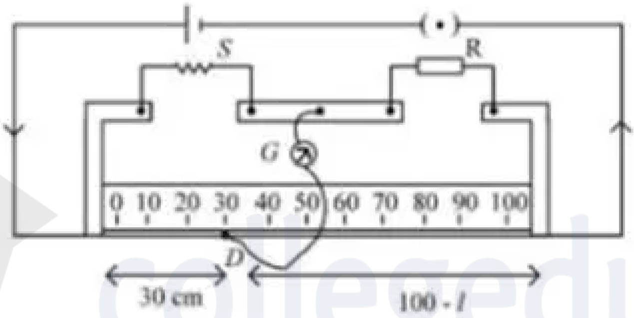

Fig. Meter Bridge

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23. Two sources of equal emfs are connected in series. This combination is connected to an external resistance R. The internal resistances of the two sources are r_1 and r_2 ($r_1 > r_2$). If the potential difference across the source of internal resistance r_1 is zero, then the value of R will be : **(+4, -1)**

a. $r_1 - r_2$

b. $\frac{r_1 r_2}{r_1 + r_2}$

c. $\frac{r_1 + r_2}{2}$

d. $r_2 - r_1$

---

24. If the total energy transferred to a surface in time t is 6.48×10^5 J, then the magnitude of the total momentum delivered to this surface for complete absorption will be : **(+4, -1)**

a. 2.16×10^{-3} kg m/s

b. 2.46×10^{-3} kg m/s

c. 1.58×10^{-3} kg m/s

d. 4.32×10^{-3} kg m/s

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25. A conducting circular loop is placed in X-Y plane in presence of magnetic field $\vec{B} = (3t^3\hat{j} + 3t^2\hat{k})$ in SI unit. If the radius of the loop is 1 m, the induced emf in the loop at time $t = 2s$ is $n\pi V$. The value of n is ______. **(+4, -1)**

Answers

1. Answer: 216 - 216

Explanation:

The power dissipated in the loop can be calculated using the formula:

$$P = I^2 R$$

Where I is the induced current and R is the resistance.

The magnetic flux change through the loop is given by:

$$\frac{dB}{dt} = 10^{-7}\,\mathrm{T/s}$$

Using Faraday's Law, the induced emf in the loop is:

$$\mathcal{E} = -N\frac{d\Phi}{dt}$$

Now, calculate the induced current I:

$$I = \frac{\mathcal{E}}{R}$$

Substituting the values, we find the power dissipated:

$$P = 2.16 \times 10^{-9}\,\mathrm{W}$$

$$P = 216 \times 10^{-9}\,\mathrm{W}$$

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2. Answer: 2 - 2

Explanation:

The mutual inductance between two coils is given as $M = 0.002\,\mathrm{H}$. The current i in the first coil changes according to $i = i_0 \sin \omega t$, where $i_0 = 5\,\mathrm{A}$ and $\omega = 50\pi\,\mathrm{rad/s}$. We need to determine the maximum emf (ϵ) induced in the second coil and find the value of α when $\epsilon_{\max} = \frac{\pi}{\alpha}$.

According to Faraday's Law of electromagnetic induction, the emf induced in the second coil is given by:

$\epsilon = -M\frac{di}{dt}$

Where $\frac{di}{dt}$ is the rate of change of current in the first coil.

Now, let's calculate $\frac{di}{dt}$:

$i(t) = i_0 \sin \omega t = 5 \sin(50\pi t)$

$\frac{di}{dt} = 5 \cdot 50\pi \cos(50\pi t)$

$\frac{di}{dt} = 250\pi \cos(50\pi t)$

The maximum value of $\cos(50\pi t)$ is 1, so the maximum rate of change of current is 250π.

Substituting into the emf formula, we get:

$\epsilon_{\max} = -0.002 \cdot 250\pi = -0.5\pi$

Ignoring the negative sign, $\epsilon_{\max} = 0.5\pi$. Given $\epsilon_{\max} = \frac{\pi}{\alpha}$, we equate and solve:

$0.5\pi = \frac{\pi}{\alpha}$

$\alpha = \frac{\pi}{0.5\pi} = 2$

The computed value of α is 2, which falls within the expected range [2, 2].

Thus, the value of α is **2**.

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3. Answer: c

Explanation:

To calculate the average electromotive force (emf) induced in the loop, we can use Faraday's Law of electromagnetic induction, which states that the induced emf in a closed loop is equal to the negative rate of change of magnetic flux through the loop. Mathematically, this is given by:

$\text{emf} = -\frac{\Delta\Phi}{\Delta t}$

where $\Delta\Phi$ is the change in magnetic flux and Δt is the change in time.

1. **Calculate the initial magnetic flux (Φ_i):**
The magnetic flux (Φ) through the loop is given by:

$$\Phi = B \cdot A \cdot \cos(\theta)$$

where $B = 4\,\text{T}$ (magnetic field strength), $A = \text{length} \times \text{width} = 2.5\,\text{m} \times 2\,\text{m} = 5\,\text{m}^2$ (area of the loop), and $\theta = 60^\circ$ (angle with the magnetic field).

