

CHAPTER 06



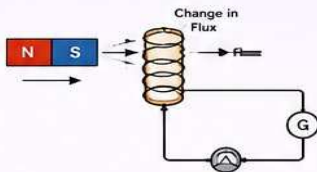
ELECTROMAGNETIC INDUCTION



1. WHAT IS ELECTROMAGNETIC INDUCTION?

It is the phenomenon of inducing an EMF in a conductor whenever the magnetic flux linked with it changes.

Key Insight
Change in magnetic flux
→ Induced EMF
(No change, No EMF)



2. FARADAY'S LAWS OF ELECTROMAGNETIC INDUCTION

1st Law

Whenever the magnetic flux linked with a conductor changes, an EMF is induced in it.

2nd Law

The magnitude of induced EMF is equal to the rate of change of magnetic flux linked with the conductor.

$$e = -N \frac{d\Phi_B}{dt}$$

N = Number of turns
 Φ_B = Magnetic flux linked with the coil
(-) sign → Lenz's Law (direction of induced EMF)

Magnetic Flux (Φ_B)

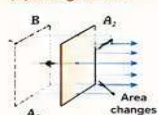
$$\Phi_B = BA \cos \theta$$

B = Magnetic field
 A = Area of coil
 θ = Angle between B and normal to the area



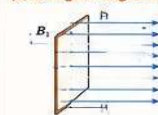
5. INDUCED EMF IN DIFFERENT CASES

(A) Change in Area



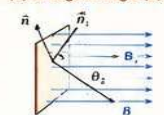
⇒ Φ_B changes
⇒ EMF induced

(B) Change in Magnetic Field



⇒ Φ_B changes
⇒ EMF induced

(C) Change in Angle (θ)

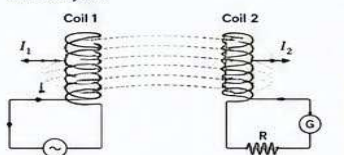


⇒ Φ_B changes
⇒ EMF induced

Quick Recall Any change in B , A , or θ → change in Φ_B → EMF induced

7. MUTUAL INDUCTION

The phenomenon of inducing an EMF in one coil due to a change in a nearby coil.



Mutually Induced EMF

$$e_2 = -M \frac{dI_1}{dt}$$

M = Mutual inductance
Unit → Henry (H)

Factors Affecting M

- Number of turns of both coils
- Area of cross-section
- Distance between coils
- Nature of medium

9. IMPORTANT APPLICATIONS

Electric Generator



Mechanical energy
→ Electrical energy
(AC Generators)

Transformer



Mutual induction
is the working
principle.

Induction Cooktop



Eddy currents
produce heat in
the utensil.

Wireless Charging



Energy transfer
through mutual
induction.

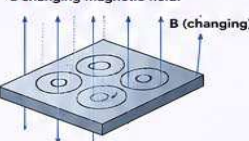
Metal Detectors



Change in flux
detected by
search coils.

10. EDDY CURRENTS

Loops of current induced in a bulk conductor when it is exposed to a changing magnetic field.



Effects

- Cause heating of the conductor
- Waste of energy

Reduction Methods

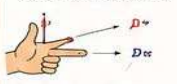
- Laminated cores
- Use of alloys (high resistance)

11. COMPARISON TABLE

Property	Self Induction	Mutual Induction
Definition	EMF induced in the same circuit due to change in current in it.	EMF induced in one circuit due to change in current in another circuit.
Symbol	L (Henry)	M (Henry)
EMF	$e_L = -L \frac{dI}{dt}$	$e_2 = -M \frac{dI_1}{dt}$
Depends on	Coil properties only	Both coils + medium + relative position

12. MEMORY TRICKS

Right Hand Rule
(Direction of Induced Current)



Thumb → Motion / Cause
Forefinger → Magnetic Field
Middle finger → Induced Current

