Blue Print (As per PU Board)

Topic	1 mark questions	2 marks questions	3 marks questions	5 marks questions	Total Marks
Electromagnetic Induction	1	1	1	1	11

One mark questions

1. **Is inductance a vector or a scalar? What are the dimensions of inductance?**
   Answer: Inductance is a scalar.
   [Inductance] $= ML^2T^{-2}A^{-2}$
2. **Write an expression for induced emf in a coil of self-inductance.**
   Answer: $V = -L \cdot \frac{dI}{dt}$ (also called back emf)
3. **When is the magnetic flux linked with a coil held in a magnetic field zero?**
   Answer: When the plane of the coil is along the magnetic field, the magnetic flux is zero.

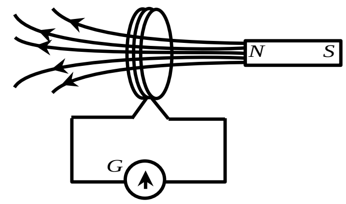
Two marks questions

4. **Current in a circuit falls from $5.0\,\text{A}$ to $0.0\,\text{A}$ in $0.1\,\text{s}$. If an average emf $200\,\text{V}$ is induced, give an estimate of the self-inductance of the coil**
   Answer: $V = L\frac{dI}{dt}$ (1 mark)
   $200 = L\frac{(5-0)}{0.1}$
   $200 = 50L$
   $\therefore\ L = \frac{200}{50} = 4\,\text{H}$ (1 mark)
5. **A $1.0\,\text{m}$ long metallic rod is rotated with an angular frequency of $400\,\text{rad}\,\text{s}^{-1}$ about an axis normal to the rod passing through its one end. The other end of the rod is in contact with a circular metallic ring. A constant and uniform magnetic field $0.5\,\text{T}$ parallel to the axis exists everywhere. Calculate the emf developed between the centre and the ring.** (2 marks)
   Answer: $e = \frac{1}{2}Br^2\omega$ (1 mark)
   $e = \frac{1}{2}\times 0.5\times 1^2 \times 400 = 100\,\text{V}$ (1 mark)
6. **What are eddy currents? How to minimise the eddy currents?**
   Answer: When a bulk sheet of metal is subjected to a varying magnetic field induced currents flowing in the patterns of swirling eddies are produced. These are called eddy currents. (1 mark)
   Eddy currents are minimised using laminations of metal to make a core. The laminations are separated by an insulating material. (1 mark)

Three marks questions

7. **Explain Faraday's Magnet – Coil experiment.**
   Answer: A bar magnet is brought near a coil the ends of which are connected to a galvanometer.
   (a) When both the magnet and the coil are at rest no deflection is observed in the galvanometer.
   (1 mark)

(b) When there is a relative motion between the magnet and the coil, a deflection is observed in the galvanometer. (1 mark)



(c) If the relative speed between. The coil and the magnet increases, then the deflection in the galvanometer also increases. (1 mark)

8. **Derive an expression for the energy stored to build up the current I in a coil.**
Answer: The self-induced emf or back emf opposes any change in the current. Work needs to be done against back emf in establishing current. This work done is stored as magnetic potential energy.
For the current I at an instant t in a circuit, the rate of work done is

$$\frac{dW}{dt} = |e| I$$ (1 mark)

But $e = L\frac{dI}{dt}$

$$\therefore \frac{dW}{dt} = L \cdot \frac{dI}{dt} I$$

$$\therefore dW = LI\, dI$$ (1 mark)

Thus the energy required to build up the current is

$$\int dW = \int_0^I LI\, dI$$

$$W = \frac{1}{2}LI^2.$$ (1 mark)

9. **A horizontal straight wire $10\,\text{m}$ long extending from east to west is falling with a speed of $5.0\,\text{ms}^{-1}$ at right angles to the horizontal component of the earth's magnetic field $0.30\times10^{-4}\ \text{Wb}\,\text{m}^{-2}$.**
(a) What is the instantaneous value of the emf induced in the wire?
(b) What is the direction of induced emf?
(c) Which end of the wire is at the higher electric potential? **(3 marks)**
Answer: $l = 10\,\text{m}$

$v = 5.0\,\text{ms}^{-1}$

$B = 0.30\times10^{-4}\ Wb\, m^{-2}$

$= 3\times10^{-5} Wb\, m^{-2}$

(a) $e = Blv$

$= 3\times10^{-5}\times10\times5$

$= 150\times10^{-5}$ volt

$= 1.5\times10^{-3} V$ (1 mark)

(b) West to east (According to Lenz's law) (1 mark)
(c) Current flows from Eastern end to the western end of the wire. (1 mark)

Five marks questions

10. **A circular coil of radius $8.0\,\text{cm}$ and 20 turns is rotated about a vertical diameter with an angular speed of $50\,\text{rad}\,s^{-1}$ in a uniform horizontal magnetic field of magnitude $3.0\times10^{-2}\,\text{T}$. Obtain the maximum and average emf induced in the coil, if the coil forms a closed loop of resistance $10\,\Omega$, calculate the average power loss due to joule heating. Where does this power come from?**
(5 marks)

Answer: $R = 8.0\,\text{cm} = 8\times10^{-2}\,\text{m}$

$n = 20$

$\omega = 50\,\text{rad}\,s^{-1}$

$B = 3.0 \times 10^{-2} T$

$R = 10\Omega$

$e = Ban\omega \sin \omega t$ (1 mark)