Plugging in the values, we get:

$$\Phi_i = 4 \times 5 \times \cos(60^\circ) = 4 \times 5 \times 0.5 = 10\,\text{Wb}$$

2. **Calculate the final magnetic flux (Φ_f):**
When the loop is removed from the field, $B = 0$, hence $\Phi_f = 0$.

3. **Calculate the change in magnetic flux ($\Delta\Phi$):**

$$\Delta\Phi = \Phi_f - \Phi_i = 0 - 10 = -10\,\text{Wb}$$

4. **Calculate the average emf:**
Given that $\Delta t = 10\,\text{sec}$, the average emf is:

$$\text{emf} = -\frac{-10}{10} = +1\,\text{V}$$

Thus, the average emf induced in the loop during this time is $+1\,\text{V}$. Therefore, the correct answer is $+1\,\text{V}$.

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4. Answer: 45 - 45

Explanation:

To find the output current of the transformer, we can use the principles of conservation of energy and the efficiency of the transformer.

Given Values: Input power $P_{\text{in}} = V_{\text{in}} \times I_{\text{in}}$.

$V_{\text{in}} = 2300\,V$ (input voltage).

$I_{\text{in}} = 5\,A$ (input current).

Efficiency $\eta = 90\% = 0.9$.

Output voltage $V_{\text{out}} = 230\,V$.

Calculating Input Power:

$$P_{\text{in}} = V_{\text{in}} \times I_{\text{in}} = 2300\,V \times 5\,A = 11500\,W.$$

Calculating Output Power: Since the transformer is 90% efficient:

$$P_{\text{out}} = \eta \times P_{\text{in}} = 0.9 \times 11500\,W = 10350\,W.$$

Calculating Output Current: Using the output power and output voltage, the output current I_{out} can be calculated as:

$$P_{\text{out}} = V_{\text{out}} \times I_{\text{out}} \Rightarrow I_{\text{out}} = \frac{P_{\text{out}}}{V_{\text{out}}} = \frac{10350\,W}{230\,V}.$$

Final Calculation:

$$I_{\text{out}} = 45\,A.$$

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5. **Answer: 3 - 3**

Explanation:

To determine the instantaneous emf induced in the wire, we use the formula for motional emf: $\text{emf} = B \cdot l \cdot v$, where B is the magnetic field strength, l is the length of the wire, and v is the velocity of the wire.
Given:

- $B = 0.60 \times 10^{-4}\,\text{Wb/m}^2$
- $l = 5\,\text{m}$
- $v = 10\,\text{m/s}$

Substitute these values into the formula:
$\text{emf} = (0.60 \times 10^{-4}) \times 5 \times 10 = 0.60 \times 10^{-3}\,\text{V}$
This value of $0.60 \times 10^{-3}\,\text{V}$ falls within the provided range of 3 to 3. Thus, the correct answer is 0.60 when expressed in units of $\times 10^{-3}\,\text{V}$. Therefore, the induced emf in the wire is $0.60 \times 10^{-3}\,\text{V}$.

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6. **Answer: 2 - 2**

Explanation:

Step 1: Calculate Area Vector of the Square Loop:

- Side of square = 10 cm = 0.1 m

- Area $A = (0.1)^2 = 0.01\,\text{m}^2$. Since the loop is placed in the east-west plane, the area vector $\vec{A}$ is along the $\hat{j}$ direction:

$$\vec{A} = 0.01\,\hat{j}\,\text{m}^2$$

Step 2: Calculate the Magnetic Field Vector $\vec{B}$:

- The magnetic field $B = 0.20\,\text{T}$ is directed at a 45° angle in the northeast direction, so:

$$\vec{B} = \frac{0.20}{\sqrt{2}}\,\hat{i} + \frac{0.20}{\sqrt{2}}\,\hat{j}$$

- Simplify:

$$\vec{B} = 0.1414\,\hat{i} + 0.1414\,\hat{j}\,\text{T}$$

Step 3: Calculate the Magnetic Flux Φ:

$$\Phi = \vec{B} \cdot \vec{A} = (0.1414\,\hat{i} + 0.1414\,\hat{j}) \cdot (0\,\hat{i} + 0.01\,\hat{j})$$

$$\Phi = 0.1414 \times 0.01 = 0.001414\,\text{Wb}$$

Step 4: Calculate Induced EMF (ε):

- The magnetic field is reduced to zero in $\Delta t = 1\,\text{s}$, so:

$$\varepsilon = -\frac{\Delta\Phi}{\Delta t} = -\frac{0.001414 - 0}{1} = 0.001414\,\text{V} = \sqrt{2} \times 10^{-3}\,\text{V}$$

Step 5: Determine x:

- Since $\varepsilon = \sqrt{x} \times 10^{-3}\,\text{V}$, we have $x = 2$.

