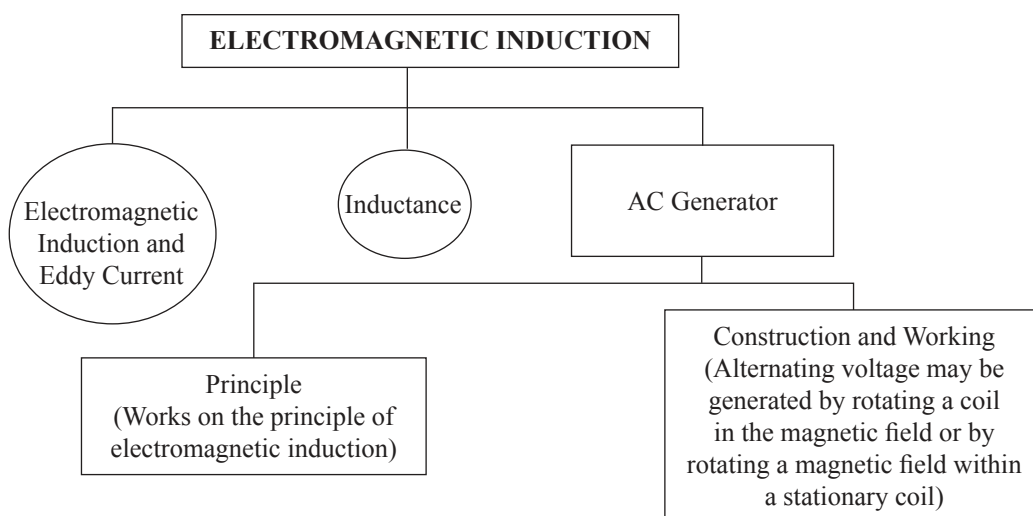


Electromagnetic Induction

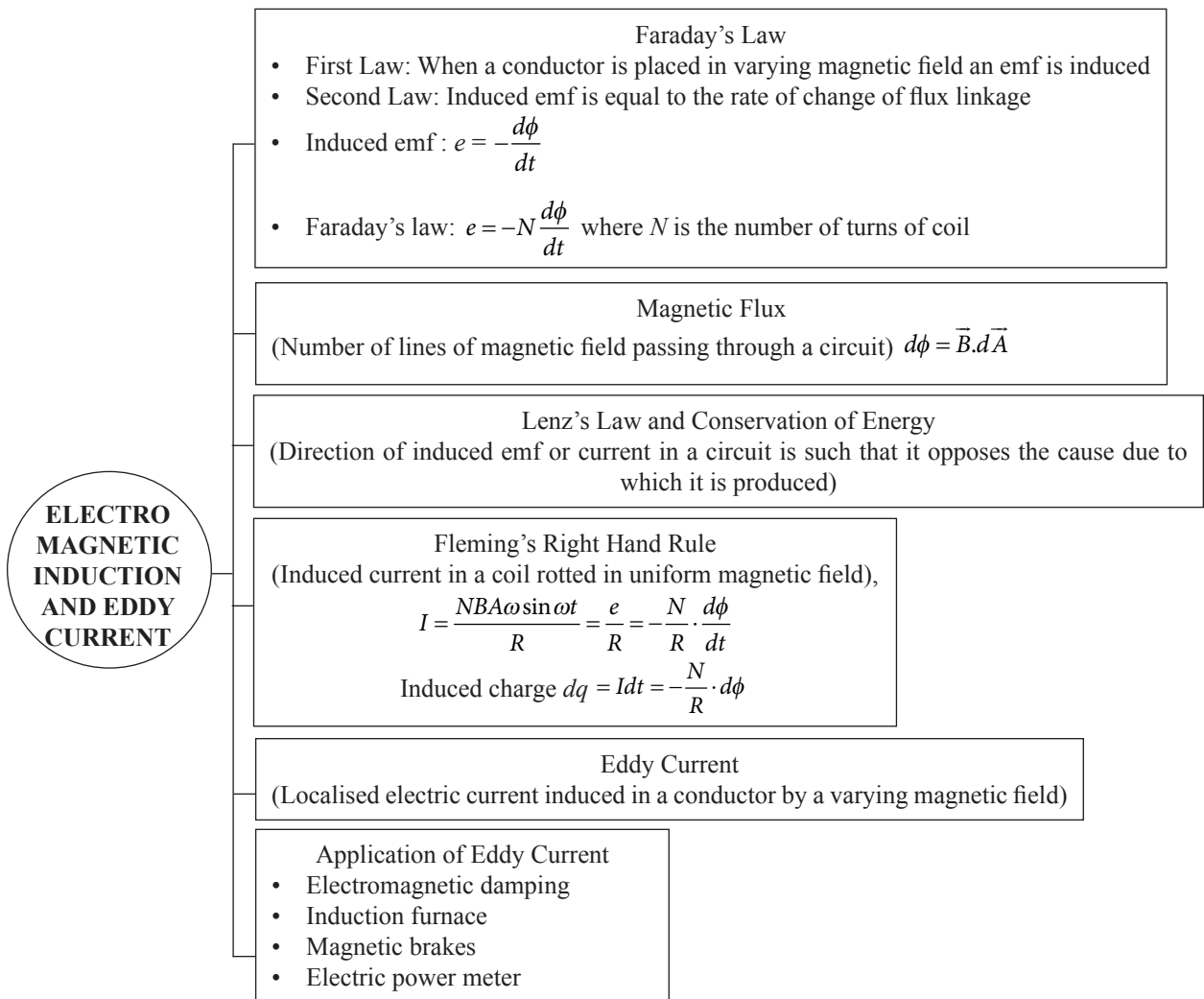
Syllabus

- Electromagnetic induction and eddy current:** Introduction, Faraday's law, Magnetic flux, Lenz's law and conservation of energy, Fleming's right hand rule; Eddy current, application of eddy current.
- Inductance:** Introduction, Mutual inductance, Self-inductance, Motional electromotive force.
- AC generator:** Introduction; Principle, Construction and working.

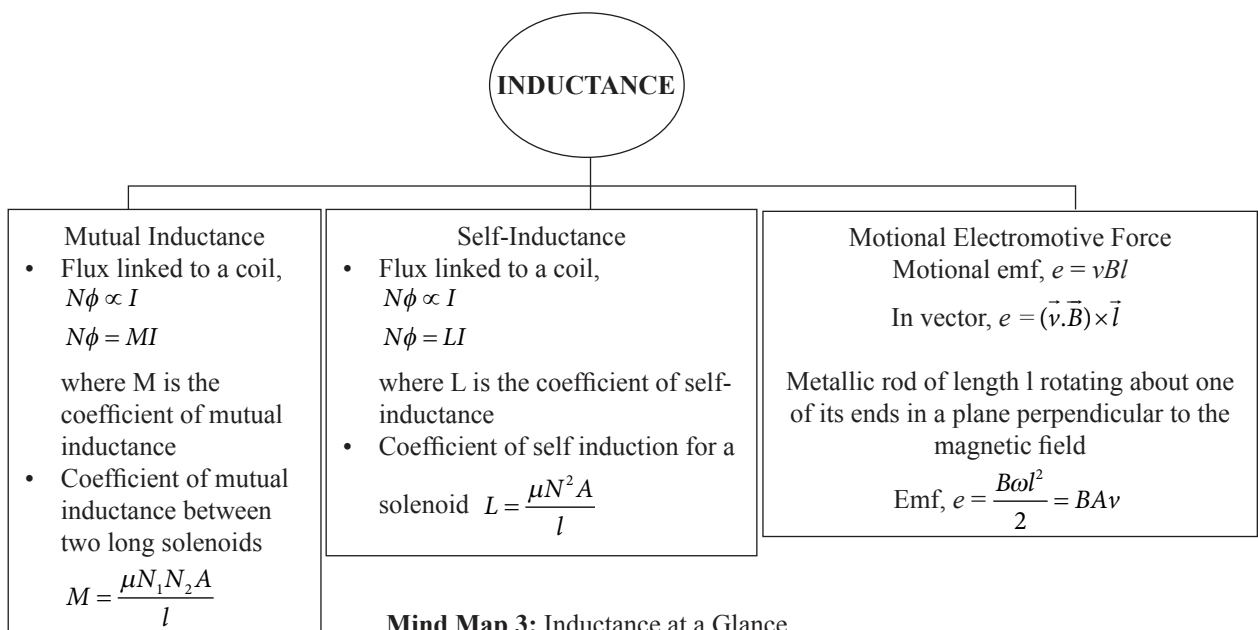
MIND MAP



Mind Map 1: Electromagnetic Induction at a Glance



Mind Map 2: Electromagnetic Induction and Eddy Current at a Glance



Mind Map 3: Inductance at a Glance

RECAP

Electromagnetic Induction and Eddy Current

Introduction

- o When ever there is a change in magnetic field, an **electromotive force (emf)** is generated. This phenomenon is called Electromagnetic Induction.
- o The emf generated is called induced emf and the current that flows in a closed circuit due to the induced emf is called **induced current**.
- o The working of power generators, dynamos, transformers, etc. are based on the phenomenon of **electromagnetic induction**.
- o Electromagnetic induction is based on the law of conservation of energy in which mechanical energy changes to electrical energy.

Faraday's Law

- o **First Law:** When a conductor is placed in varying magnetic field an emf is induced, called induced emf. In a closed conductor circuit a current is also induced, called induced current.
- o **Second Law:** Induced emf is equal to the rate of change of flux linkage.

$$\text{Induced emf: } e = -\frac{d\phi}{dt}$$

Here, negative sign indicates the direction of magnetic flux ϕ .

- o Faraday's law is written as: $e = -N\frac{d\phi}{dt}$.

where, e is the induced emf and N is the number of turns of the coil.

- o Induced emf:
 - **In rotating coil:**
 - ◆ $e = 2\pi\nu BNA \sin \omega t$
 - **In a straight conductor in translational motion:**
 - ◆ $e = Blv$
 - **In a straight conductor in rotational motion:**
 - ◆ $e = Bv\pi l^2 = \frac{1}{2}Bl^2\omega$
 - **Peak value:**
 - ◆ $e_0 = 2\pi\nu BNA$

Magnetic Flux

- o The number of lines of magnetic field passing through a circuit is called **Magnetic flux**. It is denoted by ϕ .
- o SI unit of Magnetic flux is Weber (Wb) and Maxwell in CGS unit. Its dimensional formula is: $[M^1L^2T^{-2}A^{-1}]$
- o The scalar product of field vector (\vec{B}) and area vector ($d\vec{A}$) gives the magnetic flux crossing certain area and is given as:

$$d\phi = \vec{B} \cdot d\vec{A}$$

- For uniform magnetic field:

$$\phi = \vec{B} \cdot \vec{A}$$

$$\phi = BA \cos \theta$$

- ◆ When $\theta = 0$
 $\Rightarrow \cos\theta = 1$
 $\therefore \phi = BA$

- ◆ When $\theta = 90^\circ$, $\cos 90^\circ = 0$
 $\therefore \phi = BA \cos 90^\circ = 0$

□ Magnetic Flux Density:

- Magnetic flux is given by: $d\phi = \vec{B} \cdot d\vec{A}$

- For \vec{B} parallel to $d\vec{A}$, we have
 $d\phi = B(dA)\cos 0^\circ = B(dA)$

$$\therefore B = \frac{d\phi}{dA}$$

- Magnetic induction is equal to the magnetic flux density. In other words, magnetic field may be measured in terms of the magnetic flux density.
- From above equation,

$$\text{Unit of } B = \frac{\text{Unit of } d\phi}{\text{Unit of } dA}$$

$$\text{or } T = \frac{\text{Wb}}{\text{m}^2}$$

i.e., Tesla = Weber per square metre

Lenz's Law and Conservation of Energy

- Lenz's law states that the direction of induced current is always such that it opposes the change in the circuit or the magnetic field which produces it.
- The expression for the emf induced by the electromagnetic induction is given by $e = -\frac{d\phi}{dt}$.

Where negative sign shows that induced emf opposes the cause due to which it is produced.

- Lenz's law gives the relation between current and magnetic field.
- It is based on the law of **conservation of energy** and Newton's third law.
- Positive e shows decrease in flux and negative e shows increase in flux.
- The value of e is equal to the negative slope of ϕ - t curve.

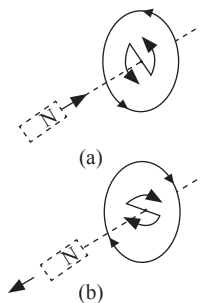


Figure: Illustration of Lenz's Law

Fleming's Right-Hand Rule

- Fleming's right-hand rule is used for generators to show the direction of induced current when a conductor attached to a circuit is moving in a magnetic field. According to Fleming's right-hand rule, when we stretch the forefinger, central finger and thumb of our right hand in mutually perpendicular directions such that the forefinger points along the direction of the magnetic field and the thumb is set along the direction of motion of the conductor, then the central finger gives the direction of the induced current or emf. The direction of the induced current given by Lenz's law is same as the direction given by Fleming's right-hand rule.

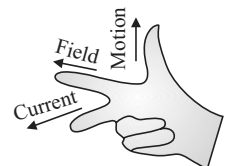


Figure: Fleming's right hand rule

Eddy Current

- Eddy currents are induced in a closed loop by changing the magnetic fields, perpendicular to the magnetic fields.
- Eddy currents are produced in the cores of transformer, in induction coil, electric motor, electromagnet, etc.
- Lenz's law or Fleming's right hand rule give the direction of eddy currents.

