Electromagnetic Induction

Question1

A coil of resistance 8Ω, number of turns 250 and area $120\ \mathrm{cm}^2$ is placed in a uniform magnetic field of 2 T such that the plane of the coil makes and angle of $\frac{\pi}{6}$ with the direction of the magnetic field. In a time of 100 ms , the coil is rotated until its plane becomes parallel to the direction of the magnetic field. The current induced in the coil is

TG EAPCET 2025 (Online) 2nd May Evening Shift

Options:

A.

5.25 A

B.

3.75 A

C.

2.75 A

D.

1.25 A

Answer: B

Solution:

Induced emf

$$
\begin{aligned}
E &= -\frac{N\Delta\phi}{\Delta t} = \frac{-N\left(\phi_2-\phi_1\right)}{\Delta t} \\
&= \frac{-N\left(BA\cos\theta_2 - BA\cos\theta_1\right)}{\Delta t} \\
&= -250\frac{\left(BA\cos 90^\circ - BA\cos 60^\circ\right)}{100\times 10^{-3}} \\
&= \frac{-250\left(-\frac{BA}{2}\right)}{100\times 10^{-3}} \\
&= 2500\times\frac{BA}{2} = 1250\times BA \\
&= 1250\times 2\times 120\times 10^{-4} = 30\text{volt}
\end{aligned}
$$

$\therefore$ Induced current

$I = \frac{E}{R} = \frac{30}{8} = 3.75$ A

Question2

The plane of a circular coil of resistance 7.5Ω is placed perpendicular to a uniform magnetic field. The flux ϕ (in weber) through the coil varies with time t (in second) as $\phi = 2t^2 + 3t - 2$. The induced power in the coil at time $t = 3$ s is

TG EAPCET 2025 (Online) 2nd May Morning Shift

Options:

A.

7.5 W

B.

15 W

C.

30 W

D.

20 W

Answer: C

Solution:

$\phi = 2t^2 + 3t - 2$

$$\therefore e = \frac{d\phi}{dt} = \frac{d}{dt}\left(2t^2 + 3t - 2\right) = 4t + 3$$
$$\text{at } t = 3 \text{ s}, e = 4 \times 3 + 3$$
$$e = 15\text{volt}$$

Induced power, $P = \frac{e^2}{R} = \frac{15^2}{7.5} = 30 \text{ W}$

Question3

The energy stored in a coil of inductance 80 mH carrying a current of 2.5 A is

TG EAPCET 2024 (Online) 11th May Morning Shift

Options:

A. 1.25 J

B. 0.75 J

C. 0.25 J

D. 0.50 J

Answer: C

Solution:

To find the energy stored in a coil with an inductance of 80 mH carrying a current of 2.5 A, we use the formula for the energy stored in an inductive coil:

$U = \frac{1}{2}Li^2$

Given:

Inductance, $L = 80\,\text{mH} = 80 \times 10^{-3}\,\text{H}$

Current, $i = 2.5\,\text{A}$

We substitute these values into the formula:

$$U=\frac{1}{2}\times 80\times 10^{-3}\times(2.5)^2$$
$$=\frac{1}{2}\times 80\times 10^{-3}\times 6.25$$
$$=40\times 10^{-3}\times 6.25$$
$$=25\times 10^{-2}\text{ J}$$
$$U=0.25\text{ J}$$

Therefore, the energy stored in the coil is 0.25 J.

Question4

The mutual inductance of two coils is 8 mH . The current in one coil changes according to the equation $I=12\sin 100t$, where I is in ampere and t is time in second. The maximum value of emf induced in the second coil is

TG EAPCET 2024 (Online) 10th May Evening Shift

Options:

A. 9.6 V

B. 4.8 V

C. 3.2 V

D. 12.8 V

Answer: A

Solution:

The mutual inductance between two coils is given as 8 mH, which can be converted to henries as:

$M=8\,\text{mH}=8\times 10^{-3}\,\text{H}$

The current in one of the coils changes over time according to the equation:

$I=12\sin(100t)$

where I is in amperes and t is in seconds.