So, the correct answer is: $x = 2$

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7. **Answer: c**

Explanation:

To find the power consumed by the load resistance connected to the secondary side of the transformer, we need to follow these steps:

1. Calculate the voltage across the secondary winding using the turns ratio. The turns ratio of the transformer is given as 10:1, meaning the primary winding has 10 times more turns than the secondary winding.
2. The voltage across the secondary (V_s) can be calculated using the formula for voltage transformation in transformers:

$$V_s = \frac{V_p}{\text{turns ratio}}$$

1. where $V_p = 230\,\text{V}$ is the primary voltage.

$$V_s = \frac{230}{10} = 23\,\text{V}$$

1. Using Ohm's Law, calculate the current flowing through the load resistance:

$$I_s = \frac{V_s}{R}$$

1. where $R = 46\,\Omega$.

$$I_s = \frac{23}{46} = 0.5\,\text{A}$$

1. Calculate the power consumed by the load:

$$P = I_s^2 \times R$$

$$P = (0.5)^2 \times 46 = 0.25 \times 46 = 11.5\,\text{W}$$

Therefore, the power consumed in the load resistance is 11.5 W.

The correct answer is **11.5 W**.

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8. Answer: 32 - 32

Explanation:

Step 1. Calculate the Effective Vertical Component of the Magnetic Field:

Given:

$B = 0.5\,\text{G} = 0.5 \times 10^{-4}\,\text{T}$

The vertical component of the magnetic field B_v, considering the angle of dip $\delta = 30^\circ$, is:

$B_v = B \sin \delta = 0.5 \times 10^{-4} \times \sin 30^\circ = 0.5 \times 10^{-4} \times \frac{1}{2} = \frac{1}{4} \times 10^{-4}\,\text{T}$

Step 2. Convert Angular Velocity from rpm to rad/s:

Angular velocity ω in rad/s is given by:

$\omega = 2\pi \times f = 2\pi \times \frac{1200}{60} = 2\pi \times 20 = 40\pi\,\text{rad/s}$

Step 3. Determine the Radius of Rotation:

The length of each blade is $\ell = 80\,\text{cm} = 0.8\,\text{m}$. Therefore, the effective radius r of rotation is:

$r = 0.8\,\text{m}$

Step 4. Calculate the Induced emf:

The emf ε induced across the tips of the blades (assuming the emf induced across two opposite ends) is given by:

$\varepsilon = \frac{1}{2} B_v \omega r^2$

Substituting the values:

$\varepsilon = \frac{1}{2} \times \frac{1}{4} \times 10^{-4} \times 40\pi \times (0.8)^2$

Simplifying further:

$\varepsilon = \frac{1}{2} \times \frac{1}{4} \times 10^{-4} \times 40\pi \times 0.64 = 32\pi \times 10^{-5}\,\text{V}$

Step 5. Conclude the Value of N:

Comparing with $N\pi \times 10^{-5}\,\text{V}$, we find:

$N = 32$

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9. Answer: c

Explanation:

The Correct answer is option is (C) : 3.24 W

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10. **Answer: 60 - 60**

Explanation:

The induced emf $(\mathcal{E})$ in the circuit is given by Faraday's law:

$$\mathcal{E} = -N\frac{\Delta\Phi_B}{\Delta t},$$

where $N = 100$ is the number of turns, and $\Delta\Phi_B$ is the change in magnetic flux. The total change in magnetic flux $(\Delta\Phi_B)$ is:

$$\Delta\Phi_B = A\Delta B,$$

where $A = 24\,\mathrm{cm}^2 = 24 \times 10^{-4}\,\mathrm{m}^2$ is the cross-sectional area, and $\Delta B = 2 \times 1.5 = 3\,\mathrm{T}$ is the change in magnetic field (from $1.5\,\mathrm{T}$ in one direction to $1.5\,\mathrm{T}$ in the opposite direction). Substitute values:

$$\Delta\Phi_B = 24 \times 10^{-4} \times 3 = 7.2 \times 10^{-3}\,\mathrm{Wb}.$$

The total emf induced is:

$$\mathcal{E} = \frac{N\Delta\Phi_B}{R},$$

where $R = 12\,\Omega$. Substitute $N = 100$:

$$\mathcal{E} = \frac{100 \cdot 7.2 \times 10^{-3}}{12} = 6 \times 10^{-3}\,\mathrm{C}.$$

Thus, the charge flowing through the circuit is $\boxed{60\,\mathrm{mC}}$.