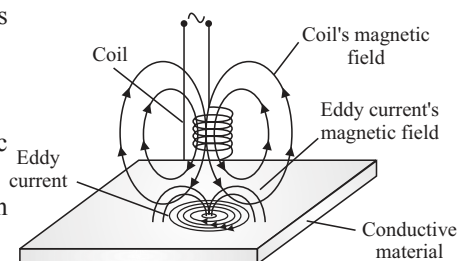


Figure: Eddy current due to magnetic field

Application of Eddy Current

- **Magnetic brakes in train:** Electrically powered trains are fitted with strong electromagnets. Eddy currents are induced in the rails when electromagnets are activated which opposes the motion of the train. No mechanical linkage provides smoothness to the braking effect.
- **Electromagnetic damping:** If we take a nonmagnetic metallic hollow cylinder and drop a magnet through the cylinder, we see that the magnet comes out slowly through the other side of the cylinder. This is due to the eddy current produced in the cylinder which opposes the motion of the magnet.

Inductance

Introduction

- Inductance is the property of an electric circuit by which an emf is induced in the circuit or neighbouring circuit when a varying current passes through it.
- A device used for storing energy in a magnetic field is known as an inductor. A coil or solenoid is used as inductor. It is denoted by,



Figure: Symbol of inductor

- The energy stored in the inductor is in the form of magnetic energy. It is given by:

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

Mutual Inductance

- Mutual inductance is the property by which an induced emf is produced in the coil when a varying current passes through the neighboring coil.
- The flux linked to the coil of N turns is proportional to the current passing through the coil, i.e.

$$N\phi \propto I$$

$$N\phi = MI$$

where, M = coefficient of mutual induction of the coil.

- Let, the instantaneous current in the circuit I . The magnetic flux linked with the secondary coil is ϕ . Then the magnetic flux is proportional to the current. That is,

$$\phi \propto I$$

$$\Rightarrow \phi = MI$$

where, M = constant of proportionality.

- Constant of proportionality is also called coefficient of mutual induction.
 - The induced emf in the secondary coil is given by,

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

- The negative sign in the above equation states that the induced emf in the secondary coil opposes the variation of current in the primary coil. It is according to the Lenz's law.
- Coefficient of mutual induction is the ratio of induced emf in the secondary coil to the rate of change of current in the primary coil.
- The unit of mutual induction is Henry (H) in SI system and Stat Henry in CGS system.
- Mutual inductance is also measured in Wb/A or volt second/ampere. Its dimensional formula is: $[M^1L^2T^{-2}A^{-2}]$
- **Coefficient of coupling (K):** A measure of the coupling between the two coils is called coefficient of coupling and is given by

$$K = \frac{M}{\sqrt{L_1L_2}}$$

where, L_1 and L_2 are coefficient of self induction of the two coil and M is the mutual inductance of the two coil.

- The coefficient of mutual inductance of two long coaxial solenoids, each of length l and area of cross section A , wound on the core is,

$$M = \frac{\mu N_1 N_2 A}{l}$$

where, μ is the permeability of the material, N_1 and N_2 are the total number of turns of the two solenoids.

- Mutual Inductance:

- **Two concentric coplanar circular coils:**

$$M = \frac{\pi \mu_0 N_1 N_2 r^2}{2R}$$

- **Two solenoids:**

$$M = \frac{\mu_0 N_1 N_2 A}{l}$$

- **Two concentric coplanar square coils:**

$$M = \frac{\mu_0 2\sqrt{2} N_1 N_2 l}{\pi L}$$

- Mutual inductance for two coils in series:

$$L = L_1 + L_2 \pm 2M$$

- Mutual inductance for two coils in parallel:

$$L_p = \frac{L_1 L_2 - M^2}{L_1 + L_2 \pm 2M}$$

Self-Inductance

- An emf is induced in a single isolated coil due to the change in flux through the coil by passing a varying current in the same coil. This phenomenon is called Self-Inductance.
- The flux linked to the coil of N turns is proportional to the current passing through the coil, i.e.

$$N\phi \propto I$$

$$N\phi = LI$$

where, L = coefficient of self induction or self-inductance of the coil.

- Let, the instantaneous current in the circuit is I . The magnetic flux linked with the solenoid is ϕ . Then,

$$\phi \propto I$$

$$\Rightarrow \phi = LI$$

where, L is constant of proportionality called the coefficient of self induction.

- The induced emf in the coil is given by

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

- The negative sign in the above equation states that the induced emf opposes the variation of current in the coil.
- Self-inductance is the ratio of induced emf in the circuit to the rate of change of the current in the circuit.
- The coefficient of self induction of a coil is said to be one Henry if induced emf equal to 1 V is produced in the coil, when the current in it changes at the rate of one ampere per second.
- The unit of self induction is Henry (H) in SI system and stat Henry in CGS system.
- Self-inductance is also measured in Wb/A or volt second/ampere. Its dimensional formula is: $[M^1 L^2 T^{-2} A^{-2}]$

- Self-inductance:

- **For a circular coil:**

$$L = \frac{\mu_0 \pi N^2 r}{2}$$

- **For a solenoid:**

$$L = \frac{\mu_0 \mu_r N^2 A}{l} = \frac{\mu N^2 A}{l}$$

$$\therefore (\mu = \mu_0 \mu_r)$$

- **For a toroid:**

$$L = \frac{\mu_0 N^2 r}{2}$$

- **For a square coil:**

$$L = \frac{2\sqrt{2}\mu_0 N^2 a}{\pi}$$

- **For a coaxial cylinder:**

$$L = \frac{\mu_0}{2\pi r} \log_e \frac{R}{r} = \frac{2.303}{2\pi r} \mu_0 \log_{10} \frac{R}{r}$$

- Self-inductance for two coils in series:

$$L_s = L_1 + L_2$$

- Self-inductance for two coils in parallel:

$$\frac{1}{L_p} = \frac{1}{L_1} + \frac{1}{L_2}$$

Motional Electromotive Force

- If a rod of length l moves perpendicular to a magnetic field B with a velocity v , then the induced emf produced across it is given by, $\varepsilon = vBl$

In general, we have $E = (\vec{v} \cdot \vec{B}) \times l$

- If a metallic rod of length l rotates about one of its ends in a plane perpendicular to the magnetic field, then the induced emf produced across its ends is given by,

$$\varepsilon = \frac{B\omega l^2}{2} = BA\nu$$

Here, ω = angular frequency of rotation,

$A = \pi l^2$ = area of circle and

ν = frequency of rotation

- If a metallic disc rotates about its own centre in a plane perpendicular to the magnetic field B , then the induced emf is produced between the centre and the edge. The induced emf is given by,

$$\varepsilon = \frac{B\omega r^2}{2} = BA\nu$$

Here, ω = angular velocity of rotation,

$A = \pi r^2$ area of disc and

ν = frequency of rotation

Illustration 1

A long solenoid of length 1 m, cross sectional area 10 cm², having 1000 turns has wound about its centre a small coil of 20 turns. Calculate the mutual inductance of the two circuits. What is the emf in the coil when the current in the solenoid changes at the rate of 10 A/s?

Soln.

Let N_1 = number of turns in solenoid

N_2 = number of turns in coil

A_1 and A_2 be their respective areas of cross-section.

($A_1 = A_2$ in this problem)

Flux ϕ_2 through coil created by current I_1 in solenoid is $\phi_2 = N_2(B_1A_2)$

$$\phi_2 = N_2(\mu_0 I_1 N_1 / l)A_2$$

$$\text{Or, } \phi_2 = (\mu_0 N_1 N_2 A_2 / l)I_1$$

Comparing with $\phi_2 = MI_1$, we get,

Mutual inductance,

$$M = \mu_0 N_1 N_2 A_2 / l = \frac{[4\pi \times 10^{-7} \times 1000 \times 20 \times 10 \times 10^{-4}]}{1} = 2.51 \times 10^{-5} \text{ H}$$

So, magnitude of induced emf,

$$E_2 = M \left| \frac{dI_1}{dt} \right|$$

AC Generator

Introduction

- An electrical machine which is used to convert the mechanical energy to electrical energy is known as A.C. generator/alternator.
- If the electric current produced varies in direction alternatively, it is called alternating current.

Principle

- It works on the principle of electromagnetic induction i.e., when a coil is rotated about an axis perpendicular to the direction of uniform magnetic field, an induced emf is produced across it.

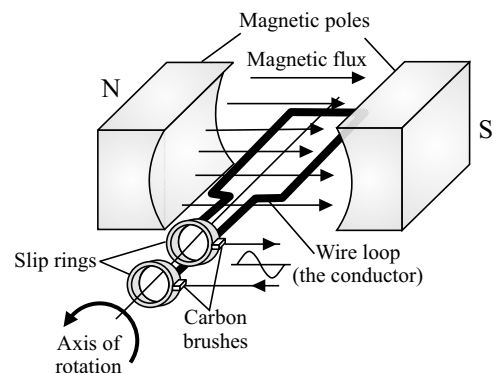


Figure: Circuit diagram of AC generator

Construction and Working

- The A.C. generator consists of an armature coil (having N turns) of insulated copper wire wound over a soft iron core, a strong permanent magnet or an electromagnet whose poles (N and S) are cylindrical in shape in a field magnet.
- The armature coil rotates between the pole pieces of the field magnet. The uniform magnetic field provided by the field magnet is perpendicular to the axis of rotation of the coil.
- Two brass slip rings R_1 and R_2 are connected to the two ends of the armature coil. These rings rotate along with the armature coil.
- Two carbon brushes (B_1 and B_2), are pressed against the slip rings. The brushes are fixed while slip rings rotate along with the armature. These brushes are connected to the load through which the output is obtained.
- When the armature coil rotates in the magnetic field provided by the strong field magnet, it cuts the magnetic lines of force. Thus, the magnetic flux linked with the coil changes and hence induced emf is set up in the coil. The direction of the induced emf or the current in the coil is determined by the Fleming's right hand rule.
- The current flows out through the brush B_1 in one direction of half of the revolution and through the brush B_2 in the next half revolution in the reverse direction. This process is repeated. Therefore, emf produced is of alternating nature.

$$e = -\frac{Nd\phi}{dt} = NBA\omega \sin \omega t = e_0 \sin \omega t$$

Where, $e = NBA\omega$

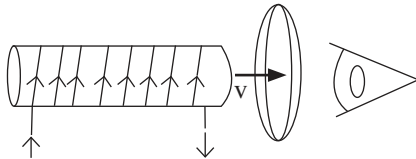
$$I = \frac{e}{R} = \frac{e_0}{R} \sin \omega t = I_0 \sin \omega t$$

Where, R is the resistance of the circuit.

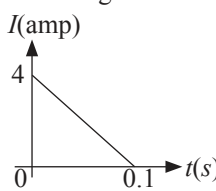
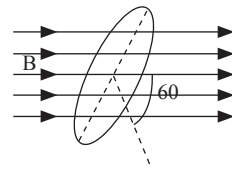
PRACTICE TIME

Electromagnetic Induction and Eddy Current

- A moving conductor coil in a magnetic field produces an induced emf. This is in accordance with:
 - Lenz's Law
 - Coulomb's Law
 - Faraday's Law
 - Ampere's Law
- The force between two current carrying parallel wires is due to:
 - magnetic effect of electric current
 - electrostatic Interaction
 - electromagnetic induction
 - electric effect of magnetic field
- An induced emf is produced when a magnet is plunge into a coil. The strength of the induced emf is independent of:
 - number of turns of coil
 - speed with which the magnet is moved
 - the strength of the magnet
 - the resistivity of the wire of the coil
- The magnetic flux through a coil is inversely proportional to:
 - magnetic field
 - number of turns
 - area
 - none of these
- Faraday's laws are consequences of conservation of:
 - energy and magnetic field
 - energy
 - magnetic field
 - charge
- A coil of insulated wire is connected to a battery. If it is taken to galvanometer, its pointer is deflected, because:
 - the number of turns in the coil of the galvanometer are changed
 - the coil acts like a magnet
 - the induced current is produced
 - none of these
- Lenz's law gives:
 - the direction of the induced current
 - the magnitude of the induced emf
 - the magnitude of the induced current
 - both the magnitude and direction of the induced current
- Which of the following phenomena makes use of electromagnetic induction?
 - Magnetising an iron piece with a bar magnet
 - Generation of hydroelectricity
 - Magnetising a soft iron piece by placing inside a current carrying solenoid
 - Charging a storage battery
- The magnetic flux (ϕ) linked with a coil due to its own magnetic field is related to the number (N) of turns of the coil as:
 - $\phi \propto N^2$
 - $\phi \propto N^{-1}$
 - $\phi \propto N$
 - $\phi \propto N^{-2}$
- In electromagnetic induction, the induced charge is independent of:
 - resistance of the coil
 - change of flux
 - time
 - None of these
- A current carrying solenoid is approaching a conducting loop as shown in the figure. The direction of induced current as observed by an observer on the other side of the loop will be:



 - clockwise
 - anti-clockwise
 - east
 - west
- A copper rod moves parallel to the horizontal direction. The induced emf developed across its ends due to earth's magnetic field will be maximum at the:
 - latitude 30°
 - latitude 60°
 - equator
 - poles
- To induce an emf in a coil, the linking magnetic flux:
 - must remain constant
 - can either increase or decrease
 - must increase
 - must decrease
- The magnetic flux linked with a coil of N turns of area of cross section A held with its plane parallel to the field B is:
 - NAB
 - Zero
 - $\frac{NAB}{2}$
 - $\frac{NAB}{4}$
- Flux of magnetic field through an area bounded by a closed conducting loop can be changed by changing:
 - magnetic field \vec{B}
 - area of the loop
 - angle between area vector and \vec{B}
 - All of the above

16. The magnetic flux through a circuit of resistance R changes by an amount $\Delta\phi$ in a time Δt . Then the total quantity of electric charge Q that passes through any point in the circuit during the time Δt is represented by:
- (a) $Q = \frac{\Delta\phi}{R}$ (b) $Q = R \frac{\Delta\phi}{\Delta t}$
- (c) $Q = \frac{1}{R} \cdot \frac{\Delta\phi}{\Delta t}$ (d) $Q = \frac{\Delta\phi}{\Delta t}$
17. A coil has 200 turns and area of 70 cm^2 . The magnetic field perpendicular to the plane of the coil is 0.3 Wb/m^2 and take 0.1 s to rotate through 180° . The value of the induced emf will be:
- (a) 84 V (b) 42 V
(c) 8.4 V (d) 4.2 V
18. The expression for the induced emf contains a negative sign $\left(e = -\frac{d\phi}{dt} \right)$. What is the significance of the negative sign?
- (a) The induced emf is opposite to the direction of the flux.
(b) The induced emf is produced only, when the magnetic flux decreases.
(c) The induced emf opposes the changes in the magnetic flux.
(d) None of the above
19. In a coil of resistance 10Ω , the induced current developed by changing magnetic flux through it, is shown in figure as a function of time. The magnitude of change in flux through the coil in Wb is:
- 
- (a) 2 (b) 4
(c) 6 (d) 8
20. Lenz's and Faraday's law is expressed by the following formula (here e = induced emf, ϕ = magnetic flux in one turn and N = number of turns):
- (a) $e = -N \frac{d\phi}{dt}$ (b) $e = N \frac{d\phi}{dt}$
- (c) $e = -\phi \frac{dN}{dt}$ (d) $e = -\frac{d}{dt} \left(\frac{\phi}{N} \right)$
21. A rectangular coil of 100 turns and size $0.1 \text{ m} \times 0.05 \text{ m}$ is placed perpendicular to a magnetic field of 0.1 T . If the field drops to 0.05 T in 0.05 s , the magnitude of the emf induced in the coil is:
- (a) 0.5 (b) 3
(c) 2 (d) 6
22. The magnetic flux associated with a conductor increases from zero to 0.8 Wb in 0.2 s . The induced emf is:
- (a) $\frac{1}{2}$ (b) 2
(c) $\frac{1}{4}$ (d) 4
23. A coil of area 10 cm^2 has 200 turns. Magnetic field of 0.1 Wb/m^2 is perpendicular to the coil. The field is reduced to zero in 0.1 s , the induced emf in the coil is:
- (a) Zero (b) 0.2 V
(c) 1 V (d) 2 V
24. A loop of wire is placed in a magnetic field $\vec{B} = 0.02\hat{i} \text{ T}$. Then the flux through the loop if its area vector $\vec{A} = 30\hat{i} + 16\hat{j} + 23\hat{k} \text{ cm}^2$ is:
- (a) $30 \mu\text{Wb}$ (b) $46 \mu\text{Wb}$
(c) $60 \mu\text{Wb}$ (d) $138 \mu\text{Wb}$
25. Fig shown below represents an area $A = 0.5 \text{ m}^2$ situated in a uniform magnetic field $B = 2.0 \text{ Wb/m}^2$ and making an angle of 60° with respect to magnetic field.
- 
- The value of the magnetic flux through the area would be equal to:
- (a) $\sqrt{3} \text{ Wb}$ (b) $\sqrt{3} / 2 \text{ Wb}$
(c) 0.5 Wb (d) 2 Wb
26. A square coil of 10^{-2} m^2 area is placed perpendicular to a uniform magnetic field of intensity 10^3 Wb/m^2 . The magnetic flux through the coil is:
- (a) 10^{-5} Wb (b) 10 Wb
(c) 100 Wb (d) 10^5 Wb
27. Magnetic Flux linked with a coil is $\phi = 5t^2 + 2t + 3$, where t is in s and ϕ is in Wb. At time $t = 1 \text{ s}$, the value of induced emf is:
- (a) 1.2 V (b) 6 V
(c) 12 V (d) 14 V
28. A copper disc of radius 0.1 m is rotated about its centre with 20 revolutions per second in a uniform magnetic field of 0.2 T with its plane perpendicular to the field. The emf induced across the radius of disc is:
- (a) $\frac{2\pi}{10} \text{ V}$ (b) $4\pi \times 10^{-2} \text{ V}$
(c) $\frac{\pi}{10} \text{ V}$ (d) $2\pi \times 10^{-2} \text{ V}$

29. When strength of eddy currents is reduced, as dissipation of electrical energy into heat depends on the A of the strength of electrical energy into heat depends on the A of the strength of electric current heat loss is substantially B. Here, A and B refer to:

- (a) square, reduced
- (b) cube, increase
- (c) inverse, increased
- (d) inverse, decreased

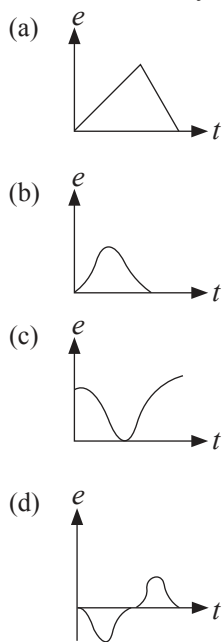
30. A rectangular coil of size $10\text{ cm} \times 20\text{ cm}$ has 60 turns. It is rotating about one of its diagonals in magnetic field 0.5 Wb/m^2 with a rate of 1800 revolution per minute. The induced emf in the coil can be:

- (i) 111 V (ii) 112 V (iii) 113 V (iv) 114 V
- (a) (i) and (ii) are correct
- (b) (i) and (iii) are correct
- (c) (ii) and (iv) are correct
- (d) (i), (ii) and (iii) are correct

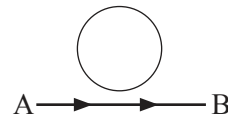
31. An aircraft with a wingspan of 40 m flies with a speed of 1080 km/hr in the eastward direction at a constant altitude in the northern hemisphere, where the vertical component of the earth's magnetic field $1.75 \times 10^{-5}\text{ T}$. Then the emf developed between the tips of the wings is:

- (a) 2.1 V (b) 0.21 V
- (c) 0.34 V (d) 0.5 V

32. The variation of induced emf (e) with time (t) in a coil if a short bar magnet is moved along its axis with a constant velocity is best represented as:



33. An electron moves along the line AB, which lies in the same plane as a circular loop of conducting wires as shown in the diagram. What will be the direction of current induced if any, in the loop?

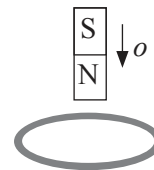


- (a) The current will change direction as the electron passes by
- (b) The current will be anticlockwise
- (c) The current will be clockwise
- (d) No current will be induced

34. A coil of resistance $400\ \Omega$ is placed in a magnetic field. If the magnetic flux ϕ (Wb) linked with the coil varies with time t (sec) as $\phi = 50t^2 + 4$. The current in the coil at $t = 2\text{ s}$ is:

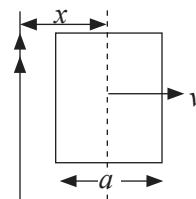
- (a) 0.1 A (b) 1 A
- (c) 0.5 A (d) 2 A

35. A metallic ring is attached with the wall of a room. When the north pole of a magnet is brought near to it, the induced current in the ring will be:



- (a) In clockwise direction
- (b) In anticlockwise direction
- (c) First clockwise then anticlockwise
- (d) First anticlockwise then clockwise

36. A conducting square frame of side a and a long straight wire carrying current I are located in the same plane as shown in the figure. The frame moves to the right with a constant velocity v . The emf induced in the frame will be proportional to:



- (a) $\frac{1}{x^2}$ (b) $\frac{1}{(2x+a)^2}$
- (c) $\frac{1}{(2x-a)^2}$ (d) $\frac{1}{(2x-a)(2x+a)}$

37. Which of the following statements are correct?

- (i) A permanent magnet is used in a small dynamo.
- (ii) The current produced by an AC generator changes in direction only.
- (iii) The direction of the current produced by electromagnetic induction is given by Lenz's law.
- (iv) Generators work on the principle of electromagnetic induction.

- (a) (ii) and (iii) (b) (ii) and (iv)
 (c) (iii) and (iv) (d) (i), (ii) and (iii)
38. A 100 turns coil of area of cross section 200 cm^2 having 2Ω resistance is held perpendicular to a magnetic field of 0.1 T . If it is removed from the magnetic field in one s, the induced charge produced in it is:
 (a) 0.1 C (b) 0.2 C
 (c) 1 C (d) 2 C
39. A circular coil of mean radius of 7 cm and having 4000 turns is rotated at the rate of 1800 revolutions per minute in the earth's magnetic field ($B = 0.5 \text{ gauss}$), the maximum emf induced in coil will be:
 (a) 0.29 V (b) 0.58 V
 (c) 1.158 V (d) 5.8 V
40. Eddy currents may be reduced by using:
 (a) thick piece of cobalt
 (b) thick piece of nickel
 (c) laminated core of steel
 (d) laminated core of soft iron
41. When a small piece of wire passes between the magnetic poles of a horse-shoe magnet in 0.1 s , emf of $4 \times 10^{-3} \text{ V}$ is induced in it. The magnetic flux between the poles is:
 (a) $4 \times 10^{-4} \text{ Wb}$ (b) $4 \times 10^{-2} \text{ Wb}$
 (c) $4 \times 10^{-3} \text{ Wb}$ (d) $4 \times 10^{-6} \text{ Wb}$
42. A metal disc of radius 100 cm is rotated at a constant angular speed of 60 rad/s in a plane at right angles to an external field of magnetic induction 0.05 Wb/m^2 . The emf induced between the centre and a point on the rim will be:
 (a) 9 V (b) 6 V
 (c) 3 V (d) 1.5 V
43. The magnetic flux lines of $3 \times 10^{-4} \text{ Wb}$ are passing through a coil of 100 turns. If the emf induced in the coil is 1.5 V , the time interval will be:
 (a) 0.1 s (b) 0.02 s
 (c) 0.4 s (d) 1 s
44. A metal plate can be heated by:
 (a) placing in a space varying magnetic field, but does not vary with time
 (b) placing in a time varying magnetic field
 (c) passing either a direct or alternating current through the plate
 (d) both (b) and (c) are correct
45. A solenoid has 2000 turns wound over a length of 0.3 m . Its cross-sectional area is $1.2 \times 10^{-3} \text{ m}^2$. Around its central section a coil of 300 turns is wound. If an initial current of 2 A flowing in the solenoid is reversed in 0.25 s , the emf induced in the coil will be:
 (a) $2.4 \times 10^{-2} \text{ V}$ (b) $2.4 \times 10^{-4} \text{ V}$
 (c) $4.8 \times 10^{-2} \text{ V}$ (d) $4.8 \times 10^{-4} \text{ V}$

46. In the given table, column I contains terms and column II contains their SI units.

	Column I (Term)		Column II (SI Unit)
A	Electromotive force	(i)	Weber (Wb)
B	Magnetic Flux	(ii)	Henry (H)
C	Magnetic field	(iii)	Volt (V)
D	Inductance	(iv)	Tesla (T)

Match column I and column II and choose the correct combination from the given options.

- (a) A-(iv), B-(iii), C-(i), D-(ii)
 (b) A-(iii), B-(i), C-(iv), D-(ii)
 (c) A-(iii), B-(ii), C-(iv), D-(i)
 (d) A-(ii), B-(i), C-(iv), D-(iii)

Inductance

47. When current changes from 13 A to 7 A in 0.5 s through a coil, the emf induced is $3 \times 10^{-4} \text{ V}$. The coefficient of self induction is:
 (a) $25 \times 10^{-6} \text{ H}$ (b) $25 \times 10^{-5} \text{ H}$
 (c) $25 \times 10^{-4} \text{ H}$ (d) $25 \times 10^{-3} \text{ H}$
48. If a current of 3 A flowing in the primary coil is reduced to zero in 0.01 s then the induced emf in the secondary coil is 1500 V , the mutual inductance between the two coils is:
 (a) 0.5 H (b) 1.5 H
 (c) 5 H (d) 10 H
49. Magnetic flux of $10 \mu\text{Wb}$ is linked with a coil, when a current of 2 mA flows through it. What is the self-inductance of the coil?
 (a) 20 mH (b) 10 mH
 (c) 15 mH (d) 5 mH
50. For two coils with number of turns 500 and 200 each of length 1 m and cross-sectional area $4 \times 10^{-4} \text{ m}^2$, the mutual inductance is:
 (a) $0.5 \mu\text{H}$ (b) 0.5 H
 (c) $5 \mu\text{H}$ (d) 0.05 mH
51. When current I passes through an inductor of self-inductance L , energy stored in it is $\frac{1}{2} \cdot LI^2$. This is stored in the _____.
 (a) electric field (b) magnetic field
 (c) voltage (d) current
52. What is the minimum value of inductance that can be obtained with the help of three inductances of 2 H , 3 H , and 6 H ?

