Electromagnetic Induction And Alternating Currents JEE Main PYQ - 3

Total Time: 25 Minute **Total Marks:** 40

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.

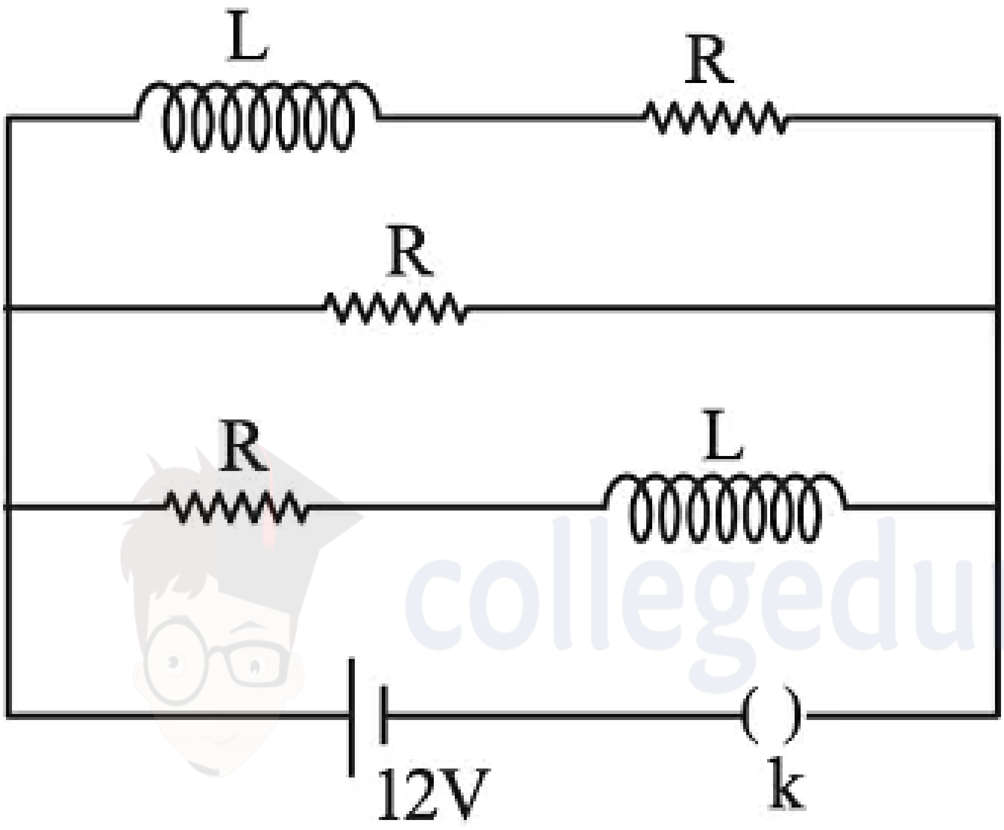
Navigating & Answering a Question

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 And Alternating Currents

1. Three identical resistors with resistance $R = 12\,\Omega$ and two identical inductors with self inductance $L = 5\,mH$ are connected to an ideal battery with emf of $12\,V$ as shown in figure. The current through the battery long after the switch has been closed will be ______A. (+4, -1)

24-Jan-2023 Shift 2



Click Here for Solution

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2. A $10\,m$ long horizontal wire extends from North East to South West. It is falling with a speed of $5.0\,ms^{-1}$, at right angles to the horizontal component of the earth's magnetic field, of $0.3 \times 10^{-4}\,Wb/m^2$. The value of the induced emf in wire is : (+4, -1)

12 Jan. 2019 II

a. $2.5 \times 10^{-3} V$

b. $1.1 \times 10^{-3} V$

Click Here for Solution

c. $0.3 \times 10^{-3} V$

d. $1.5 \times 10^{-3} V$

3. A circular loop of radius 0.3 cm lies parallel to a much bigger circular loop of radius 20 cm. The centre of the small loop is on the axis of the bigger loop. The distance between their centres is 15 cm. If a current of 2.0 A flows through the smaller loop, then the flux linked with bigger loop is (+4, -1)

2013

a. 6.6×10^{-9} Weber

b. 9.1×10^{-11} Weber

c. 6×10^{-11} Weber

d. 3.3×10^{-11} Weber

Click Here for Solution

4. A coil of cross-sectional area A having n turns is placed in a uniform magnetic field B. When it is rotated with an angular velocity ω, the maximum e.m.f. induced in the coil will be : (+4, -1)