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11. **Answer: 625 - 625**

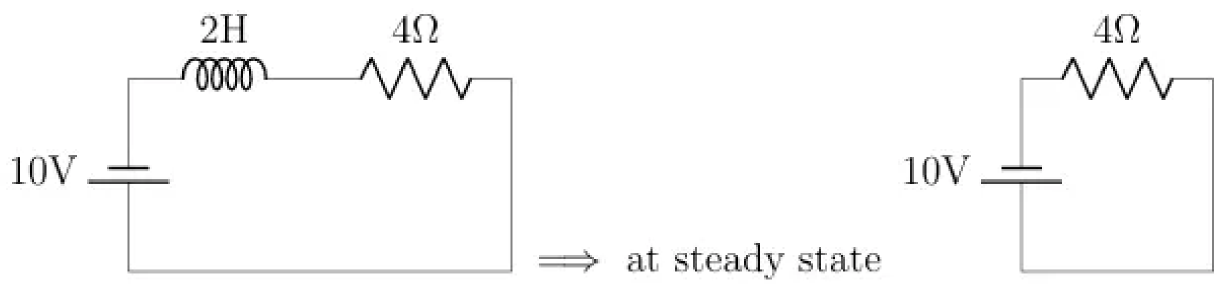
Explanation:

Given:

- Inductance (L) = 2 H
- Resistance (R) = 4 Ω
- Applied voltage (V) = 10 V

Step 1: Analyze the Circuit at Steady State

At steady state, the inductor behaves as a short circuit, meaning it has zero resistance. The circuit becomes a simple resistor connected to the voltage source.



Step 2: Calculate the Current at Steady State

Using Ohm's law, the steady-state current (I) through the resistor is given by:

$$I = \frac{V}{R}.$$

Substitute $V = 10\,\text{V}$ and $R = 4\,\Omega$:

$$I = \frac{10}{4} = \frac{5}{2} = 2.5\,\text{A}.$$

Step 3: Calculate the Energy Stored in the Magnetic Field

The energy (E) stored in the magnetic field of the inductor is given by:

$$E = \frac{1}{2}LI^2.$$

Substitute $L = 2\,\text{H}$ and $I = 2.5\,\text{A}$:

$$E = \frac{1}{2} \cdot 2 \cdot (2.5)^2\,.$$

Calculate $(2.5)^2$:

$$(2.5)^2 = 6.25.$$

Substitute back into the equation:

$$E = \frac{1}{2} \cdot 2 \cdot 6.25 = 6.25\,\text{J}.$$

Convert to scientific notation:

$$E = 625 \times 10^{-2}\,\text{J}.$$

Final Answer:

The energy stored in the magnetic field is $625 \times 10^{-2}\,\text{J}$.

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12. **Answer: b**

Explanation:

Electromagnetic Induction Problem

Step 1: Faraday's Law of Electromagnetic Induction

Faraday's law states that an emf is induced in a coil when the magnetic flux through the coil changes with time.

Step 2: Magnetic Flux

Magnetic flux (Φ) is given by:

$$\Phi = \vec{B} \cdot \vec{A} = BA\cos\theta$$

where $\vec{B}$ is the magnetic field, $\vec{A}$ is the area vector of the coil, and θ is the angle between the magnetic field and the area vector.

Step 3: Analyze Options

- **A. Moving with uniform speed:** If the coil moves with uniform speed in a uniform magnetic field, the flux remains constant (assuming the orientation of the coil relative to the field remains unchanged). Therefore, no emf is induced.
- **B. Moving with non-uniform speed:** Similar to case A, if the orientation doesn't change with respect to the field, a non-uniform speed doesn't change the flux. Thus no emf is induced.

- **C. Rotating the coil:** When the coil rotates in a uniform magnetic field, the angle between the magnetic field and the area vector changes. This changes the magnetic flux, inducing an emf.
- **D. Changing the area:** Changing the area of the coil directly changes the magnetic flux, inducing an emf.

Conclusion:

An induced emf can be produced by **rotating the coil (C)** and by **changing the area of the coil (D)** (Option 2).

Induced emf can be induced in a coil by changing magnetic flux. And $\phi = \vec{B}.\, d\vec{A}$ By rotating coil, angle between coil and magnetic field changes and hence flux changes. By changing area, magnetic flux changes.

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13. **Answer: c**

Explanation:

- Magnetic field contributions due to segments BC and ET are outward at point O.

Total magnetic field:

$$B = \frac{\mu_0 I}{4\pi r} + \frac{\mu_0 I}{4\pi r} = \frac{\mu_0 I}{\pi a}.$$

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14. **Answer: 10 - 10**

Explanation:

Electromagnetic Force and Current:

The force on a current-carrying conductor in a magnetic field is given by:

$$F_m = iLB$$

Equating with the gravitational force $F_m = mg$, we get:

$$iLB = mg$$

Solving for i:

$$i = \frac{mg}{LB}$$

Substitute the given values:

- $m = 1 \times 10^{-3}\ \text{kg}$
- $g = 10\ \text{m/s}^2$
- $L = 0.1\ \text{m}$
- $B = 0.1\ \text{T}$

$$i = \frac{(1 \times 10^{-3})(10)}{(0.1)(0.1)}$$

$$i = \frac{1 \times 10^{-2}}{0.01} = 1\ \text{A}$$

Voltage Across the Loop:

The resistance of the loop is given as $R = 10\ \Omega$. Using Ohm's Law:

$$V = iR$$

Substitute $i = 1\ \text{A}$ and $R = 10\ \Omega$:

$$V = (1)(10) = 10\ \text{V}$$

Final Answer:

$V = 10\ \text{V}$

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15. **Answer: b**

Explanation:

The magnetic field B is initially given by the equation:

Step 1: $B = \frac{\mu_0 i}{2R} \times 4$, which is the original magnetic field expression.