- (a) 1 H (b) $\frac{1}{3}$ H
 (c) $\frac{1}{6}$ H (d) 11 H

[Hint: Connect in parallel.]

53. A small coil of N_1 turns, l_1 length is tightly wound over the centre of a long solenoid of length l_2 , area of cross-section A and number of turns N_2 . If a current I flows in the small coil, then the flux through the long solenoid is:

- (a) Zero (b) $\frac{\mu_0 N_1 N_2 A I}{l_2}$
 (c) $\frac{\mu_0 N_1^2 A I}{l_1}$ (d) Infinite

54. Which of the following is not a factor to determine the mutual inductance of the two coils?

- (a) Current through each coil
 (b) The number of turns of each coil
 (c) Separation between the coils
 (d) The shape of each coil

55. A coil of wire of radius R has 200 turns and a self-inductance of 108 mH. The self-inductance of a similar coil of 500 turns will be:

- (a) 375 mH (b) 675 mH
 (c) 527 mH (d) None of these

56. A circular coil of radius 5 cm has 500 turns of a wire. The approximate value of the coefficient of self induction of the coil will be:

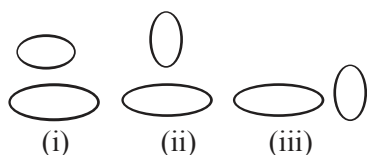
- (a) 25×10^{-3} mH (b) 25 mH
 (c) 50×10^{-3} H (d) 50×10^{-3} mH

[Hint: Magnetic field at the centre of circular coil carrying current is given by, $B = \frac{\mu_0}{4\pi} \cdot \frac{2\pi N I}{r}$]

57. A coil is wound on a frame of rectangular cross-section. If all the linear dimensions of the frame are increased by a factor two and the number of turns per unit length of the coil remains the same, self-inductance of the coil increases by a factor of:

- (a) 16 (b) 12
 (c) 8 (d) 4

58. Two circular coils can be arranged in any of the three situations shown in the figure. Their mutual inductance will be:



- (a) The same in all situations
 (b) Maximum in (i)

- (c) Maximum in (ii)
 (d) Maximum in (iii)

59. A long solenoid has 1000 turns. When a current of 4 A flows through it, the magnetic flux linked with each turn of the solenoid is 4×10^{-3} Wb. The self-inductance of the solenoid is:

- (a) 1 H (b) 2 H
 (c) 3 H (d) 4 H

60. Mutual inductance of two coils can be increased by:

- (a) winding the coils on wooden cores
 (b) decreasing the number of turns in the coils
 (c) increasing the number of turns in the coils
 (d) none of these

61. The coefficient of self-inductance of a solenoid is 0.18 mH. If a core of soft iron of relative permeability 900 is inserted, then the coefficient of self-inductance will become nearly:

- (a) 0.0002 mH (b) 0.006 mH
 (c) 5.4 mH (d) 162 mH

62. The mutual inductance between two coils depends upon _____.

- (a) medium between the coils
 (b) separation between coils
 (c) neither A nor B
 (d) both A and B

63. A gramophone disc of brass of diameter 30 cm rotates horizontally at the rate of 100/3 revolutions per minute. If the vertical component of the earth's magnetic field be 0.01 Wb/m², then the emf induced between the centre and the rim of the disc will be:

- (a) 3.9×10^{-4} V (b) 2.32×10^{-4} V
 (c) 7.065×10^{-4} V (d) None of the above

64. If the magnetic flux linked with a coil through which a current is x A is set up is y Wb, then the coefficient of self-inductance of the coil is:

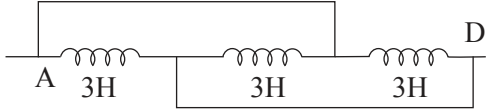
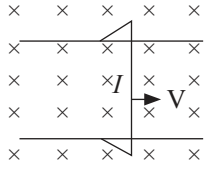
- (a) $\frac{x}{y}$ H (b) xy H
 (c) $(x - y)$ H (d) $\frac{y}{x}$ H

65. The mutual inductance between two coils is 1.25 H. If the current in the primary changes at the rate of 80 A/s, then the induced emf in the secondary is:

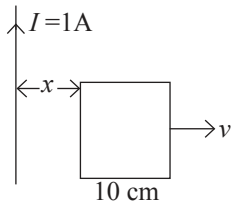
- (a) 0.016 V (b) 12.5 V
 (c) 64.0 V (d) 100.0 V

66. A copper disc of radius 0.1 m rotates about its centre with 10 revolutions per second in a uniform magnetic field of 0.1 T. The emf induced across the radius of the disc is:

- (a) 10π mV (b) 20π mV
 (c) $2\pi/10$ V (d) $\pi/10$ V

67. Self-inductance _____ when the number of turns of a coil is doubled.
- is halved
 - is doubled
 - becomes four times
 - becomes one quarter
68. Self induction of a solenoid is:
- inversely proportional to area of cross section
 - directly proportional to area of cross section
 - directly proportional to its length
 - directly proportional to current flowing through the coil
69. Two solenoids of same cross sectional area have their lengths and number of turns in ratio of 1:2 both. The ratio of self-inductance of two solenoids is:
- 1:2
 - 2:1
 - 1:4
 - 1:1
70. A 50 Hz AC current of crest value 1 A flows through the primary of a transformer. If the mutual inductance between the primary and secondary be 0.5 H, the crest voltage induced in the secondary is:
- 100 V
 - 150 V
 - 200 V
 - None of the above
71. A coil of wire of a certain radius has 600 turns and a self-inductance of 108 mH. The self-inductance of a second similar coil of 500 turns will be:
- 77 mH
 - 76 mH
 - 75 mH
 - 74 mH
72. The inductance of a closed-packed coil of 400 turns is 8 mH. A current of 5 mA is passed through it. The magnetic flux through each turn of the coil is:
- $0.4\epsilon_0$ Wb
 - $\frac{1}{2\pi}\mu_0$ Wb
 - $\frac{1}{3\pi}\mu_0$ Wb
 - $\frac{1}{4\pi}\mu_0$ Wb
73. For perfect coupling of two coils of inductance L_1 and L_2 their mutual inductance M should be given by:
- $M = \sqrt{L_1 L_2}$
 - $M = \frac{L_1}{L_2}$
 - $M = \left(\frac{L_1}{L_2}\right)^{1/2}$
 - $M = L_1 L_2$
74. The equivalent inductance of two inductors is 2.4 H when connected in parallel and 10 H when connected in series. The difference between the two inductances is:
- 4 H
 - 3 H
 - 2 H
 - 5 H
75. Two coaxial solenoids are made by winding thin insulated wire over a pipe of cross-sectional area $A = 10 \text{ cm}^2$ and length = 20 cm. If one of the solenoid has 300 turns and the other 400 turns, their mutual inductance is:
- [Hint: $\mu_0 = 4\pi \times 10^{-7} \text{ TmA}^{-1}$]
- $2.4\pi \times 10^{-4} \text{ H}$
 - $4.8\pi \times 10^{-4} \text{ H}$
 - $2.4\pi \times 10^{-5} \text{ H}$
 - $4.8\pi \times 10^{-5} \text{ H}$
76. In an inductor of inductance $L = 100 \text{ mH}$, a current of $I = 10 \text{ A}$ is flowing. The energy stored in the inductor is:
- 1000 J
 - 100 J
 - 10 J
 - 5 J
77. The total inductance between A and D in the given figure is:
- 
- 0.66 H
 - 0.99 H
 - 1 H
 - 9 H
78. The figure shows a wire sliding on two parallel conducting rails placed at a separation l . A magnetic field B exists in a direction perpendicular to the plane of the rails. The force required to keep the wire moving at a constant velocity v will be:
- 
- Zero
 - Blv
 - $\frac{\mu_0 Bv}{4\pi I}$
 - evB
79. What will be the self-inductance of a coil of 100 turns if a current of 5 A produces a magnetic flux of $5 \times 10^{-5} \text{ Wb}$?
- 1 μH
 - 10 μH
 - 1 mH
 - 10 mH
80. If the current 30 A flowing in the primary coil is made zero in 0.1 s. The emf induced in the secondary coil is 1.5 V. The mutual inductance between the coil is:
- 0.1 H
 - 0.2 H
 - 0.05 H
 - 1.05 H
81. The physical quantity which is measured in the unit of WbA^{-1} is:
- magnetic flux
 - self-inductance
 - mutual inductance
 - both (b) and (c)

82. 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^{-1} (see figure). The emf induced at the time the left arm of the frame is at $x = 10 \text{ cm}$ from the wire is:



- (a) $0.5 \mu\text{V}$ (b) $0.75 \mu\text{V}$
 (c) $1 \mu\text{V}$ (d) $2 \mu\text{V}$
83. The self-inductance of two coils of a transformer is 20 mH and 30 mH. What is the resistance between them?
 (a) Infinite (b) Zero
 (c) 1.5Ω (d) 600Ω
84. The coefficient of mutual inductance of two coils is 6 mH. If the current flowing in one is 2 A, then the induced emf in the second coil will be:
 (a) Zero (b) 2 mV
 (c) 3 mV (d) 3 V
85. An emf of 12 V is induced in a given coil when the current in it changes at the rate of 48 A/min. The inductance of the coil is:
 (a) 9.6 H (b) 15 H
 (c) 0.25 H (d) 1.5 H
86. The mutual inductance of a pair of coils is 0.75 H. If current in the primary coil changes from 0.5 A to zero in 0.01 s, find average induced emf in secondary coil:
 (a) 22.5 V (b) 12.5 V
 (c) 25.5 V (d) 37.5 V
87. An air cored solenoid is of length 0.3 m, area of cross section $1.2 \times 10^{-3} \text{ m}^2$ and has 2500 turns. Around its central section, a coil of 350 turns is wound. The solenoid and the coil are electrically insulated from each other. Calculate the emf induced in the coil if the initial current of 3 A in the solenoid is reversed in 0.25 s.
 (a) 0.1056 V (b) $0.1056 \times 10^{-3} \text{ V}$
 (c) 2.1056 V (d) $2.1056 \times 10^{-3} \text{ V}$
88. The induced emf in a coil is proportional to:
 (a) product of magnetic flux and area of the coil
 (b) magnetic flux through the coil
 (c) area of the coil
 (d) rate of change of magnetic flux through the coil
89. A 100 mH coil carries a current of 1 A. Energy stored in its magnetic field is:
 (a) 0.5 J (b) 0.05 J
 (c) 0.1 J (d) 1 J
90. A circular coil X of radius 0.02 m and turns 100 is placed co-axially at the centre of another circular coil Y of radius 0.2 m and turns 1000. The mutual inductance of the coils when current in Y changes from 7 A to 5 A in $4 \times 10^{-2} \text{ s}$ and the emf induced in X are respectively.
 (a) $69.44 \times 10^{-5} \text{ H}$; 17.70 mV
 (b) $69.44 \times 10^{-3} \text{ H}$; 17.70 V
 (c) $39.44 \times 10^{-5} \text{ H}$; 19.72 mV
 (d) $39.44 \times 10^{-3} \text{ H}$; 19.72 V
91. In an inductor, having a self-inductance of 10 H, the current changes from 10 A to 5 A in 0.2 s. The induced emf in a inductor is:
 (a) 2.5 V (b) 10 V
 (c) 25 V (d) 250 V
92. Two coils have a mutual inductance 0.005 H. The current changes in first coil according to equation $I = I_0 \sin \omega t$ where $I_0 = 10 \text{ A}$ and $\omega = 100\pi \text{ radian/sec}$. The max value of emf in s coil is:
 (a) π (b) 5 π
 (c) 4π (d) 2π
93. Two inductors each of inductance L are joined in parallel. What is their equivalent inductance?
 (a) $L/2$ (b) L
 (c) 2L (d) Zero
94. Energy stored in a coil of self-inductance 40 mH carrying a steady current of 2 A is:
 (a) 8 J (b) 0.08 J
 (c) 0.8 J (d) 80 J
95. The equivalent inductance between A and B is:

 (a) 0.8 H (b) 1 H
 (c) 4 H (d) 16 H
96. The mutual inductance of an induction coil is 5 H. In the primary coil, the current reduces from 5 A to zero in 10^{-3} s . What is the induced emf in the secondary coil?
 (a) Zero (b) 2500 V
 (c) 2510 V (d) 25000 V
97. An air core solenoid has 1000 turns and is one meter long. Its cross-sectional area is 10 cm^2 . Its self-inductance is:
 (a) 0.1256 mH (b) 1.256 mH
 (c) 12.56 mH (d) 125.6 mH

AC Generator

98. The working of dynamo is based on principle of _____.
- electromagnetic induction
 - heating effect of current
 - magnetic effect of current
 - chemical effect of current
99. The output of a dynamo using a splitting commutator is:
- D.C.
 - fluctuating D.C.

- half-wave rectified voltage
- A.C.