EMF Formula
Remember →

$$e = -N \frac{d\Phi_B}{dt}$$

"e = -N d Phi by dt"
(Change in Phi → EMF)

ELI Rule

E Leads
 I in Capacitor
 I in Inductor

13. EXAM BOOSTER (CBSE)

- ★ Draw neat diagrams (Flux, Lenz's Law, Generators)
- ★ Always write reason in Lenz's Law based questions
- ★ Use Faraday's Law: $e \propto$ rate of change of flux
- ★ Focus on direction in numerical + theory
- ★ Assertion-Reason, MCQs, Case Study → High Weightage

14. COMMON MISTAKES TO AVOID

- ✗ Ignoring the negative sign in Faraday's law.
- ✗ Not identifying what causes the change in flux.
- ✗ Forgetting Lenz's Law in direction questions.
- ✗ Confusing self inductance with mutual inductance.

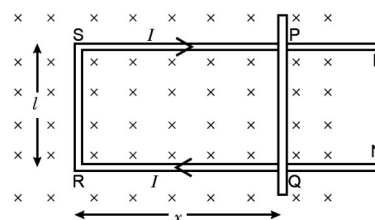
- ✓ Direction of induced current (Lenz's Law)
- ✓ Faraday's Law applications
- ✓ Self & Mutual Induction basics

PYQ TIP

Revise NCERT examples, diagrams and derivations. They are commonly asked in exams!

MULTIPLE CHOICE QUESTIONS

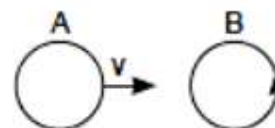
1. Figure shows a rectangular conductor PSRQ in which movable arm PQ has a resistance 'r' and resistance of PSRQ is negligible. The magnitude of emf induced when PQ is moved with a velocity v does not depend on (CBSE 2025)



- (a) magnetic field $\mathbf{B}$ (b) velocity field $\mathbf{v}$
(c) resistance r (d) length of PQ

2. There are two coils A and B as shown in 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 (CBSE 2025)

(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.

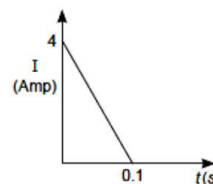
(d) there is a constant current in the counterclockwise direction in A.

3. A coil of 100 turns carries a current of 5 mA and creates a magnetic flux of 10^{-5} weber. The inductance is (CBSE 2025)

- (a) 0.2 H (b) 2.0 mH (c) 0.02 mH (d) 0.002 H

4. In a coil of resistance 10π , the induced current developed by changing magnitude of change in flux through the coil in weber is (CBSE 2025)

- (a) 8 (b) 2 (c) 6 (d) 4



5. The current in the primary coil of a pair of coils changes from 7A to 3A in 0.04 s. The mutual inductance between the two coils is 0.5 H. The induced emf in the secondary coil is (CBSE 2025)

- (a) 50 V (b) 75V (c) 100 V (d) 220 V

6. Rohan and his sister were playing with two coils of insulated copper wire. They placed the coils close to each other. Rohan noticed that whenever the current in one coil was changed rapidly, a deflection was observed in the galvanometer connected to the other coil. The mutual inductance of such a pair of coils depends upon the:

- (a) relative orientation of the two coils (b) number of turns in the coils
(c) nature of the material placed between the coils (d) All of the above

7. During a school science exhibition, a square loop of side 0.50 m was placed in a uniform magnetic field of 0.4T acting perpendicular to the plane of the loop. To demonstrate electromagnetic induction, the loop was rotated by an angle of 60° about one of its sides in 0.2 seconds. The value of the induced emf in the loop will be:

- (a) 0.1 V (b) 0.25 V (c) 0.5 V (d) 1.0 V

8. In a school physics laboratory, an electromagnet A (a long solenoid) is connected to a battery and a rheostat, as shown in the figure. An aluminium ring B is placed coaxially facing one end

of the electromagnet. The current I through the electromagnet can be increased or decreased by adjusting the rheostat. Which of the following statements is correct?