Step 2: For the new radius $R' = 4R$, the new field B' is given by:

Step 3: Substitute R' into the magnetic field formula: $B' = \frac{\mu_0 i}{2R'} = \frac{\mu_0 i}{8R}$.

Step 4: Now, calculate the ratio $\frac{B'}{B} = \frac{1}{16}$, indicating that the new magnetic field is $\frac{1}{16}$ of the original field.

Step 5: With this ratio, we conclude that the new magnetic field B' is $2T$.

Concepts:

1. Electromagnetic Induction:

Electromagnetic Induction is a current produced by the voltage production due to a changing magnetic field. This happens in one of the two conditions:-

1. When we place the conductor in a changing magnetic field.
2. When the conductor constantly moves in a stationary field.

Formula:

The electromagnetic induction is mathematically represented as:-

e=N × dØ.dt

Where

- e = induced voltage
- N = number of turns in the coil
- Φ = Magnetic flux (This is the amount of magnetic field present on the surface)
- t = time

Applications of Electromagnetic Induction

1. Electromagnetic induction in AC generator
2. Electrical Transformers
3. Magnetic Flow Meter

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16. Answer: a

Explanation:

Step 1: Write the formula for work done:
The work done (W) in pulling the loop is related to the induced emf and the resistance of the loop:

$$W = F \cdot l = \frac{B^2 v l^2}{R}$$

where: $B = 40\,\mathrm{T}$ (magnetic field strength), $v = 0.05\,\mathrm{m/s}$ (velocity of pulling the loop), $l = 0.05\,\mathrm{m}$ (length of one side of the loop, calculated as $\sqrt{\mathrm{Area}} = \sqrt{25\,\mathrm{cm}^2}$), \item $R = 10\,\Omega$ (resistance of the loop).
Step 2: Substitute the values into the formula:

$$W = \frac{40^2 \cdot 0.05 \cdot 0.05^2}{10}$$

$$W = \frac{1600 \cdot 0.05 \cdot 0.0025}{10}$$

$$W = \frac{1600 \cdot 0.000125}{10} = \frac{0.2}{10} = 0.001\,\mathrm{J}$$

Step 3: Convert to millijoules:

$$W = 1.0 \times 10^{-3}\,\mathrm{J}$$

Concepts:

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2. When the conductor constantly moves in a stationary field.

Formula:

The electromagnetic induction is mathematically represented as:-

e=N × dØ.dt

Where

- e = induced voltage
- N = number of turns in the coil

- Φ = Magnetic flux (This is the amount of magnetic field present on the surface)
- t = time

Applications of Electromagnetic Induction

1. Electromagnetic induction in AC generator
2. Electrical Transformers
3. Magnetic Flow Meter

---

17. **Answer: a**

Explanation:

Rate of decrease in the radius of the loop is 2 mm/s.
Final radius = 2 cm= 0.02 m
Initial radius = 2.2 cm = 0.022 m. B = 0.04 T
Induced emf in the loop is given by

$$e = -B.\frac{dA}{dt} \text{ where } A \text{ is the area of the loop.}$$

$$e = -B.\frac{d}{dt}(\pi r^2) = -B\pi 2r\frac{dr}{dt}$$

$$r = 2\,cm = 2 \times 10^{-2}m$$

$$dr = 2\,mm = 2 \times 10^{-3}m$$

$$dt = 1s$$

$$e = -0.04 \times 3.14 \times 2 \times 2 \times 10^{-2} \times \frac{2 \times 10^{-3}}{1}V$$

$$= 0.32\pi \times 10^{-5}V$$

$$= 3.2\pi \times 10^{-6}V$$

$$= 3.2\pi\mu V.$$

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Applications of Electromagnetic Induction

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18. **Answer: 11 - 11**

Explanation:

To find the magnetic moment of a wire bent to form a circle, we first need the formula for the magnetic moment m of a coil: $m = n \cdot I \cdot A$, where n is the number of turns, I is the current, and A is the area of the circle.
1. The wire length is given as 314 cm. When bent into a circle, the circumference C of the circle is the length of the wire, so $C = 2\pi r$.
2. Solving for the radius r gives: $r = \frac{C}{2\pi} = \frac{314}{2\times3.14} = 50$ cm.
3. Convert radius into meters: 50 cm = 0.5 m.
4. Calculate the area A of the circle: $A = \pi r^2 = 3.14 \times (0.5)^2 = 3.14 \times 0.25 = 0.785$ m^2.
5. Since it's a single loop, $n = 1$.
6. The current I is given as 14 A.
7. Substitute the values to find the magnetic moment: $m = 1 \times 14 \times 0.785 = 10.99\ \text{A-m}^2$.
8. Given range is from 11 to 11, hence 10.99 is approximately equal to 11 A-m^2 which is within the accepted range.