100. A generator of 220 V having internal resistance $r = 10 \Omega$ and external resistance $R = 100 \Omega$. What is the power developed in the external circuit?
- 369 W
 - 400 W
 - 441 W
 - 484 W
101. A generator has an emf of 440 V and internal resistance of 400Ω . Its terminals are connected to a load of 4000Ω . The voltage across the load is:
- 200 V
 - 220 V
 - 400 V
 - 440 V

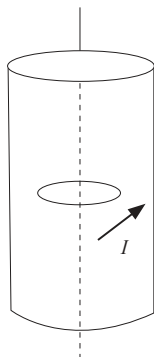
HIGH-ORDER THINKING SKILL

Electromagnetic Induction and Eddy Current

1. Two different coils have self-inductance $L_1 = 8 \text{ mH}$, $L_2 = 2 \text{ mH}$. The current in one coil is increased at a constant rate. The current in the second coil is also increased at the same rate. At a certain instant of time, the power given to the two coils is the same. At that time the current, the induced voltage and the energy stored in the first coil are I_1 , V_1 and W_1 respectively. Corresponding values for the second coil at the same instant are I_2 , V_2 and W_2 respectively. Then:
- $\frac{V_2}{V_1} = \frac{1}{4}$
 - $\frac{W_2}{W_1} = 4$
 - $\frac{I_1}{I_2} = \frac{1}{4}$
 - $\frac{I_1}{I_2} = 48$

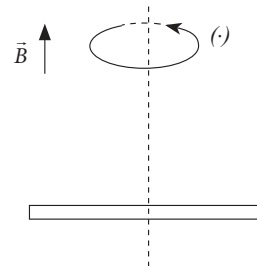
[Hint: Use Faraday's law.]

2. A long circular tube of length 10 m and radius 0.3 m carries a current I along its curved surface as shown. A wire-loop of resistance 0.005Ω and of radius 0.1 m is placed inside the tube with its axis coinciding with the axis of the tube.

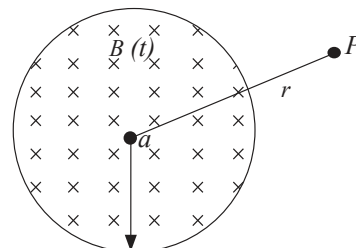


The current varies as $I = I_0 \cos(300t)$ where I_0 is constant. If the magnetic moment of the loop is $N\mu_0 I_0 \sin(300t)$, then N is:

- 6
 - 3
 - 4
 - 5
3. A conducting rod of length $2l$ is rotating with constant angular speed ω about its perpendicular bisector. A uniform magnetic field \vec{B} exists parallel to the axis of rotation. The emf induced between two ends of the rod is:



- Zero
 - $B\omega l^2$
 - $\frac{1}{2}B\omega l^2$
 - $\frac{1}{8}B\omega l^2$
4. A uniform but time-varying magnetic field $B(t)$ exists in a circular region of radius a and is directed into the plane of the paper, as shown. The magnitude of the induced electric field at point P at a distance r from the centre of the circular region:



(a) Decreases as $\frac{1}{r^2}$ (b) Increases as r

(c) Decreases as $\frac{1}{r}$ (d) Is zero

[Hint: Construct a concentric circle of radius r .]

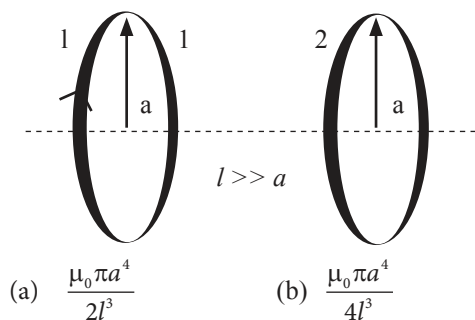
Inductance

5. A small square loop of wire of side l is placed inside a large square loop of wire of side L ($L > l$). The loop are coplanar and their centre coincide. The mutual inductance of the system is proportional to:

(a) $\frac{L^2}{l}$ (b) $\frac{L}{l}$

(c) $\frac{l^2}{L}$ (d) $\frac{l}{L}$

6. What is the mutual inductance of a two-loop system as shown with centre separation l ?



(c) $\frac{\mu_0 \pi a^4}{6l^3}$ (d) $\frac{\mu_0 \pi a^4}{8l^3}$

[Hint: Magnetic field of the coil.]

7. How much length of a very thin wire is required to obtain a solenoid of length l_0 and inductance L ?

(a) $\sqrt{\frac{4\pi Ll_0}{\mu_0^2}}$ (b) $\sqrt{\frac{8\pi Ll_0}{\mu_0}}$

(c) $\sqrt{\frac{2\pi Ll_0}{\mu_0}}$ (d) $\sqrt{\frac{4\pi Ll_0}{\mu_0}}$

8. Find the inductance of a unit length of two long parallel wires, each of radius a , whose centers are a distance d apart and carry equal currents in opposite directions. Neglect the flux within the wire.

(a) $\frac{\mu_0}{\pi} \ln\left(\frac{d-a}{a}\right)$ (b) $\frac{\mu_0}{3\pi} \ln\left(\frac{d-a}{a}\right)$

(c) $\frac{\mu_0}{2\pi} \ln\left(\frac{d-a}{a}\right)$ (d) $\frac{3\mu_0}{\pi} \ln\left(\frac{d-a}{a}\right)$

AC Generator

9. The armature coil of an AC generator has 1000 turns, each of area 2 m^2 . It was rotating in a uniform magnetic field of $B = 0.2 \text{ T}$ at an angular speed of 60 rad/s . It was found that in a certain position of the coil, the current in the circuit became zero. What was the flux in the coil?

(a) 200 Wb (b) 400 Wb

(c) 150 Wb (d) 300 Wb

NCERT EXEMPLAR PROBLEMS

Electromagnetic Induction and Eddy Current

1. A square of side $L \text{ m}$ lies in the x - y plane in a region, where the magnetic field is given by, $\vec{B} = B_0(2\hat{i} + 3\hat{j} + 4\hat{k}) \text{ T}$, where B_0 is constant. The magnitude of flux passing through the square is:

(a) $2B_0L^2 \text{ Wb}$ (b) $3B_0L^2 \text{ Wb}$

(c) $4B_0L^2 \text{ Wb}$ (d) $\sqrt{29}B_0L^2 \text{ Wb}$

2. A loop, made of straight edges has six corners at $A(0,0,0)$, $B(L,0,0)$, $C(L,L,0)$, $D(0,L,0)$, $E(0,L,L)$, and $F(0,0,L)$. A magnetic field $B = B_0(\hat{i} + \hat{k}) \text{ T}$ is present

in the region. The flux passing through the loop ABCDEFA (in that order) is:

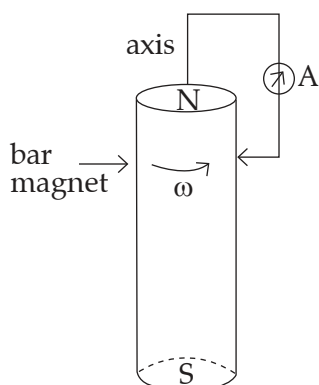
(a) $B_0L^2 \text{ Wb}$

(b) $2B_0L^2 \text{ Wb}$

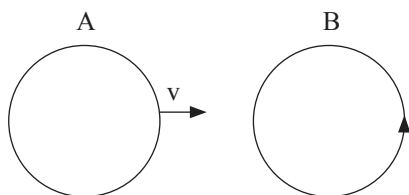
(c) $\sqrt{2}B_0L^2 \text{ Wb}$

(d) $4B_0L^2 \text{ Wb}$

3. A cylindrical bar magnet is rotated about its axis as shown in the figure. A wire is connected from the axis and is made to touch the cylindrical surface through a contact. Then:



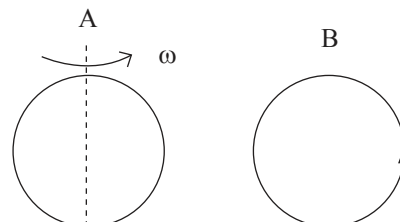
- (a) a direct current flows in the ammeter A.
 (b) no current flows through the ammeter A.
 (c) an alternating sinusoidal current flows through the ammeter A with a time period $T = 2\pi / \omega$.
 (d) a time varying non-sinusoidal current flows through the ammeter A.
4. There are two coils A and B as shown in the figure. A current starts flowing in B as shown, when A is moved towards B and stops when A stops moving. The current in A is counter clockwise. B is kept stationary when A moves. We can infer that:



- (a) there is a constant current in the clockwise direction in A

- (b) there is a varying current in A
 (c) there is no current in A
 (d) there is a constant current in the counter clockwise direction in A

5. Same as problem 4 except the coil A is made to rotate about a vertical axis as shown in the figure. No current flows in B if A is at rest. The current in coil A, when the current in B (at $t = 0$) is counter clockwise and the coil A is as shown at this instant, $t = 0$, is:



- (a) constant current clockwise
 (b) varying current clockwise
 (c) varying current counter clockwise
 (d) constant current counter clockwise

Inductance

6. The self-inductance L of a solenoid of length l and area of cross section A , with a fixed number of turns N increases as:
- (a) l and A increase.
 (b) l decreases and A increases.
 (c) l increases and A decreases.
 (d) both l and A decrease.

ASSERTION AND REASONS

Directions: In the following questions, a statement of assertion is followed by a statement of reason. Mark the correct choice as:

- (a) If both assertion and reason are true and reason is the correct explanation of assertion.
 (b) If both assertion and reason are true but reason is not the correct explanation of assertion.
 (c) If assertion is true but reason is false.
 (d) If both assertion and reason are false.

Electromagnetic Induction and Eddy Current

1. **Assertion:** Faraday's laws are consequence of conservation of energy.

Reason: In a purely resistive AC circuit, the current lags behind the emf in phase.

2. **Assertion:** Lenz's law violates the principle of conservation of energy.

Reason: Induced emf always opposes the change in magnetic flux responsible for its production.

3. **Assertion:** Two identical loops, one of copper and another of aluminium are rotated with the same speed in the same magnetic field. The emf induced in both the loop will be same.

Reason: The magnitude of induced emf is directly proportional to the rate of change of magnetic flux linked with the circuit.

4. Assertion: An aircraft flies along the meridian, the potential at the ends of its wings will be the same.

Reason: Whenever there is change in the magnetic flux emf induces.

5. Assertion: An induced current will be developed in a conductor, if it is moved in a direction parallel to magnetic field.

Reason: Whenever there is relative motion between loop and magnet an induced current is produced in the loop.

6. Assertion: Eddy currents are produced in any metallic conductor when magnetic flux is changed around it.

Reason: Electric potential determines the flow of charge.

7. Assertion: An artificial satellite with a metal surface is moving above the earth in a circular orbit. A current will be induced in satellite if the plane of the orbit is inclined to the plane of the equator.

Reason: The current will be induced only when the speed of satellite is more than 8 km/sec.

8. Assertion: An induced emf is generated when magnet is withdrawn from the solenoid.

Reason: The relative motion between magnet and solenoid induces emf.

9. Assertion: Only a change in magnetic flux will maintain an induced current the coil.

Reason: The presence of large magnetic flux through a coil maintains a current in the coil if the circuit is continuous.

Inductance

10. Assertion: Mutual inductance of a pair of coils depends on their separation as well as their relative orientation.

Reason: Mutual inductance depend upon the length of the coil only.

11. Assertion: In the phenomenon of mutual induction, self induction of each of the coil persists.

Reason: Self induction arises due to change in current in the coil itself. In mutual induction current changes in both the individual coil.

12. Assertion: The self-inductance of a long solenoid is proportional to the area of cross-section and length of the solenoid.

Reason: Self-inductance of a solenoid is independent of the number of turns per unit length.

13. Assertion: When two coils are wound on each other, the mutual induction between the coils is maximum.

Reason: Mutual induction does not depend on the orientation of the coils.

14. Assertion: Inductance coil are made of copper.

Reason: Induced current is more in wire having less resistance.

AC Generator

15. Assertion: An ac generator is based on the phenomenon of electromagnetic induction.

Reason: In single coil, we consider self-induction only.