- (a) If the current I is increased, the ring B is attracted towards the electromagnet.
- (b) If the current I is decreased, the ring B is repelled away from the electromagnet.
- (c) If the current I is increased suddenly, the ring B is repelled away from the electromagnet.
- (d) The ring B will always be attracted towards the electromagnet irrespective of whether the current is increased or decreased.

9. A metallic ring is placed on top of a fixed solenoid as shown in the figure. When the current in the solenoid is suddenly switched on, the ring jumps up. This happens because:

- (a) The ring is attracted upwards due to the magnetic field of the solenoid.
- (b) A repulsive force acts on the ring due to Lenz's law.
- (c) The ring experiences an upward force due to gravity.
- (d) The current in the solenoid produces eddy currents that heat the ring.

10. A bicycle mechanic was repairing a bicycle wheel having ten metallic spokes. Each spoke is 0.50 m long. The wheel was rotated at a speed of 120 revolutions per minute in a plane perpendicular to the Earth's magnetic field. The magnitude of the Earth's magnetic field at that place was 0.4 Gauss. The induced emf between the axle and the rim of the wheel is equal to:

- (a) 1.256×10^{-3} V
- (b) 6.28×10^{-5} V
- (c) 1.256×10^{-4} V
- (d) 6.28×10^{-2} V

11. A farmer installed a small coil of area A_0 near an electromagnet in his irrigation pump system. The magnetic field linked with the coil changed uniformly from B_0 to $4B_0$ in a time interval t . The magnitude of the emf induced in the coil will be:

- (a) $\frac{3A_0B_0}{t}$
- (b) $\frac{4A_0B_0}{t}$
- (c) $\frac{3B_0}{A_0t}$
- (d) $\frac{4B_0}{A_0t}$

12. Karan dropped a small bar magnet vertically along the axis of a long hollow metallic cylinder held in the vertical position. The magnet will fall with:

- (a) $a > g$
- (b) $a < g$
- (c) $a = g$
- (d) $a = 0$

13. A student constructed two solenoids of the same length and same cross-sectional area for an electromagnet project. In the second solenoid, he doubled the number of turns per unit length while keeping all other dimensions the same. The self-inductance of the second solenoid will become:

- (a) Halved
- (b) Doubled
- (c) Four times
- (d) Eight times

14. A conducting circular loop of face area $2.5 \times 10^{-3} \text{ m}^2$ is placed perpendicular to a magnetic field which varies as $B=0.5 \sin(100\pi t)$ T. The magnitude of induced emf in the loop at $t = 0$ s: (NEET 2025)

- (a) $125\pi \text{ mV}$
- (b) $12.5\pi \text{ mV}$
- (c) $125\pi \text{ V}$
- (d) $12.5\pi \text{ V}$

15. Rohan constructed a long solenoid for his school science project. He wanted to increase its self-inductance. The self-inductance of the long solenoid cannot be increased by:

- (a) increasing its area of cross-section
- (b) increasing its length
- (c) changing the medium inside it
- (d) increasing the current through it

ANSWERS

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

TAKE THE CHALLENGE

1. The magnetic potential energy stored in a certain inductor is 25 mJ, when the current in the inductor is 60 mA. This inductor is of inductance (NEET-2018)

(a) 1.389 H
(b) 138.88 H
(c) 0.138 H
(d) 13.89 H
2. The self inductance L of a solenoid of length l and area of crosssection 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.
3. An emf can be induced in stationary coil if it is kept in

(a) Stationary uniform magnetic field
(b) Stationary non uniform magnetic field

(c) Time varying magnetic field
(d) Not possible
4. The battery of a mobile phone is rated as 4.2 V, 5800 mAh. How much energy is stored in it when fully charged?