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Applications of Electromagnetic Induction

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19. Answer: 3 - 3

Explanation:

The magnetic field B at the center of a circular coil of radius r is given by the formula:

$$B = \frac{\mu_0 \cdot n \cdot I}{2r}$$

where $B = 37.68 \times 10^{-4}\,\mathrm{T}$, $n = 100$ turns, $r = 5\,\mathrm{cm} = 0.05\,\mathrm{m}$, and $\mu_0 = 4\pi \times 10^{-7}\,\mathrm{Tm/A}$. Given $\pi = 3.14$, calculate I:

$$I = \frac{2rB}{\mu_0 n} = \frac{2 \times 0.05 \times 37.68 \times 10^{-4}}{4 \times 3.14 \times 10^{-7} \times 100}$$

Simplify further:

$$I = \frac{0.003768}{1.256 \times 10^{-4}}$$

$I \approx 3.0\,\mathrm{A}$

The calculated current I is $3.0\,\mathrm{A}$, which falls within the given range of 3 to 3. This confirms the solution is correct and consistent with the provided range.

Concepts:

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Applications of Electromagnetic Induction

1. Electromagnetic induction in AC generator
2. Electrical Transformers
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20. Answer: c

Explanation:

To solve this problem, we need to address two parts: the time elapsed before the current reaches half of its steady-state value and the energy stored in the magnetic field after a certain time.

1. **Steady-state current calculation:**
    - The steady-state current, I_0, can be found using Ohm's Law: $I_0 = \frac{V}{R}$.
    - Given that the voltage $V = 6\,\mathrm{V}$ and resistance $R = 100\,\Omega$, we have: $I_0 = \frac{6}{100} = 0.06\,\mathrm{A}$.

2. **Time for current to reach half of the steady-state value:**
    - The current $I(t)$ at time t is given by the formula: $I(t) = I_0(1 - e^{-\frac{t}{\tau}})$,
    - where $\tau = \frac{L}{R}$ is the time constant.
      For $L = 1\,\mathrm{H}$ and $R = 100\,\Omega$, $\tau = \frac{1}{100} = 0.01\,\mathrm{s} = 10\,\mathrm{ms}$.
    - For the current to be half its steady-state value: $\frac{I_0}{2} = I_0(1 - e^{-\frac{t}{\tau}})$,
    - This simplifies to: $e^{-\frac{t}{\tau}} = \frac{1}{2}$.
    - Taking the natural log on both sides, we get: $-\frac{t}{\tau} = \ln(\frac{1}{2}) = -\ln(2) = -0.693$.
    - Substituting the values, we get: $-\frac{t}{10\,\mathrm{ms}} = -0.693 \Rightarrow t \approx 6.93\,\mathrm{ms} \approx 7\,\mathrm{ms}$.
3. **Energy stored in the magnetic field after 15 ms:**
    - The energy stored in the magnetic field, $U(t)$, is given by: $U(t) = \frac{1}{2}LI(t)^2$.
    - Let's first find $I(15\,\mathrm{ms})$: $I(t) = 0.06(1 - e^{-\frac{t}{\tau}})$
      For $t = 15\,\mathrm{ms}$, $\frac{t}{\tau} = \frac{15}{10} = 1.5$,
    - thus $I(15\,\mathrm{ms}) = 0.06(1 - e^{-1.5}) \approx 0.06(1 - 0.25) = 0.045\,\mathrm{A}$.
    - Now, substitute into the formula for energy: $U(t) = \frac{1}{2} \times 1\,\mathrm{H} \times (0.045\,\mathrm{A})^2 = \frac{1}{2} \times 0.002025\,\mathrm{J} = 0.0010125\,\mathrm{J}$,
    - which is approximately $1\,\mathrm{mJ}$.
4. **Conclusion:**
    - Therefore, the time elapsed before the current acquires half of its steady-state value is approximately **7 ms**, and the energy stored after 15 ms is **1 mJ**.

Thus, the correct answer is: **t = 7 ms; U = 1 mJ**.

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Formula:

The electromagnetic induction is mathematically represented as:-

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Where

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Applications of Electromagnetic Induction

1. Electromagnetic induction in AC generator
2. Electrical Transformers
3. Magnetic Flow Meter

---

21. Answer: d

Explanation:

To solve this problem, we need to understand how changes in the coil's dimensions affect the electrical power dissipated due to the current induced. This involves Faraday's law of electromagnetic induction and the resistance formula.