To find the maximum emf induced in the second coil, we use Faraday's law of mutual induction, which states:

$e=M\frac{dI}{dt}$

Calculating the derivative of the current with respect to time, we have:

$\frac{dI}{dt} = \frac{d}{dt}[12\sin(100t)] = 12 \times 100\cos(100t)$

Substituting this into the formula for emf, we get:

$$e = M \cdot \frac{dI}{dt}$$

$$= 8 \times 10^{-3} \times 12 \times 100\cos(100t)$$

$$= 9.6\cos(100t)$$

The expression $e = 9.6\cos(100t)$ is in the form of the standard equation for emf:

$e = e_0\cos(\omega t)$

From this, we can identify the maximum emf, e_0, as:

$e_0 = 9.6\,\text{V}$

Question5

A circular coil of area $200\ \text{cm}^2$ and 50 turns is rotating about its vertical diameter with an angular speed of $\theta\ 40\text{rads}^{-1}$ in a uniform horizontal magnetic field of magnitude 2×10^{-2} T. The maximum emf induced in the coil is

TG EAPCET 2024 (Online) 10th May Morning Shift

Options:

A. 1.2 V

B. 0.8 V

C. 0.6 V

D. 0.3 V

Answer: B

Solution:

Given,

Area of coil, $A = 200\ \text{cm}^2$

Number of turn, $N = 50$

Angular speed, $\omega = 40 \mathrm{rad/s}$

Magnetic field, $B = 2 \times 10^{-2}$ T

Maximum emf induced is given as emf $= NAB\omega \sin \omega t$

For maximum value $\sin \omega t = 1$

$(\mathrm{emf})_{\max} = NAB\omega$

$$= 50 \times 200 \times 10^{-4} \times 2 \times 10^{-2} \times 40$$

$$= 0.8 \mathrm{~V}$$

Question6

A train with an axle of length 1.66 m is moving towards north with a speed of $90 \mathrm{kmh}^{-1}$. If the vertical component of the earth's magnetic field is 0.2×10^{-4} T, the emf induced across the ends of the axle of the train is

TG EAPCET 2024 (Online) 9th May Evening Shift

Options:

A. 16.6 mV

B. 1.66 mV

C. 0.83 mV

D. 8.3 mV

Answer: C

Solution:

Given, $l = 1.66$ m

Speed $= 90 \mathrm{kmph} = 25 \mathrm{~m/s}$

$B_v = 0.2 \times 10^{-4}$ T

Induced emf $=$ Blv

$= 0.2 \times 10^{-4} \times 1.66 \times 25$

$= 8.3 \times 10^{-4}$ V

$= 0.83$mV

Question7

Two circular coils of radii r_1 and r_2 $(r_1 \ll r_2)$ are placed coaxially with their centres coinciding. The mutual inductance of the arrangement is

TG EAPCET 2024 (Online) 9th May Morning Shift

Options:

A. $\frac{\mu_0 \pi \pi_2^2}{2 r_1}$

B. $\frac{\mu_0 \pi r_1 r_2}{2(r_1+r_2)}$

C. $\frac{\mu_0 \pi r_1^2}{2 r_2}$

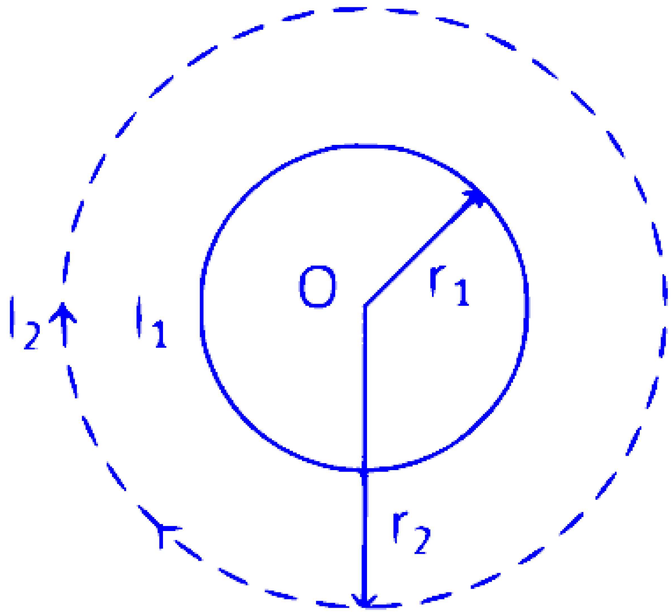
D. $\frac{\mu_0 \pi (r_1+r_2)}{2 r_1 r_2}$

Answer: C

Solution:

Here, coil 1 has a radius of r_1 and coil 2 has a radius of r_2.

Given, $r_1 \ll r_2$



Let current I_2 flow in the coil 2 and magnetic field at its centre

$B=\frac{\mu_0 I_2}{2 r_2}$

Since, $r_1 \ll r_2$

Flux through the coil, $\phi=\frac{\mu_0 I_2}{2 r_2} \times \pi \pi_1^2$

By definition of mutual inductance,

$\phi=M_{12} I_2=\frac{\mu_0 I_2}{2 r_2} \pi r_1^2 \Rightarrow M_{12}=\frac{\mu_0}{2 r_2} \pi r_1^2$

Hence, mutual inductance of the arrangement is $\frac{\mu_0}{2 r_2} \pi r_1^2$.

Question8

If the vertical component of earth's magnetic field is 0.5×10^{-4} T at a point. When an aeroplane of wing span 4 m is moving horizontally at this place at $360 \mathrm{kmh}^{-1}$, then the motional emf forced across the ends of the wings is

TS EAMCET 2023 (Online) 12th May Evening Shift

Options:

A. 20×10^{-4} V

B. 20×10^{-2} V

C. 20×10^{-3} V

D. 2×10^{-4} V

Answer: C

Solution:

Given the problem, let's break down the information provided and the calculations involved.

Given Data:

Speed of the aeroplane: $360\,\text{km/h}$

Convert the speed to meters per second:

$360\,\text{km/h} = 100\,\text{m/s}$

Wing span of the aeroplane: $4\,\text{m}$

Vertical component of Earth's magnetic field: $0.5 \times 10^{-4}\,\text{T}$

Formula Used:

The induced electromotive force (emf) generated across the wing span of the aeroplane due to its movement in the Earth's magnetic field is calculated using the formula:

$e = B \cdot L \cdot v$

Where:

e is the induced emf

B is the magnetic field component ($0.5 \times 10^{-4}\,\text{T}$)

L is the wing span ($4\,\text{m}$)

v is the speed of the aeroplane ($100\,\text{m/s}$)

Calculation:

Substitute the values into the formula:

$e = 0.5 \times 10^{-4} \times 4 \times 100$

Solving this gives:

$e = 2 \times 10^{-2}\,\text{V} = 20 \times 10^{-3}\,\text{V}$

Result:

Thus, the induced emf across the ends of the wings is $20 \times 10^{-3}\,\text{V}$.

Question9

A boy is playing with the empty rim of a cycle wheel of radius 40 cm by rolling it along a horizontal road towards north with angular speed of $20 \mathrm{rads}^{-1}$. Considering the effect of magnetic field of earth, the e.m.f induced in the rim is

(Horizontal component of earth's magnetic field $= 0.26 \mathrm{G}$)

TS EAMCET 2023 (Online) 12th May Evening Shift

Options:

A. zero

B. 2μ V

C. 2.4 mV

D. 3 V

Answer: A

Solution:

Explanation:

To determine the induced electromotive force (emf) in the rim of the bicycle wheel, we need to consider the following information:

Radius of the Rim, r: The radius is given as 40 cm, which converts to 0.4 m.