(a) 87.7 kJ
(b) 43.8 kJ
(c) 48.7 kJ
(d) 24.4 kJ
5. 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 ($B=B_0 (i+k)$) T is present in the region. The flux passing through the loop ABCDEFA (in that order) is

(a) $B_0 L^2$
(b) $2B_0 L^2$
(c) $\sqrt{2}B_0 L^2$
(d) $4B_0 L^2$

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

ASSERTION-REASON

In the following questions 9 and 10, a statement of assertion (A) is followed by a statement of reason (R). Mark the correct choice as:

- (a) Both assertion (A) and reason (R) are true and reason (R) is the correct explanation of assertion (A).
- (b) Both assertion (A) and reason (R) are true but reason (R) is not the correct explanation of assertion (A).
- (c) Assertion (A) is true but reason (R) is false.
- (d) Assertion (A) is false but reason (R) is true.
- (e) Both Assertion (A) and Reason(R) are false.

1. **Assertion (A):** Mutual induction is the phenomenon in which the emf is induced in the coil due to change in magnetic flux.

Reason (R): It follows law of conservation of energy.

2. **Assertion (A):** Making and breaking of current in a coil produces no momentary current in the neighbouring coil of another circuit.

Reason (R): Momentary current in the neighbouring coil of another circuit is an eddy current

3. **Assertion (A):** If primary coil is connected by voltmeter and secondary coil by ac source. If large copper sheet is placed between two coils, induced emf in primary coil is reduced

Reason (R): Copper sheet between coils has no effect on induced emf in primary coil.

4. **Assertion (A):** An electric lamp is connected in series with a long solenoid of copper with air core and then connected to AC source. If an iron rod is inserted in solenoid the lamp will become dim.

Reason (R): If an iron rod is inserted in solenoid, the inductance of solenoid increases.

5. **Assertion (A):** Induced emf produced in a coil will be more when the magnetic flux linked with the coil is more.

Reason (R): Induced emf produced is directly proportional to the magnetic flux (CBSE 2026)

6. **Assertion (A):** A changing magnetic flux linked with a closed circuit induces an emf in the circuit.

Reason (R): The induced emf is directly proportional to the rate of change of magnetic flux linked with the circuit as given by Faraday's law.

7. **Assertion (A):** An induced current always opposes the cause that produces it.

Reason (R): This opposition is due to Lenz's law.

8. **Assertion (A):** When a magnet is moved towards a coil, a current is induced in the coil.

Reason (R): The magnetic flux linked with the coil changes with time.

9. **Assertion (A):** A conductor moving parallel to the direction of a uniform magnetic field experiences no induced emf.

Reason (R): The rate of change of magnetic flux is maximum when the motion of the conductor is along the magnetic field.

10. **Assertion (A):** The induced emf in a coil depends on the rate of change of current in the neighbouring coil.

Reason (R): Mutual inductance must exist between the two nearby coils.

11. **Assertion (A):** The self-inductance of a coil is a measure of its ability to resist any change in current flowing through it.

Reason (R): When the current in a coil changes, a back emf is induced in the coil which opposes the change in current.

12. **Assertion (A):** An ideal transformer has 100% efficiency.

Reason (R): There is no loss of energy in a practical transformer due to heat, eddy currents or hysteresis.

13. **Assertion (A):** The core of a transformer is made of soft iron and is laminated.

Reason (R): Lamination of the core reduces eddy current losses and soft iron increases magnetic coupling.

14. **Assertion (A):** No emf is induced in a stationary coil placed in a constant magnetic field.

Reason (R): Emf is induced in a coil only when there is a change in magnetic flux linked with the coil.

15. **Assertion (A):** The mutual inductance between two coils depends on their relative orientation.

Reason (R): Changing the orientation of the coils affects the amount of magnetic flux linking the two coils.