ANSWER KEY

Practice Time

- | | | | | | | | | | |
|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 1 (c) | 2 (a) | 3 (d) | 4 (d) | 5 (b) | 6 (c) | 7 (a) | 8 (b) | 9 (a) | 10 (c) |
| 11 (b) | 12 (d) | 13 (b) | 14 (b) | 15 (d) | 16 (a) | 17 (c) | 18 (c) | 19 (a) | 20 (a) |
| 21 (a) | 22 (d) | 23 (b) | 24 (c) | 25 (c) | 26 (b) | 27 (c) | 28 (b) | 29 (a) | 30 (d) |
| 31 (b) | 32 (d) | 33 (a) | 34 (c) | 35 (b) | 36 (d) | 37 (d) | 38 (a) | 39 (b) | 40 (d) |
| 41 (a) | 42 (d) | 43 (b) | 44 (d) | 45 (a) | 46 (b) | 47 (a) | 48 (c) | 49 (d) | 50 (d) |
| 51 (b) | 52 (a) | 53 (b) | 54 (a) | 55 (b) | 56 (b) | 57 (c) | 58 (b) | 59 (a) | 60 (c) |
| 61 (d) | 62 (d) | 63 (a) | 64 (d) | 65 (d) | 66 (a) | 67 (c) | 68 (b) | 69 (a) | 70 (a) |
| 71 (c) | 72 (d) | 73 (a) | 74 (c) | 75 (a) | 76 (d) | 77 (c) | 78 (a) | 79 (c) | 80 (c) |
| 81 (d) | 82 (c) | 83 (a) | 84 (a) | 85 (b) | 86 (d) | 87 (a) | 88 (d) | 89 (b) | 90 (c) |

- 91 (d) 92 (b) 93 (a) 94 (b) 95 (a) 96 (d) 97 (b) 98 (a) 99 (b) 100 (b)
101 (c)

High-Order Thinking Skill

- 1 (b) 2 (a) 3 (a) 4 (c) 5 (c) 6 (a) 7 (d) 8 (a) 9 (b)

NCERT Exemplar Problems

- 1 (c) 2 (b) 3 (b) 4 (d) 5 (a) 6 (b)

Assertion and Reason

- 1 (b) 2 (a) 3 (a) 4 (c) 5 (d) 6 (b) 7 (c) 8 (a) 9 (c) 10 (c)
11 (c) 12 (c) 13 (a) 14 (b) 15 (b)

HINTS AND EXPLANATIONS

Practice Time

- 1 (c) Faraday's law of induction is a basic law of electromagnetism predicting how a magnetic field will interact with an electric circuit to produce an electromotive force.
- 2 (a) Electric current also produces magnetic effect.
- 3 (d) When the conductor is moved in a stationary magnetic field to procure a change in the flux linkage, the emf is statically induced.
- 4 (d) The magnetic flux through some surface is proportional to the number of field lines passing through that surface.
- 5 (b) Faraday's laws involve conversion of mechanical energy into electric energy. This is in accordance with the law of conservation of energy.
- 6 (c) The galvanometer shows deflection in the opposite direction indicating the direction of induced current in the reversed direction.
- 7 (a) Lenz's law states that an induced electric current flows in a direction such that the current opposes the change that induced it.
- 8 (b) Hydroelectric plant uses mechanical energy of water to move a magnetic field past coils of wire to generate voltage.
- 9 (a) Since,

$$\phi = N\vec{B} \cdot \vec{A} \text{ and } B \propto N^*$$

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

where $\phi = NBA$

- Thus, ε is independent of resistance of the coil.
- 11 (b) The direction of current in the solenoid is clockwise. On displacing it towards the loop a current in the loop will be induced in opposite sense so as to oppose its approach. Therefore the direction of induced current as observed by the observer will be anticlockwise.
- 12 (d) At the poles, the magnitude of vertical component of the earth's magnetic field, is maximum.
- 13 (b) Emf is induced when there is change in magnetic flux in the coil.
- 14 (b) Magnetic flux linked with a coil

$$\phi = NBA \cos \theta$$

Since the magnetic field B is parallel to the area A ,
i.e., $\theta = 90^\circ$
 $\therefore \phi = 0$
- 15 (d) The magnetic flux (often denoted ϕ or ϕ_B) through a surface is the surface integral of the normal component of the magnetic field B passing through that surface.

- 16 (a) Since,

$$\begin{aligned}\frac{\Delta\phi}{\Delta t} &= \varepsilon \\ &= IR \\ \Rightarrow \Delta\phi &= (I\Delta t)R \\ &= QR \\ \Rightarrow Q &= \frac{\Delta\phi}{R}\end{aligned}$$

17 (c) As we know that,
Change in flux = $2BAN$

$$\therefore \text{Induced emf} = \frac{2 \times 0.3 \times 200 \times 70 \times 10^{-4}}{0.1} \text{ V} = 8.4 \text{ V}$$

18 (c) The negative sign gives the direction of the induced emf.

19 (a) The charge through the coil = area of current-time (i - t) graph

$$\begin{aligned}q &= \frac{1}{2} \times 0.1 \times 4 \\ &= 0.2 \text{ C} \quad \dots(i)\end{aligned}$$

$$\therefore q = \frac{\Delta\phi}{R} \quad (\because \text{Change in flux, } \Delta\phi = q \times R)$$

$$\Rightarrow 0.2 = \frac{\Delta\phi}{10} \quad \dots(\text{By using (i)})$$

$$\therefore \Delta\phi = 2 \text{ Wb}$$

20 (a) Induced emf $e = -N \frac{d\phi}{dt}$, where N is the number of turns of the coil.

21 (a) Here, area of coil.

$$\begin{aligned}A &= 0.1 \text{ m} \times 0.05 \text{ m} \\ &= 5 \times 10^{-3} \text{ m}^2\end{aligned}$$

$$N = 100$$

Initial flux linked with the coil,

$$\begin{aligned}\phi_1 &= BA \cos \theta \\ &= 0.1 \times 5 \times 10^{-3} \cos 0^\circ \\ &= 5 \times 10^{-4} \text{ Wb}\end{aligned}$$

Final flux linked with the coil,

$$\begin{aligned}\phi_2 &= 0.05 \times 5 \times 10^{-3} \cos 0^\circ \\ &= 25 \times 10^{-5} \text{ Wb} \\ &= 2.5 \times 10^{-4} \text{ Wb}\end{aligned}$$

The magnitude of induced emf in the coil is,

$$\begin{aligned}e &= \frac{N|\Delta\phi|}{\Delta t} \\ &= \frac{N|\phi_2 - \phi_1|}{t}\end{aligned}$$

$$\begin{aligned}&= \frac{100|2.5 \times 10^{-4} - 5 \times 10^{-4}|}{0.05} \\ &= \frac{100 \times 2.5 \times 10^{-4}}{0.05} \text{ V} \\ &= 0.5 \text{ V}\end{aligned}$$

22 (d) Induced emf = rate of change of magnetic flux

$$\begin{aligned}&= \frac{0.8}{0.2} \\ &= 4 \text{ V}\end{aligned}$$

23 (b) The induced emf in the coil is,

$$\begin{aligned}e &= N \frac{d\phi}{dt} \\ &= N \frac{d(BA)}{dt} \\ &= NA \left(\frac{dB}{dt} \right) \\ e &= 200 \times (10 \times 10^{-4}) \times \frac{0.1 - 0}{0.1} \\ &= 0.2 \text{ V}\end{aligned}$$

24 (c) Magnetic flux,

$$\begin{aligned}\phi &= \vec{B} \cdot \vec{A} \\ &= (0.02\hat{i}) \cdot (30\hat{i} + 16\hat{j} + 23\hat{k}) \times 10^{-4} \\ &= 0.6 \times 10^{-4} \text{ Wb} \\ &= 60 \mu\text{Wb}\end{aligned}$$

25 (c) Magnetic flux,

$$\begin{aligned}\phi &= BA \cos \theta \\ &= 2.0 \times 0.5 \times \cos 60^\circ \\ &= \frac{2.0 \times 0.5}{2} \\ &= 0.5 \text{ Wb}\end{aligned}$$

26 (b) As we know that,

$$\begin{aligned}\phi &= BA \\ &= 10^3 \times 10^{-2} \text{ Wb} \\ &= 10 \text{ Wb}\end{aligned}$$

27 (c) Since,

$$\begin{aligned}e &= \frac{d\phi}{dt} \quad (\text{in magnitude}) \\ &= 10t + 2\end{aligned}$$

when $t = 1$ s, then $e = 12$ V

28 (b) Emf induced,

$$\begin{aligned}e &= \frac{1}{2} Br^2 \omega \\ &= \frac{1}{2} Br^2 (2\pi n)\end{aligned}$$

$$\begin{aligned}
 &= \frac{1}{2} \times 0.2 \times (0.1)^2 (2\pi \times 20) \\
 &= \frac{1}{2} \times 0.2 \times 0.01 \times 40\pi \\
 &= 4\pi \times 10^{-2} \text{ V}
 \end{aligned}$$

- 29 (a)** $P = I^2 R$ when I becomes half, then P becomes one fourth, heat per unit time depends on square of I . When I is reduced P is substantially reduced.

- 30 (d)** Given,

$$\begin{aligned}
 \text{area} &= 10 \times 20 \text{ cm}^2 \\
 &= 200 \times 10^{-4} \text{ m}^2
 \end{aligned}$$

$$B = 0.5 \text{ T}$$

$$N = 60$$

$$\omega = 2\pi \times 1800 / 60$$

$$\begin{aligned}
 \therefore e &= -\frac{d(N\phi)}{dt} \\
 &= -N \frac{d}{dt}(BA \cos \omega t) \\
 &= NBA \omega \sin \omega t
 \end{aligned}$$

$$\therefore e_{\text{max}} = NAB\omega$$

$$\begin{aligned}
 &= \frac{60 \times 2 \times 10^{-2} \times 0.5 \times 2\pi \times 1800}{60} \\
 &= 113 \text{ V}
 \end{aligned}$$

Hence, induced emf can be 111 V, 112 V and 113 V.

- 31 (b)** Emf developed between the tips of the wing is,

$$\begin{aligned}
 e &= \frac{B}{v} \\
 &= 1.75 \times 10^{-5} \times 40 \times 300 \\
 &= 0.21 \text{ V}
 \end{aligned}$$

- 32 (d)** The polarity of emf will be opposite in the two cases while the magnet enters the coil and while the magnetic leaves the coil. Only in option (d) polarity is changing.

- 33 (a)** If electron is moving from left to right, the flux linked with the loop (which is into the page) will first increase and then decrease as the electron passes by. So, the induced current in the loop will be first anticlockwise and will change direction as the electron passes by.

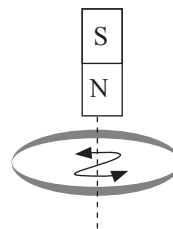
- 34 (c)** According, to Faraday's law of induction, Induced emf,

$$e = -\frac{d\phi}{dt} = -(100t)$$

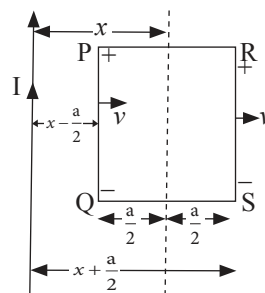
Induced current I at $t = 2$ s,

$$\begin{aligned}
 I &= \left| \frac{e}{R} \right| \\
 &= +\frac{100 \times 2}{400} = +0.5 \text{ A}
 \end{aligned}$$

- 35 (b)** As it is seen from the magnet side induced current will be anticlockwise.



- 36 (d)**



Emf induced in the frame is given by,

$$\begin{aligned}
 e_{PQRS} &= e_{PQ} + e_{RS} \\
 &= av(B_1 - B_2) \dots (\because e = Blv \sin \theta) \\
 &= av \left[\frac{\mu_0 I}{2\pi r_1} - \frac{\mu_0 I}{2\pi r_2} \right] \dots \left(\because B = \frac{\mu_0 2I}{4\pi r} \right) \\
 &= \frac{av\mu_0 I}{2\pi} \left[\frac{1}{\left(x - \frac{a}{2}\right)} - \frac{1}{\left(x + \frac{a}{2}\right)} \right] \left(\because r_1 = x - \frac{a}{2} \right. \\
 &\quad \left. r_2 = x + \frac{a}{2} \right) \\
 &= \frac{av\mu_0 I}{2\pi} \left[\frac{2}{(2x - a)} - \frac{2}{(2x + a)} \right] \\
 &= 2 \frac{a^2 v \mu_0 I}{\pi} \left[\frac{1}{(2x - a)(2x + a)} \right] \\
 \square e_{PQRS} &\square \frac{1}{(2x - a)(2x + a)}
 \end{aligned}$$

- 37 (d)** Permanent magnet is used in AC generator. Current produced by an AC generator is alternate in nature. Lenz's law gives the direction of the current produced by electromagnetic induction.

- 38 (a)** Initial magnetic flux linked with the coil is,

$$\begin{aligned}
 \phi_i &= BA \cos \theta \\
 &= 0.1 \times 200 \times 10^{-4} \times \cos 0^\circ \\
 &= 2 \times 10^{-3} \text{ Wb}
 \end{aligned}$$

Final magnetic flux linked with the coil is $\phi_f = 0$
Therefore, by Faraday's law,

$$e = -\frac{N\Delta\phi}{\Delta t} = -\frac{N(\phi_f - \phi_i)}{\Delta t}$$

$$= 100 \times 2 \times 10^{-3}$$

$$= 0.2 \text{ V}$$

$$I = \frac{e}{R} = \frac{0.2}{2} = 0.1 \text{ A}$$

$$q = I\Delta t = 0.1 \text{ C}$$

39 (b) We know that,

$$e_0 = \omega NBA$$

$$= (2\pi\nu)NB(\pi r^2)$$

$$= 2\pi^2\nu NBr^2$$

$$= 2 \times (3.14)^2 \times \frac{1800}{60} \times 4000 \times 0.5 \times 10^{-4} \times (7 \times 10^{-2})^2$$

$$= 0.58 \text{ V}$$

40 (d) To reduce eddy current, the resistance of the core should be increased.