April 16, 2018

a. $3\,nBA\omega$

b. $\frac{3}{2}\,nBA\omega$

c. $nBA\omega$

d. $\frac{1}{2}\,nBA\omega$

Click Here for Solution

5. A copper rod of mass m slides under gravity on two smooth parallel rails, with separation l and set at an angle of θ with the horizontal. At the bottom, rails are joined by a resistance R. There is a uniform magnetic field B normal to the plane of the rails, as shown in the figure. The terminal speed of the copper rod is : (+4, -1)

April 15, 2018

a. $\frac{mg\,R\,\tan\,\theta}{B^2l^2}$

b. $\frac{mg\,R\,\cot\,\theta}{B^2l^2}$

c. $\frac{mg\,R\,\sin\,\theta}{B^2l^2}$

d. $\frac{mg\,R\,\cos\,\theta}{B^2l^2}$

Click Here for Solution

6. A copper wire is wound on a wooden frame, whose shape is that of an equilateral triangle. If the linear dimension of each side of the frame is increased by a factor of 3, keeping the number of turns of the coil per unit length of the frame the same, then the self inductance of the coil : (+4, -1)

11 Jan. 2019 II

a. Decreases by a factor of $9\sqrt{3}$

b. Increases by a factor of 3

Click Here for Solution

c. Decreases by a factor of 9

d. Increases by a factor of 27

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7. A metallic rod of length l is tied to a string of length $2l$ and made to rotate with angular speed (ω on a horizontal table with one end of the string fixed. If there is a vertical magnetic field B in the region, the emf induced across the ends of the rod is (+4, -1)

2013

a. $\frac{2B\omega l^3}{2}$

b. $\frac{3B\omega l^3}{2}$

Click Here for Solution

c. $\frac{4B\omega l^2}{2}$

d. $\frac{5B\omega l^2}{2}$

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8. A square frame of side 10 cm and a long straight wire carrying current 1 A are in the plane of the paper. Starting from close to the wire, the frame moves towards the right with a constant speed of 10 ms (see figure). The e.m.f induced at the time the left arm of the frame is at x = 10 cm from the wire is : (+4, -1)

April 19, 2014

a. $2\,\mu V$

b. $1\,\mu V$

Click Here for Solution

c. $0.75\,\mu V$

d. $0.5\,\mu V$

9. An insulating thin rod of length ℓ has a x linear charge density $p(x) = \rho_0 \frac{x}{\ell}$ on it . The rod is rotated about an axis passing through the origin $(x = 0)$ and perpendicular to the rod. If the rod makes n rotations per second, then the time averaged magnetic moment of the rod is : 10 Jan. 2019 I **(+4, -1)**

a. $\frac{\pi}{4} n \rho \ell^3$

b. $n \rho \ell^3$

Click Here for Solution

c. $\pi n \rho \ell^3$

d. $\frac{\pi}{3} n \rho \ell^3$

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10. A square shaped coil of area $70\, cm^2$ having 600 turns rotates in a magnetic field of 04 wbm $^{-2}$, about an axis which is parallel to one of the side of the coil and perpendicular to the direction of field If the coil completes 500 revolution in a minute, the instantaneous emf when the plane of the coil is inclined at 60° with the field, will be ___ V. (Take $\pi = \frac{22}{7}$) **(+4, -1)**

Click Here for Solution

Answers

1. **Answer: 3 - 3**

Explanation:

The correct answer is 3.
After long time an inductor behaves as a resistance-less path.
So current through cell
$I = \frac{12}{R/3} = 3A\{\because R = 12\,\Omega\}$

Concepts:

1. Electromagnetic waves:

The waves that are produced when an electric field comes into contact with a magnetic field are known as Electromagnetic Waves or EM waves. The constitution of an oscillating magnetic field and electric fields gives rise to electromagnetic waves.

Types of Electromagnetic Waves:

Electromagnetic waves can be grouped according to the direction of disturbance in them and according to the range of their frequency. Recall that a wave transfers energy from one point to another point in space. That means there are two things going on: the disturbance that defines a wave, and the propagation of wave. In this context the waves are grouped into the following two categories:

- **Longitudinal waves:** A wave is called a longitudinal wave when the disturbances in the wave are parallel to the direction of propagation of the wave. For example, sound waves are longitudinal waves because the change of pressure occurs parallel to the direction of wave propagation.
- **Transverse waves:** A wave is called a transverse wave when the disturbances in the wave are perpendicular (at right angles) to the direction of propagation of the wave.