ANSWERS

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

TAKE THE CHALLENGE

1. **Assertion (A):** When a coil is rotated in a uniform magnetic field about an axis perpendicular to the field, emf is induced in it which is maximum for the orientation of coil in which magnetic flux through the coil is zero.

Reason (R): In an electric generator, electrical energy is generated by rotating a coil in a magnetic field.

2. **Assertion (A):** It is more difficult to push a magnet into a coil with more loops.

Reason (R): This is because emf induced in each current loop resists the motion of the magnet.

3. **Assertion (A):** At any instant, if the current through an inductor is zero, then the induced emf may not be zero.

Reason (R): An inductor tends to keep the flux constant.

4. **Assertion (A):** A system cannot have mutual inductance without having self-inductance.

Reason (R): If mutual inductance of system is zero, its self-inductance must be zero.

5. **Assertion (A):** Only a change of magnetic flux with time, will maintain an induced current in the coil.

Reason (R): The presence of a large magnetic flux will maintain an induced current in the coil.

1-(b), 2-(a), 3-(b), 4-(c), 5-(c)

2 MARKS QUESTIONS

1. A light copper ring is freely suspended by a light string. A bar magnet is held horizontally with its length along the axis of the ring. The magnet is moved towards the ring with its N pole facing the loop. What will happen to the ring and its position? Explain.

2. In a laboratory experiment, a student observed that the magnetic flux ϕ (in Wb) linked with a coil varies with time t (in seconds) according to the relation: $\phi = 5At^2 + Bt - 2C$ where A, B and C are positive constants.

(a) Find the expression for the induced emf in the coil as a function of time.

(b) At what value of time (t) will the magnitude of induced emf be minimum?

3. A bar magnet falls freely from a height 'h' through a closed metallic ring as shown in the figure.

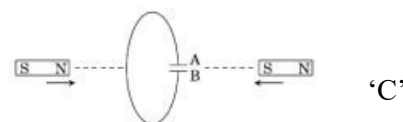
(a) Will the acceleration of the bar magnet be equal to 'g' while passing through the ring? Give reason.

(b) What will happen to the acceleration of the magnet if the ring is cut open so that it does not form a closed loop? Explain.

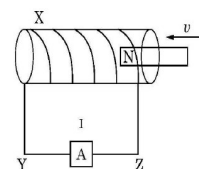
4. (a) How does the mutual inductance of a pair of coils change when the distance between the two coils is increased?

(b) How does the mutual inductance of a pair of coils change when the number of turns in each coil is increased? Give reason in each case.

5. During a physics demonstration in the laboratory, two identical bar magnets are placed on opposite sides of a metallic circular loop connected to an uncharged capacitor as shown in the figure. Both the magnets are moved quickly towards the loop simultaneously. Predict the polarity of the plates A and B of the capacitor. Give reason for your answer.

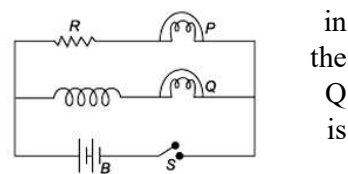


6. In a science laboratory experiment, two identical coils of the same radius, number of turns and area, one made of copper wire and the other of aluminium wire are rotated with the same angular speed in a uniform external magnetic field. Which of the two coils will have a greater induced current? Give reason for your answer.

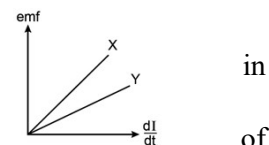


7. In the given figure, X is a coil wound over a hollow wooden pipe. A permanent magnet is pushed at a constant speed v from the right into the pipe and it comes out of at the left end of the pipe. During the entry and the exit of the magnet. What will be the current in the wire YZ.

8. The given figure shows an inductor L and resistor R connected parallel to a battery B through a switch S . The resistance of R is same as that of the coil that makes L . Two identical bulbs, P and Q are put in each arm of the circuit as shown in the figure. When S closed, which of the two bulbs will light up earlier? Justify your answer.