41 (a) We know that,

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

$$\text{or } d\phi = -edt$$

$$\text{or } \phi = 4 \times 10^{-3} \times 0.1$$

$$= 4 \times 10^{-4} \text{ Wb}$$

42 (d) Induced emf produced between the centre and a point on the disc is given by,

$$e = \frac{1}{2}\omega Br^2$$

Putting the values,

$$\omega = 60 \text{ rad/s}$$

$$B = 0.05 \text{ Wb/m}^2$$

$$r = 100 \text{ cm} = 1 \text{ m}$$

We get,

$$e = \frac{1}{2} \times 60 \times 0.05 \times (1)^2 = 1.5 \text{ V}$$

43 (b) Since, we know that,

$$e = \frac{Nd\phi}{dt}$$

$$dt = \frac{Nd\phi}{e} = \frac{100 \times 3 \times 10^{-4}}{1.5}$$

$$dt = 2 \times 10^{-2} \text{ s}$$

$$= 0.02 \text{ s}$$

44 (d) When a metal plate is getting heated, it may be due to the passage of direct current, alternating current or even induced current through the plate. As time varying magnetic field produces induced current in the plate, so both (b) and (c) are correct.

45 (a) Given,

$$n = \frac{N}{l}$$

$$= \frac{2000}{0.3}$$

$$= \frac{20000}{3}$$

$$e = \frac{d}{dt}(NBA)$$

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

Since $B = \mu_0 nI$,

$$\Rightarrow e = (\mu_0 NA n) \frac{dI}{dt} = 4\pi \times 10^{-7} \times 300 N^2 \times 10^{-3} \times \frac{20000}{3} \times \frac{2}{0.25}$$

$$\Rightarrow e = 0.024 \text{ V}$$

46 (b) SI unit of electromotive force is Volt (V). SI unit of magnetic flux is Weber (Wb). SI unit of magnetic field is Tesla (T). SI unit of Inductance is Henry (H).

47 (a) Coefficient of self induction is given by,

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

$$\therefore L = -\frac{e}{\frac{dI}{dt}}$$

$$= -\frac{300 \times 10^{-6} \times 0.5}{(7-13)}$$

$$= 25 \times 10^{-6} \text{ H}$$

48 (c) Since,

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

$$1500 = -M \left(\frac{0-3}{0.01} \right)$$

$$M = \frac{1500 \times 0.01}{3}$$

$$= 5 \text{ H}$$

49 (d) We know that,

$$\phi = LI$$

$$\Rightarrow L = \frac{\phi}{I}$$

$$= \frac{10 \times 10^{-6}}{2 \times 10^{-3}}$$

$$= 5 \text{ mH}$$

50 (d) From the formula,

$$M = \frac{\mu_0 n_2 n_1 A}{l}$$

$$= \frac{4\pi \times 10^{-7} \times 500 \times 200 \times \frac{4}{10^4}}{1}$$

1

$$= 160\pi \times 10^{-7}$$

$$= 0.05 \times 10^{-3} \text{ H}$$

51 (b) Inductor is used to store magnetic field.

52 (a) Minimum inductance is obtained, when they are connected in parallel. Therefore,

$$\frac{1}{L_p} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} = \frac{1}{2} + \frac{1}{3} + \frac{1}{6}$$

$$\therefore L_p = 1 \text{ H}$$

53 (b) If we try to find field of the small coil and then calculate flux through long solenoid, the problem becomes very difficult. So, we use the following fact about mutual inductance.

$$M_{21} = M_{12}$$

$$\frac{\phi_2}{I_1} = \frac{\phi_1}{I_2}$$

Thus, if I current flows in long solenoid, then flux ϕ_1 through small coil is the same as the flux ϕ_2 that is obtained when I current flows through the small coil. Therefore,

$$\phi_2 = \phi_1$$

$$= (\text{Field at small coil}) \times (\text{area}) \times (\text{turns})$$

$$= \left(\mu_0 \frac{N_2 I}{l_2} \right) (AN_1) = \frac{\mu_0 N_1 N_2 AI}{l_2}$$

54 (a) Mutual inductance of two coils is

$$M = \frac{\mu_0 N_1 N_2 A}{l}$$

Thus, M is independent of current passing through each coil.

55 (b) We know that,

$$L_1 = \frac{\mu_0 N_1^2 \pi r^2}{2}$$

$$\text{and, } L_2 = \frac{\mu_0 N_2^2 \pi r^2}{2}$$

$$\frac{L_2}{L_1} = \left(\frac{N_2}{N_1} \right)^2$$

$$\text{or, } L_2 = L_1 \left(\frac{N_2}{N_1} \right)^2$$

$$L_2 = 108 \times \left(\frac{500}{200} \right)^2 = 108 \times 6.25$$

$$= 675 \text{ mH}$$

56 (b) Magnetic flux,

$$\Rightarrow \phi = LI$$

$$\Rightarrow NBA = LI$$

Since magnetic field at the centre of circular coil carrying current is given by,

$$B = \frac{\mu_0}{4\pi} \cdot \frac{2\pi NI}{r}$$

$$\therefore N \cdot \frac{\mu_0}{4\pi} \cdot \frac{2\pi NI}{r} \cdot \pi r^2 = LI$$

$$\Rightarrow L = \frac{\mu_0 N^2 \pi r^2}{2}$$

Hence self-inductance of a coil,

$$= \frac{4\pi \times 10^{-7} \times 500 \times 500 \times \pi \times 0.05}{2} = 25 \text{ mH}$$

57 (c) Self-inductance,

$$= \mu_0 n^2 AL = \mu_0 n^2 (l \times b) \times L$$

So, when all linear dimensions are increased by a factor of two. The new self-inductance becomes $L' = 8L$.

58 (b) The mutual inductance between two coils depends on their degree of flux linkage, i.e., the fraction of flux linked with one coil which is also linked to the other coil. Here, the two coils in arrangement (i) are placed with their planes parallel. This will allow maximum flux linkage.

59 (a) Given,

$$N = 1000$$

$$I = 4 \text{ A}$$

$$\phi = 4 \times 10^{-3} \text{ Wb}$$

Therefore, total magnetic flux linked with solenoid = $N\phi$

Self-inductance,

$$L = \frac{N\phi}{I} \quad (\because \phi = LI)$$

$$L = \frac{1000 \times 4 \times 10^{-3}}{4} = 1 \text{ H}$$

60 (c) As we know that,

$$M = \frac{\mu_0 N_1 N_2 A}{l}$$

i.e., M can be increased by increasing the number of turns in the coils.

61 (d) Self-inductance,

$$L = \mu_0 nI$$

$$\therefore \frac{L_2}{L_1} = \frac{\mu}{\mu_0} \quad (\because n \text{ and } I \text{ are same})$$

$$\therefore L_2 = \mu_r L_1$$

$$= 900 \times 0.18$$

$$= 162 \text{ mH}$$

62 (d) Mutual inductance of two coils is,

$$M = \frac{\mu_0 N_1 N_2 A}{l}$$

63 (a) Magnetic flux passing through the disc is,

$$\begin{aligned}\phi &= BA \\ &= 0.01 \frac{\text{Wb}}{\text{m}^2} \times 3.14 \times (15 \times 10^{-2} \text{ m})^2 \\ &= 7.065 \times 10^{-4} \text{ Wb}\end{aligned}$$

The line joining the centre and the circumference of the disc cuts 7.065×10^{-4} Wb flux in one round.

So, the rate of changing flux (i.e. induced emf)

$$\begin{aligned}&= \text{flux} \times \text{number of revolutions per second} \\ &= 7.065 \times 10^{-4} \times \frac{100}{60 \times 3} \\ &= 3.9 \times 10^{-4} \text{ V}\end{aligned}$$

64 (d) Since,

$$\begin{aligned}\phi &= LI \\ \text{Hence, } L &= \frac{\phi}{I} \\ &= \frac{y}{x}\end{aligned}$$

65 (d) We know that,

$$\begin{aligned}e &= M \frac{dI}{dt} \\ &= 1.25 \times 80 \\ &= 100 \text{ V}\end{aligned}$$

66 (a) The induced emf between centre and rim of the rotating disc is,

$$\begin{aligned}E &= \frac{1}{2} B \omega r^2 \\ &= \frac{1}{2} \times 0.1 \times 2\pi \times 10 \times (0.1)^2 \\ &= 10\pi \times 10^{-3} \text{ V} \\ &= 10\pi \text{ mV}\end{aligned}$$

67 (c) We know that,

$$L \propto \frac{N^2}{l}$$

68 (b) We know that,

$$L = \frac{\mu_0 N^2 A}{l}$$

69 (a) We know that,

$$\frac{l_1}{l_2} = \frac{1}{2} \text{ and, } \frac{N_1}{N_2} = \frac{1}{2}$$

From,

$$L = \frac{\mu_0 N^2 A}{l} \propto \frac{N^2}{l}$$

We get,

$$\begin{aligned}\frac{L_1}{L_2} &= \frac{\left(\frac{N_1}{N_2}\right)^2}{\left(\frac{l_1}{l_2}\right)} \\ &= \frac{\left(\frac{1}{2}\right)^2}{\frac{1}{2}} \\ &= \frac{1}{2}\end{aligned}$$

70 (a) Given,

$$di = 1 - (-1)$$

$$= 2 \text{ A}$$

$$dt = \left(\frac{1}{100}\right)$$

$$M = 0.5 \text{ H}$$

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

$$\begin{aligned}&= 0.5 \left(\frac{2}{1/100}\right) = 0.5 \times 2 \times 100 \\ &= 100 \text{ V}\end{aligned}$$

71 (c) $\therefore \alpha \propto N^2$

We know that,

$$\begin{aligned}\frac{L_B}{L_A} &= \left(\frac{N_B}{N_A}\right)^2 \\ \Rightarrow L_B &= \left(\frac{500}{600}\right)^2 \times 108 \\ &= 75 \text{ mH}\end{aligned}$$

72 (d) As we know that,

$$N\phi = LI$$

$$\therefore \phi = \frac{LI}{N}$$

$$= \frac{8 \times 10^{-3} \times 5 \times 10^{-3}}{400}$$

$$= 10^{-7}$$

$$= \frac{\mu_0}{4\pi} \text{ Wb}$$

73 (a) Since coefficient of coupling is given by,

$$K = \frac{M}{\sqrt{L_1 L_2}}$$

74 (c) According to question,

$$L_s = L_1 + L_2$$

$$= 10 \text{ H} \quad \dots(\text{i})$$

$$L_p = \frac{L_1 L_2}{L_1 + L_2}$$

$$= 2.4 \text{ H} \quad \dots(\text{ii})$$

On solving (i) and (ii),

$$L_1 L_2 = 24 \quad \dots \text{(iii)}$$

$$\text{Also, } (L_1 - L_2)^2 = (L_1 + L_2)^2 - 4L_1 L_2$$

$$\therefore (L_1 - L_2)^2 = (10)^2 - 4 \times 24 \quad \dots \text{(By using (iii))}$$

$$= 4$$

$$\therefore L_1 - L_2 = 2 \text{ H}$$

75 (a) Mutual inductance,

$$M = \frac{\mu_0 N_1 N_2 A}{\ell}$$

$$= \frac{4\pi \times 10^{-7} \times 300 \times 400 \times 10 \times 10^{-4}}{0.2}$$

$$= 2.4\pi \times 10^{-4} \text{ H}$$

76 (d) Energy stored,

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

$$= \frac{1}{2} \times 100 \times 10^{-3} \times (10)^2$$

$$= 5 \text{ J}$$

77 (c) The three inductors are connected in parallel.

Hence,

$$\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}$$

$$= \frac{1}{3} + \frac{1}{3} + \frac{1}{3}$$

$$\Rightarrow L = 1 \text{ H}$$

78 (a) No change in flux, hence no force required.

79 (c) Self-inductance,

$$L = \frac{N\phi}{I}$$

$$= \frac{100 \times 5 \times 10^{-5}}{5}$$

$$= 10^{-3} \text{ H}$$

80 (c) We know that,

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

$$\Rightarrow 1.5 = M \times \frac{30}{0.1}$$

$$\therefore M = 0.05 \text{ H}$$

81 (d) Inductance is measured in WbA^{-1} .

82 (c) In the given question.

Current flowing through the wire, $I = 1 \text{ A}$

Speed of the frame, $v = 10 \text{ ms}^{-1}$

Side of square loop, $l = 10 \text{ cm}$

Distance of square frame from current carrying wires

$x = 10 \text{ cm}$.

According to Biot-Savart's law,

$$B = \frac{\mu_0}{4\pi} \frac{Idl \sin \theta}{x^2}$$

$$= \frac{4\pi \times 10^{-7} \times 1 \times 10^{-1}}{4\pi (10^{-1})^2}$$

$$= 10^{-6}$$

Induced emf,

$$e = Blv$$

$$= 10^{-6} \times 10^{-1} \times 10$$

$$= 1 \mu\text{V}$$

83 (a) The two coils of a transformer are insulated from each other.

84 (a) In secondary, emf induces only when current through primary changes.