Angular Speed, ω: The wheel is rotating with an angular speed of 20 rad/s.

Horizontal Component of Earth's Magnetic Field: Given as 0.26 G, which is 0.26×10^{-4} T.

The formula for the induced emf is given by:

$e = l(\mathbf{v} \times \mathbf{B})$

Where:

e is the induced emf.

l is the length of the conductor or loop.

$\mathbf{v}$ is the velocity of the loop.

$\mathbf{B}$ is the magnetic field.

Since the plane of the wheel's revolution is parallel to the horizontal component of Earth's magnetic field, the cross product $\mathbf{v} \times \mathbf{B}$ becomes zero. This is because the velocity vector of the wheel's rim is parallel to the direction of the magnetic field.

Thus, the induced emf is zero:

$e = 0$

Therefore, no emf is induced in this specific orientation of the wheel because the necessary conditions for inducing emf (a changing magnetic field perpendicular to the motion) are not met.

Question10

When a current i through a solenoid is increasing at a constant rate, then the induced current is

TS EAMCET 2023 (Online) 12th May Morning Shift

Options:

A. constant and it will be in the direction of i

B. constant and it will be in a direction opposite to the i

C. increased with time and it will be in the direction of i

D. increased with time and opposite to the direction of i

Answer: B

Solution:

When the current i through a solenoid increases at a constant rate, the analysis of the induced current involves understanding the behavior of magnetic field, magnetic flux, and their rates of change:

Magnetic Field through the Solenoid:

The expression for the magnetic field B within a solenoid is given by:

$B = \mu_0 n I$

where μ_0 is the permeability of free space, n is the number of turns per unit length, and I is the current.

Rate of Change of Magnetic Field:

The rate of change of the magnetic field with respect to time is:

$\frac{dB}{dt} = \mu_0 n \frac{dI}{dt}$

Since $\frac{dI}{dt}$ is constant (the current is increasing at a constant rate), $\frac{dB}{dt}$ is also constant.

Magnetic Flux through the Solenoid:

Magnetic flux ϕ through the solenoid is given by:

$\phi = B \cdot A$

where A is the cross-sectional area of the solenoid.

Rate of Change of Magnetic Flux:

The rate of change of magnetic flux is expressed as:

$\frac{d\phi}{dt} = A\frac{dB}{dt}$

Given that $\frac{dB}{dt}$ is constant, $\frac{d\phi}{dt}$ is also constant.

Induced Current:

According to Lenz's law, the induced current will act to oppose the change in magnetic flux. Therefore, even though the induced current is **constant**, it arises due to the constant rate of change of flux, working in opposition to the increase in the original current i.

Thus, the induced current is constant and occurs in a direction opposite to the original increasing current i.

Question11

In a pair of adjacent coils, if the current in one coil changes from 10 A to 2 A in a time 0.2 s , an emf of 120 V is induced in another coil. The mutual inductance of the pair of the coils is

TS EAMCET 2023 (Online) 12th May Morning Shift

Options:

A. 2 H

B. 3 H

C. 6 H

D. 9 H

Answer: B

Solution:

To determine the mutual inductance of a pair of adjacent coils, we start with the given information:

The change in current (ΔI) is from 10 A to 2 A, so $\Delta I = 10\,\text{A} - 2\,\text{A} = 8\,\text{A}$.

The time interval (Δt) for this change is 0.2 s.

The induced electromotive force (emf) is 120 V.

We use Faraday's law of mutual induction to find the mutual inductance M. The formula for the induced emf (E) can be derived from Faraday's law as:

$$E = \frac{M \cdot \Delta I}{\Delta t}$$

Substitute the known values into the equation:

$$120 = \frac{M \times 8}{0.2}$$

Solving for M:

$$120 = \frac{M \times 8}{0.2}$$

$$120 = M \times 40$$

$$M = \frac{120}{40} = 3\,\text{H}$$

Thus, the mutual inductance of the pair of coils is 3 H.