9. State Faraday's law of electromagnetic induction. Express it mathematically. A conducting loop is placed in a magnetic field that is decreasing at a constant rate. What is the direction of induced current the loop?



10. The figure shows the variation of induced emf as a function of rate change of current for two identical solenoids X and Y . One is air cored and the other is iron cored. Which one of them is iron cored and why?

SOLUTIONS- 2 MARKS QUESTIONS

1. Explaining the effect on the motion and position of the ring. Current is induced in the ring. Reason- Due to electromagnetic induction. The ring will be repelled. Reason- As per Lenz's law, Current is induced in the anticlockwise direction and magnetic moment associated with this current has north polarity.

2. (a) Induced emf, $\varepsilon = -\frac{d\phi}{dt} = -(10At + B)$

(b) The magnitude of induced emf will be minimum at $t = 0$ s

3. (a) No, acceleration $< g$. Reason: As the magnet falls, magnetic flux through the ring changes $\rightarrow$ induced current flows (Faraday's law) $\rightarrow$ opposing magnetic field is produced (Lenz's law) $\rightarrow$ retarding force acts on the magnet.

(b) Acceleration $= g$. Reason: Ring is open $\rightarrow$ no induced current $\rightarrow$ no opposing force.

4. Mutual Inductance (M) $\propto (N_1 N_2) / d$

(a) When distance (d) is increased $\rightarrow$ Mutual inductance decreases.

(b) When number of turns (N_1 and N_2) are increased $\rightarrow$ Mutual inductance increases.

5. Polarity: Plate A becomes positive (+) and Plate B becomes negative (-). Reason: Magnetic flux through the loop increases (due to approach of both N-poles towards the loop). Induced current flows in the direction that opposes the increase in flux (Lenz's law).

6. Induced current is greater in the copper coil. Reason: Induced emf is the same in both ($\varepsilon = NBA\omega \sin \omega t$), but resistance of copper coil is less $\rho_{Cu} < \rho_{Al}$, so $I = \varepsilon/R$ is larger for copper.

7. Z to Y and then Y to Z by using Lenz law.

8. When switch S is closed, bulb P will light up earlier. Bulb P is connected in series with a resistor. So, the current in bulb P will instantly rise to its steady value. On the other hand, bulb Q is in series with an inductor. On closing the switch S , current in bulb Q will grow exponentially to its steady value which will be the same as for bulb P . This is due to the production of induced emf in the inductor. However, the steady state value of current will be the same in both the bulbs.

9. Faraday's Law definition: $\varepsilon = -\frac{d\phi}{dt}$. Direction of induced current is such that it tries to increase the magnetic flux (opposes the decrease).

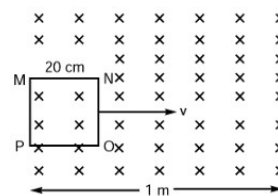
10. From the graph, $\frac{\varepsilon}{\frac{dI}{dt}} = L$. Slope of X is more than that of Y . Hence X is iron-cored because inductance of iron cored coil is more than that of air-cored coil.

3 MARKS QUESTIONS

1. (a) Define mutual inductance of a pair of coils. Write its SI unit. (CBSE 2026)

(b) A long solenoid of radius R and length L has n turns per unit length. A circular loop of radius r ($< R$) is placed inside at the centre of the solenoid such that its axis coincides with the axis of the solenoid. Obtain the mutual inductance of the solenoid and the loop.

2. A square loop MNOP of side 20 cm is placed horizontally in a uniform magnetic field acting vertically downwards as shown in the figure. The loop is pulled with a constant velocity of 20 cm s^{-1} till it goes out of the field.



(a) Depict the direction of the induced current in the loop as it goes out of the field.

(b) For how long would the current in the loop persist?