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2. **Answer: b**

Explanation:

Induced emf $= Bv\ell \sin 45$
$= 0.3 \times 10^{-4} \times 5 \times 10 \times \frac{1}{\sqrt{2}}$
$= 1.1 \times 10^{-3} V$

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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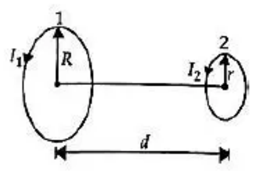
3. Answer: b

Explanation:

Let the current in the bigger loop be i_2 and the smaller loop be i_1

- ϕ_1 is the flux due to the smaller loop at the bigger loop
- ϕ_2 be flux due to a bigger loop at the smaller loop



The field due to the current loop 1 at an axial point -

$$B_1 = \frac{\mu_0 I_1 R^2}{2(d^2+R^2)^{3/2}}$$

Flux linked with the smaller loop 2 due to B_1 is

$$\phi_2 = B_1 A_2 = \frac{\mu_0 I_1 R^2}{2(d^2+R^2)^{3/2}} \pi r^2$$

The coefficient of mutual inductance between the loops is

$$M = \frac{\phi_2}{I_1} = \frac{\mu_0 R^2 \pi r^2}{2(d^2+R^2)^{3/2}}$$

Flux linked with bigger loop 1 is

$$\phi_1 = M I_2 = \frac{\mu_0 R^2 \pi r^2 l^2}{2(d^2+R^2)^{3/2}}$$

Substituting the given values, we get

$$\phi_1 = \frac{4\pi \times 10^{-7} \times \left(20 \times 10^{-2}\right)^2 \times \pi \times \left(0.3 \times 10^{-2}\right)^2 \times 2}{2\left[(15 \times 10^{-2})^2 + (20 \times 10^{-2})^2\right]^{3/2}}$$

Option B is the correct answer, $\phi 1 = 9.1 \times 10^{-11}$ Weber

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Applications of Electromagnetic Induction

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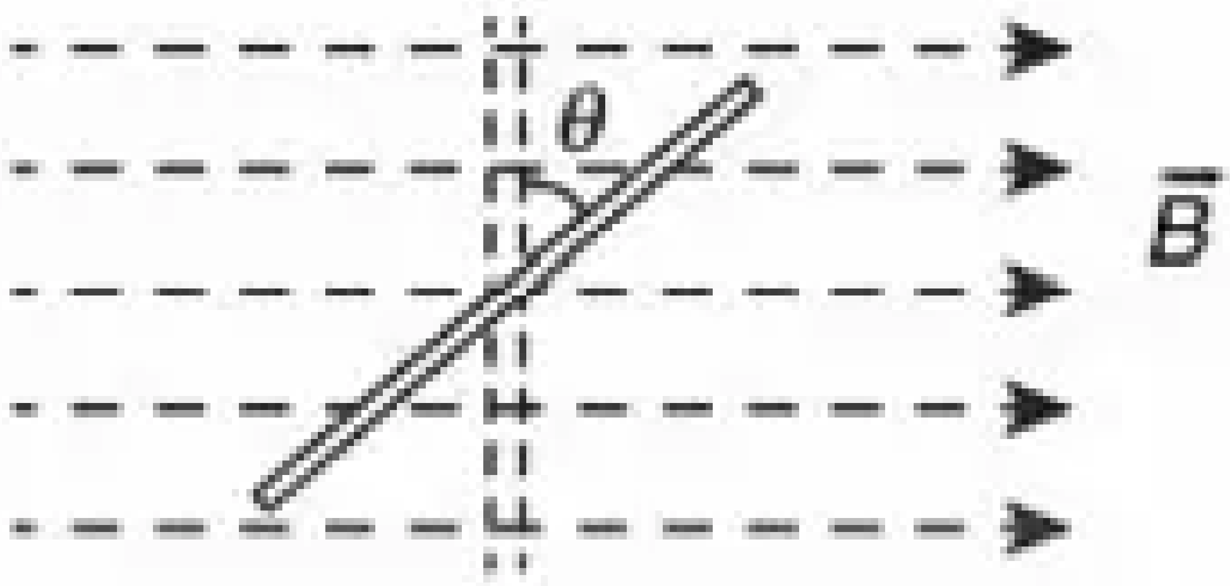
4. **Answer: c**