1. **Faraday's Law:** The induced electromotive force (EMF) in the coil due to a change in magnetic flux is given by:

$E = -N\frac{d\Phi}{dt}$

where E is the EMF, N is the number of turns, and $\frac{d\Phi}{dt}$ is the rate of change of magnetic flux.

2. **Resistance of the Coil:** The resistance (R) of the coil is given by:

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

where ρ is the resistivity, L is the length of the wire, and A is the cross-sectional area of the wire. The cross-sectional area for a wire of radius r is $A = \pi r^2$. With the radius doubled, A becomes $4\pi r^2$.

3. **Effect on Resistance:** Given that the radius is doubled, the new resistance becomes:

$R_{new} = \rho\frac{L}{4\pi r^2} = \frac{R}{4}$

4. **Induced Current**: The induced current I can be expressed as:

$I = \frac{E}{R}$ or $I_{new} = \frac{E_{new}}{R_{new}}$
As N is halved, $E_{new} = \frac{E}{2}$

5. **Electrical Power Dissipated**: Power (P) dissipated is given by $P = I^2R$. For the new configuration:

$$P_{new} = (I_{new})^2 R_{new}$$

Substituting the expressions for I and R:

$$P_{new} = \left(\frac{\frac{E}{2}}{\frac{R}{4}}\right)^2 \cdot \frac{R}{4} = \left(\frac{2E}{R}\right)^2 \cdot \frac{R}{4} = \frac{4E^2}{R^2} \cdot \frac{R}{4} = \frac{E^2}{R} \cdot 2 = 2P$$

This indicates the power is doubled.

Conclusion: The correct answer is **Doubled**, confirming that the electrical power dissipated in the coil, under the given changes, is doubled.

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Applications of Electromagnetic Induction

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22. Answer: 2400 - 2400

Explanation:

In a meter bridge setup, the balance condition for measuring resistance is given by the equation:

$$S/R = l/(100-l)$$

where S is the unknown resistance, R is the known resistance (5.6 kΩ), l is the length of the wire from one end to the null point (30 cm), and $(100-l)$ is the remaining length (70 cm).

Now, let's calculate the unknown resistance S:

$S = R \times l/(100-l)$

Substitute the values:

$S = 5600 \times 30/70$

$S = 2400\ \Omega$

Upon calculating, the value of S is 2400 Ω, which fits within the given range of [2400, 2400]. Thus, the calculated unknown resistance is confirmed to be accurate.

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Applications of Electromagnetic Induction

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23. Answer: a

Explanation:

The correct answer is (A) : $r_1 - r_2$

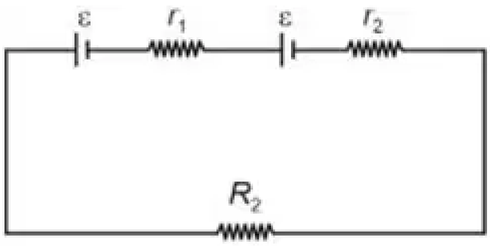

Fig.

$\Delta V = 0 \Rightarrow \frac{2\varepsilon}{r_1+r_2+R} r_1 = \varepsilon$
$\Rightarrow R = r_1 - r_2$

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Applications of Electromagnetic Induction

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---

24. Answer: a

Explanation:

The relationship between energy E and momentum p for electromagnetic radiation can be expressed as:

$$p = \frac{E}{c},$$

where:
- p is the momentum,
- E is the energy transferred,
- c is the speed of light $(c \approx 3 \times 10^8 \, \mathrm{m/s})$.

Given:

$$E = 6.48 \times 10^5 \, \mathrm{J}.$$

Substituting the values into the momentum formula:

$$p = \frac{6.48 \times 10^5\,\mathrm{J}}{3 \times 10^8\,\mathrm{m/s}}.$$

Calculating:

$$p = \frac{6.48}{3} \times 10^{-3} = 2.16 \times 10^{-3}\,\mathrm{kg\ m/s}.$$

Thus, the magnitude of the total momentum delivered to this surface for complete absorption is:

$$2.16 \times 10^{-3}\,\mathrm{kg\ m/s}.$$

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25. **Answer: 12 - 12**

Explanation:

The correct answer is 12

$B_{\perp} = 3t^2$

$\frac{dB_{\perp}}{dt} = 6t = 12at\ t = 2$

$\frac{d\phi_{\perp}}{dt} = 12 \times \pi(1)^2$

$= 12\pi$

Therefore , value of n is 12.