$e_{\max} = Ban\omega = B\left(\pi R^2\right)n\omega$

$= 3\times10^{-2} \times 3.14 \times \left(8\times10^{-2}\right)^2 \times 50 \times 20$

$= 602.88 \times 10^{-3}$

$= 0.603$ volt (1 mark)

$\text{I}_{\max} = \frac{e_{\max}}{R} = \frac{0.603}{10} = 0.0603\,A$ (1 mark)

Average power $= p_{av} = \frac{1}{2} p_{\max}$

$= \frac{1}{2} e_{amx} \cdot I_{\max}$

$= \frac{1}{2} \times 0.603 \times 0.0603$

$= 0.018\,\text{W}$ (1 mark)

The induced current causes a torque opposing the rotation of the coil. An external agent (rotor) must supply torque and do work to counter this torque in order to keep the coil rotating uniformly. Thus the source of the power dissipated as heat in the coil is the external rotor. (1 mark)

11. Derive an expression for the emf induced in a coil when it is rotated with a constant angular velocity in a magnetic field. (5 marks)

Answer: Consider a rectangular coil having n number of turns. Let A be the area of the face of the coil. Let the coil be rotated with a constant angular velocity ω. At any instant of time, let the normal to the plane of the coil make an angle θ with the direction of the magnetic field B applied on the coil. To start with, the plane of the coil is perpendicular to the magnetic field.

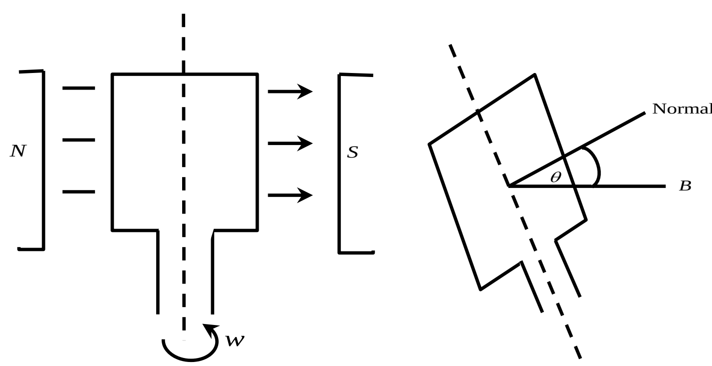


Fig. (1 mark)

The flux passing through the coil at this instant is

$\phi = B\left(A\cos\theta\right)n$ (1 mark)

Here $\theta = \omega t$

$\therefore \phi = BAn\cos\omega t$

$\frac{d\phi}{dt} = BAn\left(-\omega \sin \omega t\right)$

$\frac{d\phi}{dt} = -BAnw\sin\omega t$ (1 mark)

This is the rate of change of magnetic flux passing through the coil. According to Faraday's law, the induced emf is given by

$e = -\frac{d\phi}{dt}$

$e = BAn\omega \sin\omega t$ (1 mark)

The magnitude of the induced emf when the change in the magnetic flux passing through the coil is maximum when the coil is rotated through $90°$, from its initial position.

When $\omega t = 90°$,

$e = Ban\omega \sin 90°$

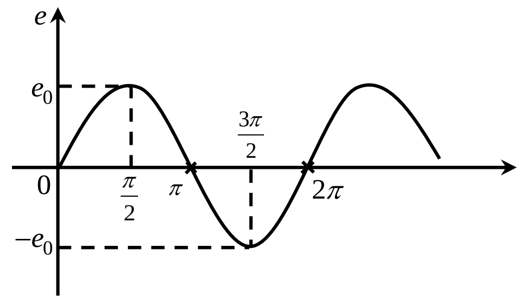
$e_0 = Ban\omega$

This is called the peak value of the induced emf.

Substitute this in (1)

$e = e_0 \sin \omega t$ (1 mark)

If a graph of e against t is drawn, we get a curve as shown in the figure.



12. A long solenoid with 15 turns per cm has a small loop of area $2.0\,\text{cm}^2$ placed inside the solenoid normal to its axis. If the current carried by the solenoid changes steadily from $2.0\,\text{A}$ to $4.0\,\text{A}$ in $0.1s$, what is the induced emf in the loop while the current is changing?

Answer: $B = \mu_0 n I$

$n = 15\,\text{turns/cm}$ (1 mark)

$= 1500\,\text{turns/m}^2 = 1.5\times10^3\,\text{turns/m}^2$

$A = 2\,\text{cm}^2 = 2\times10^{-4}\,m^2$

$\frac{dI}{dt} = \frac{4-2}{0.1} = 20\,As^{-1}$ (1 mark)

Now $\phi = BA$

$\frac{d\phi}{dt} = \frac{d}{dt}(BA)$ (1 mark)

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

$= A\cdot\frac{d}{dt}(\mu_0 n I)$

$= A\cdot\mu_0 n\cdot\frac{dI}{dt}$ (1 mark)

$= 2\times10^{-4}\times4\pi\times10^{-7}\times1.5\times10^3\times20$

$= 753.6\times10^{-8}$

$= 7.5\times10^{-6}\,\text{V}$ *or* $7.5\,\mu\text{V}$ (1 mark)