85 (b) Since,

$$E = L \frac{dI}{dt}$$

$$\text{Hence, } L = E \frac{dt}{dI}$$

$$= 12 \times \frac{60}{48}$$

$$= 15 \text{ H}$$

86 (d) Given,

$$M = 0.75 \text{ H}$$

$$\frac{dI}{dt} = \frac{0.5 - 0}{0.01}$$

$$= 50 \text{ A/s}$$

Therefore, average induced emf in secondary coil,

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

$$= 0.75 \times 50$$

$$= 37.5 \text{ V}$$

87 (a) Given,

$$dI = -3 - (3)$$

$$= -6 \text{ A}$$

$$dt = 0.25 \text{ s}$$

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

$$= \frac{-\mu_0 N_1 N_2 A}{l} \left(\frac{dI}{dt} \right)$$

$$= \frac{-4\pi \times 10^{-7} \times 2500 \times 350 \times 1.2 \times 10^{-3} (-6)}{0.3 \times 0.25}$$

$$\therefore e = 0.1056 \text{ V}$$

88 (d) Induced emf in the circuit is given by,

$$E = \frac{-\Delta\phi}{\Delta t}$$

89 (b) Energy stored U is given by,

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

$$= \frac{1}{2} \times (100 \times 10^{-3}) (1)^2 = 0.05 \text{ J}$$

90 (c) Magnetic field at the centre of coil,

$$B = \frac{\mu_0 N_2 I}{2r_2}$$

Magnetic flux linked with X ,

$$\phi = \left(\frac{\mu_0 N_2 I \times A_1}{2r_2} \right) \times N_1$$

As, $\phi = MI$

$$M = \frac{\mu_0 N_1 N_2 A_1}{2r_2}$$

$$= \frac{4\pi \times 10^{-7} \times 100 \times 1000 \pi (0.02)^2}{2 \times 0.2}$$

$$= 39.44 \times 10^{-5} \text{ H}$$

$$e = M \frac{dI}{dt} = 39.44 \times 10^{-5} \frac{(7-5)}{4 \times 10^{-2}} \text{ V}$$

$$\therefore e = 19.72 \times 10^{-3} \text{ V}$$

$$= 19.72 \text{ mV}$$

91 (d) Here,

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

$$dI = 10 - 5 = 5 \text{ A}$$

$$dt = 0.2 \text{ s}$$

$$\therefore e = \frac{LdI}{dt}$$

$$= \frac{10 \times 5}{0.2}$$

$$= 250 \text{ V}$$

92 (b) We know that,

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

$$= 0.005 \times I_0 \cos \omega t \times \omega$$

$$e_{\max} = 0.005 \times I_0 \times \omega = 0.005 \times 10 \times 100\pi$$

$$= 5\pi$$

93 (a) When the inductors are connected in parallel, then the equivalent inductance is given by,

$$\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2} + \dots$$

Here, $L_1 = L$

$$L_2 = L$$

$$\therefore \frac{1}{L} = \frac{1}{L} + \frac{1}{L}$$

$$= \frac{2}{L}$$

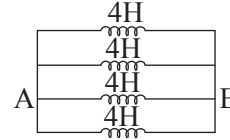
$$\Rightarrow L = \frac{L}{2}$$

94 (b) Energy stored in a self-inductance coil is given by,

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

$$= \frac{1}{2} \times 40 \times 10^{-3} \times 4 = 0.08 \text{ J}$$

95 (a) The equivalent circuit diagram is as shown in the figure.



Here, all the inductors are connected in parallel.

Hence, the equivalent inductance between A and B is,

$$\frac{1}{L_{AB}} = \frac{1}{4} + \frac{1}{4} + \frac{1}{4} + \frac{1}{4} = \frac{4}{4} = 1$$

or $L_{AB} = 1 \text{ H}$

96 (d) Since,

$$e = -M \frac{dI}{dt} = -5 \times \frac{(-5)}{10^{-3}} = 25000 \text{ V}$$

97 (b) Self-inductance of solenoid coil having N number of turns, length l and area of cross-section A is given by,

$$L = \mu_0 \frac{N^2}{l} A$$

Here, $N = 1000$,

$$A = 10 \text{ cm}^2$$

$$\text{or, } A = 10 \times 10^{-4} \text{ m}^2$$

and, $l = 1 \text{ m}$

Substituting these values in the above equation, we get,

$$L = 4\pi \times 10^{-7} \times \frac{(1000)^2}{1} \times 10 \times 10^{-4}$$

$$\Rightarrow L = 1.256 \text{ mH}$$

98 (a) Rotation of magnet in the dynamo creates the variable flux which in turn produces the induced current.

99 (b) Commutator converts AC into fluctuating DC.

100 (b) According to question,

$$V = 200 \text{ V}$$

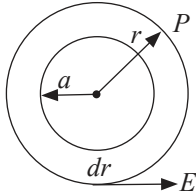
$$r = 10 \Omega$$

$$R' = 10 + 100 \Omega$$

$$R' = 110 \Omega \quad \dots(i)$$

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

- 4 (c) Construct a concentric circle of radius r . The induced electric field (E) at any point on the circle is equal to that at P. For this circle,



$$\oint \vec{E} \cdot d\vec{l} = \left| \frac{d\phi}{dt} \right|$$

$$= A \left| \frac{dB}{dt} \right|$$

$$\text{or, } E \times (2\pi r) = \pi a^2 \cdot \left| \frac{dB}{dt} \right|$$

$$\Rightarrow E = \frac{a^2}{2r} \left| \frac{dB}{dt} \right|$$

$$\Rightarrow E \propto \frac{1}{r}$$

- 5 (c) Magnetic field produced due to large loop,

$$B = \frac{\mu_0}{4\pi} \frac{8\sqrt{2}I}{L}$$

Flux linked with smaller loop,

$$\phi = B(l^2)$$

$$= \frac{\mu_0}{4\pi} \frac{8\pi I l^2}{L}$$

$$\therefore \phi = MI$$

$$\Rightarrow M = \frac{\phi}{I}$$

$$= \frac{\mu_0}{4\pi} \cdot \frac{8\sqrt{2}l^2}{L}$$

$$\Rightarrow M \propto \frac{l^2}{L}$$

- 6 (a) Magnetic field at the location of coil (2) produced due to coil (1),

$$B_1 = \frac{\mu_0}{4\pi} \cdot \frac{2m}{l^3}$$

where, m = magnetic dipole moment flux linked with coil (2),

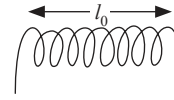
$$\phi_2 = B_1 A_2$$

$$= \frac{\mu_0}{4\pi} \frac{2I(\pi a^2)}{l^3} \times (\pi a^2) \dots (\because m = NIA)$$

$$\text{Also, } \phi_2 = MI$$

$$\Rightarrow M = \frac{\mu_0 \pi a^4}{2l^3}$$

- 7 (d) Suppose the solenoid has N turns, each of radius r and length of wire is l .



It's self-inductance,

$$L = \frac{\mu_0 N^2 A}{l_0}$$

$$= \frac{\mu_0 N^2 \pi r^2}{l_0}$$

Also, length of the wire,

$$l = N \times 2\pi r$$

$$\Rightarrow N^2 r^2 = \frac{l^2}{4\pi^2}$$

From above equations,

$$l = \sqrt{\frac{4\pi L l_0}{\mu_0}}$$

- 8 (a) According to question the wires are parallel, so these two wires can be considered as a closed rectangle of infinite length and breadth equal to d . Flux through the strip of area ldr , due to current flowing in one wire is given by,

$$\phi = \int_a^{d-a} \frac{\mu_0 I}{2\pi r} (ldr)$$

$$= \frac{\mu_0 I l}{2\pi} \ln\left(\frac{d-a}{a}\right)$$

The other wire produces the same result, so the total flux through the dotted rectangle is,

$$\phi_{\text{total}} = \frac{\mu_0 I l}{\pi} \ln\left(\frac{d-a}{a}\right)$$

The total inductance of length l ,

$$L = \frac{\phi_{\text{total}}}{I}$$

$$= \frac{\mu_0 l}{\pi} \ln\left(\frac{d-a}{a}\right)$$

Inductance per unit length = $\frac{L}{l}$

$$= \frac{\mu_0}{\pi} \ln\left(\frac{d-a}{a}\right)$$

- 9 (b) For the A.C. generators, Flux,

$$\phi = NAB \cos \omega t$$

$$\text{and, } I = I_0 \sin \omega t$$

When, $I = 0$

$$\sin \omega t = 0$$

$$\text{or, } \omega t = 0$$

$$\begin{aligned} \text{Then,} \\ \phi &= NAB \cos 0^\circ \\ &= NAB \end{aligned}$$

$$\begin{aligned} &= 1000 \times 2 \times 0.2 \\ &= 400 \text{ Wb} \end{aligned}$$

NCERT Exemplar Problems

1 (c) Given,

$$\vec{B} = B_0(2\hat{i} + 3\hat{j} + 4\hat{k})T$$

Area of square,

$$A = L^2 \hat{k} \text{ m}^2$$

$$\therefore \phi = \vec{B} \cdot \vec{A}$$

$$= B_0(2\hat{i} + 3\hat{j} + 4\hat{k}) \cdot L^2 \hat{k} = 4B_0L^2 \text{ Wb}$$

2 (b) In this problem first we have to analyse area vector, loop ABCDA lies in x-y plane whose area vector $\vec{A}_1 = L^2 \hat{k}$ whereas loop ADEFA lies in y-z plane whose area vector $\vec{A}_2 = L^2 \hat{i}$.

And the magnetic flux is,

$$\phi_m = \vec{B} \cdot \vec{A}$$

$$\vec{A} = \vec{A}_1 + \vec{A}_2 = (L^2 \hat{k} + L^2 \hat{i})$$

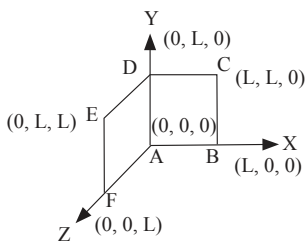
$$\text{and, } \vec{B} = B_0(\hat{i} + \hat{k})$$

Now,

$$\phi_m = \vec{B} \cdot \vec{A}$$

$$= B_0(\hat{i} + \hat{k}) \cdot (L^2 \hat{k} + L^2 \hat{i})$$

$$= 2B_0L^2 \text{ Wb}$$



3 (b) When cylindrical bar magnet is rotated about its axis, no change in flux linked with the circuit takes place, consequently no emf induces and hence, no current flows through the ammeter A. Hence the ammeter shows no deflection.

4 (d) Due to variation in the flux linked with coil B an emf will be induced in coil B. Current in coil B becomes zero when coil A stops moving, it is possible only if the current in coil A is constant. If the current in coil A would be variable, there must be some changing flux and then there must be an induced emf. Hence an induced current will be in coil B even when coil A is not moving.

5 (a) When the current in coil B (at $t = 0$) is counter clockwise and the coil A is considered above it. The counter clockwise flow of the current in coil B is equivalent to north pole of magnet and magnetic field lines are eliminating upward to coil A. When coil A starts rotating at $t = 0$, the current in A is constant along clockwise direction by Lenz's rule.

6 (b) For a solenoid of length l and area of cross section A with fixed number of turns N , the self-inductance L is given by,

$$L = \frac{\mu_0 N^2 A}{l}$$

So, L increases when l decreases and A increases.

Assertion and Reasons

- 1 (b) According to Faraday's laws, the conversion of mechanical energy into electrical energy. This is in accordance with the law of conservation of energy. It is also clearly known that in pure resistance, the emf is in phase with the current.
- 2 (a) Lenz's Law is based on conservation of energy and induced emf opposes the cause of it i.e., change in magnetic flux.
- 3 (a) Since, both the loops are identical (same area and number of turns) and moving with a same speed in same magnetic field. Therefore, same emf is

induced in both the coils. But the induced current will be more in the copper loop as its resistance will be lesser as compared to that of the aluminium loop.

4 (c) As the aircraft flies, magnetic flux changes through its wings due to the vertical component of the earth's magnetic field. Due to this, induced emf is produced across the wings of the aircraft. Therefore, the wings of the aircraft will not be at the same potential.

- 5 (d)** Induced current will not be developed in a conductor, if it is moved in direction parallel to magnetic field. It is because, in this case, the Lorentz force on free electrons in the conductor is zero. The induced emf is produced only when the magnetic flux linked with the loop changes.
- 6 (b)** When a metallic conductor is moved in a magnetic field; magnetic flux is varied. It disturbs the free electrons of the metal and set up an induced emf in it. As there are no free ends of the metal i.e. it will be closed in itself so there will be an induced current.
- 7 (c)** When the satellite moves in inclined plane with equatorial plane (including orbit around the poles), the value of magnetic field will change both in magnitude and direction. Due to this, the magnetic flux through the satellite will change and hence induced currents will be produced in the metal of the satellite. But no current will induced if satellite orbits in the equatorial plane because the magnetic flux does not change through the metal of the satellite in this plane.
- 8 (a)** Emf is induced when there is change in magnetic flux.
- 9 (c)** Presence of magnetic flux cannot produce current.
- 10 (c)** The mutual inductance in case of a medium of relative permeability present is,
- $$M = \frac{\mu_r \mu_0 n_1 n_2 \pi r_1^2}{l}$$
- 11 (c)** The self-inductance of a solenoid is given by,
- $$L = \mu_r \mu_0 n^2 A l.$$
- 12 (c)** The manner in which the two coils are oriented, determines the coefficient of coupling between them.
- $$M = K^2 \cdot L_1 L_2.$$
- When the two coils are wound on each other, the coefficient of coupling is maximum and hence mutual inductance between the coil is maximum.
- 13 (a)** The inductance coils made of copper will have very small ohmic resistance. Due to change in magnetic flux a large induced current will be produced in such an inductance, which will offer appreciable opposition to the flow of current.
- 14 (b)** Self-inductance of a coil is its property virtue of which the coil opposes any change in the current flowing through it.
- 15 (b)** According to electromagnetic induction whenever the magnetic flux changes an emf will be induced in the coil.