Concepts:

1. Faradays Laws of Induction:

There are two laws, given by Faraday which explain the phenomena of electromagnetic induction:

Faraday's First Law:

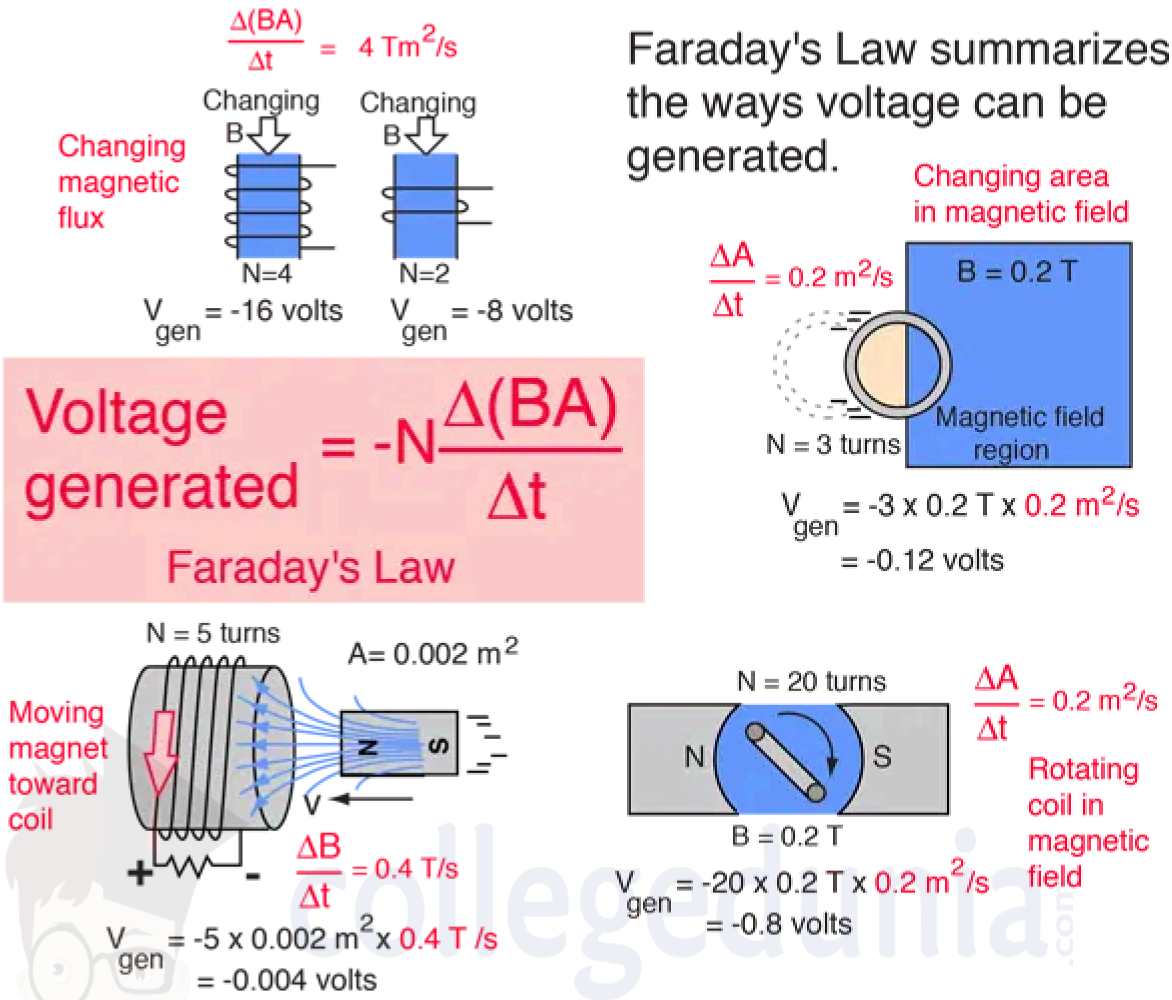
Whenever a conductor is placed in a varying magnetic field, an emf is induced. If the conductor circuit is closed, a current is induced, known as the induced current.

Faraday's Second Law:

The **Emf induced** inside a coil is equal to the **rate of change of associated magnetic flux.**

This law can be mathematically written as:

$\in -N\frac{\triangle\phi}{\triangle t}$



Δ(BA)/Δt = 4 Tm²/s
Changing B
Changing B
Changing magnetic flux
N=4
N=2
Vgen = -16 volts
Vgen = -8 volts
Faraday's Law summarizes the ways voltage can be generated.
Changing area in magnetic field
ΔA/Δt = 0.2 m²/s
B = 0.2 T
Magnetic field region
N = 3 turns
Vgen = -3 x 0.2 T x 0.2 m²/s
= -0.12 volts
Voltage generated = -N Δ(BA)/Δt
Faraday's Law
N = 5 turns
A= 0.002 m²
Moving magnet toward coil
N
S
V
+
-
ΔB/Δt = 0.4 T/s
Vgen = -5 x 0.002 m² x 0.4 T /s
= -0.004 volts
N = 20 turns
ΔA/Δt = 0.2 m²/s
N
S
B = 0.2 T
Rotating coil in magnetic field
Vgen = -20 x 0.2 T x 0.2 m²/s
= -0.8 volts