Explanation:

We know that flux through the coil is given by



$\phi = n\vec{B} \cdot \vec{A} \Rightarrow \phi = nBA\cos\theta$

$\omega = \frac{\theta}{t} \Rightarrow \theta = \omega t$...(1)

$\phi = nBA\cos\omega t$

Therefore, emf induced in the coil is given by $\varepsilon = -\frac{d}{dt}\phi$

So, $\varepsilon = -\frac{d}{dt}nBA\cos\omega t = -nBA[-\sin\omega t]\omega$

$\varepsilon = nBA\omega\sin\omega t$

For $\theta = \omega t = 0, \sin\omega t = 0$ $\varepsilon = 0$

For $\theta = \omega t = 90, \sin\omega t = 1$ $\varepsilon_0 = nBA\omega \cdot 1$

$\Rightarrow \varepsilon = \varepsilon_0 \sin\omega t$

Therefore $\varepsilon_0 = BAn\omega$

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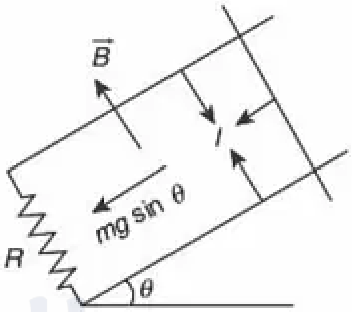
5. **Answer: c**

Explanation:

At terminal velocity, net force on rod $= mg\sin\theta$
$\Rightarrow mg\sin\theta = iBl$
Now, $IBl = \left(\frac{Bvl}{R}\right)Bl = \frac{B^2l^2v}{R}$
$\Rightarrow mg\sin\theta = \frac{B^2l^2v}{R}$
$\Rightarrow v = \frac{mgR\sin\theta}{B^2l^2}$



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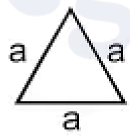
6. **Answer: b**

Explanation:

Total length L will remain constant

$L = (3a)N$ **(N = total\, turns)**

and length of winding (l)= $(d)N$ **(d = diameter of wire)**



Self inductance = $\mu_o n^2 Al = \mu_o n^2 (\frac{\sqrt{3}}{4}a^2)dN$

Self inductance (L) ∝ $a^2 N$

As $N = \frac{l}{3a} \rightarrow N \propto \frac{1}{a}$

$\therefore L \propto a$

So, as a is increased to 3a the Self inductance will be 3 times.

Hence, the correct answer is option (B): Increases by a factor of 3

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Applications of Electromagnetic Induction

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7. Answer: d

Explanation:

$$e = \int_{2l}^{3l} (\omega x)\, B dx = B\omega \frac{[(3l)^2 - (2l)^2]}{2}$$
$$= \frac{5Bl^2\omega}{2}$$

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8. Answer: b

Explanation:

In given $fig_x = 15$ because left arm of the frame is at $10cm$ from the wire. and $a = 10cm$. emf in $AD \implies e_1 \implies \frac{a\mu_o iv}{2\pi(x-a/2)}$

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9. Answer: a

Explanation:

$\because M = NIA$
$dq = \lambda dx \& A = \pi x^2$
$\int dm = \int (x) \frac{\rho_0 x}{\ell} dx.\pi x^2$
$M = \frac{n\rho_0\pi}{\ell}.\int_0^{\ell} x^3.dx = \frac{n\rho_0\pi}{\ell}.\left[\frac{L^4}{4}\right]$
$M = \frac{n\rho_0\pi\ell^3}{4}$ or $\frac{\pi}{4}n\rho\ell^3$

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10. **Answer: 44 - 44**

Explanation:

The correct answer is 44.

$N = 600, A = 70 \times 10^{-4} m^2, B = 0.4T$

$\omega = \frac{500 \times 2\pi}{60} = \frac{100\pi}{6} rad/s$

$E = NAB\omega \sin \omega t$

ωt is angle $b/w \vec{A}$ & $\vec{B}$

$= 600 \times 70 \times 10^{-4} \times 0.4 \times \frac{100\pi}{6} \times \frac{1}{2}$

$= 44\, V$

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