3. State Faraday's law of electromagnetic induction. Briefly describe two methods for producing induced emf. (CBSE 2026)

4. Two coils, one of radius 0.5 cm having 10 turns and the other of radius 5 cm having 50 turns are placed coaxially in air such that their centres are coincident. Calculate: (CBSE 2026)

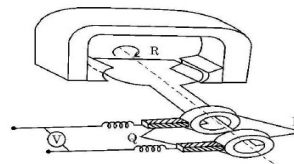
(a) the magnetic flux through the smaller coil if the larger coil carries a current of 3 A, and

(b) the mutual inductance of the two coils.

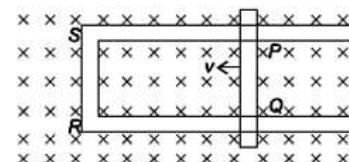
5. (a) Identify the machine in the given figure.

(b) Identify the parts P, Q and R of the machine

(c) Give the polarities of the magnetic poles.



6. Figure shows a rectangular loop conducting PQRS in which the arm PQ is free to move. A uniform magnetic field acts in the direction perpendicular to the plane of the loop. Arm PQ is moved with a velocity v towards the arm RS. Assuming that the arms QR, RS and SP have negligible resistances and the moving arm PQ has the resistance r . Obtain the expression for



(a) the current in the loop

(b) the force and

(c) the power required to move arm PQ.

7. How does the mutual inductance of a pair of coils change when

(a) the distance between the coils is increased?

(b) the number of turns in each coil is decreased?

(c) a thin iron sheet is placed between the two coils, other factors remaining the same? Justify your answer in each case.

8. A conducting coil of 50 turns and area $5/\pi \text{ cm}^2$ is rotating along the axis of solenoid of length 50cm and 2000 turns, carrying current of 5 A. What will be the value of maximum emf generated? (CBSE SQP 2025-26)

9. The currents through two inductors of self-inductance 12 mH and 24 mH are increasing with time at the same rate. Draw graphs showing the variation of the: (CBSE COMPT. 2025)

(a) Magnitude of emf induced with the rate of change of current in each inductor.

(b) Energy stored in each inductor with the current flowing through it.

10. In a physics laboratory, a student is studying a long solenoid used in an electromagnet. Using Faraday's law of electromagnetic induction and Lenz's law, derive an expression for the self-inductance of this long solenoid in terms of its geometry (number of turns N , area of cross-section A and length l) and the permeability of the medium (μ) inside the solenoid.

SOLUTIONS- 3 MARKS QUESTIONS

1. (a) Define Mutual induction and write its SI Unit

(b) Derive to get $M = \mu_0 n^2 \pi r^2 l$

2. (a) Clockwise MNOP.

(b) $v = 20$ cm/s; $d = 20$ cm, Time taken by the loop to move out of magnetic field, $t = 1$ sec

3. The magnitude of the induced emf in a circuit is equal to the time rate of change of magnetic flux through the circuit.

Methods of producing induced emf:

(i) By changing magnetic field with time.

(ii) By changing area of the coil with time in the magnetic field.

(iii) By changing the angle between magnetic field and normal to the coil with time (Any two)

4. Using suitable formulas we get,

(a) 1.48×10^{-6} Wb

(b) $M_{12} = 4.92 \times 10^{-7}$ H

5. (a) AC generator

(b) P - Slip rings Q - Carbon brushes R - Armature coil

(c) Left side of the magnet is North & right side is South or vice-versa.

6. (a) $I = \frac{Blv}{r}$ (b) $F = B^2 l^2 \frac{v}{r}$ (c) $P = B^2 l^2 \frac{v^2}{r}$

7. (a) Mutual inductance decreases. (b) Mutual inductance decreases. (c) Mutual inductance increases. Using Formula: $M = (\mu_0 \mu_r N_1 N_2 A) / d$ (or $M = \phi_{21} / I_1$)

8. The instantaneous induced emf is given by: $\varepsilon = NBA\omega \sin \omega t$

The maximum value of induced emf is: $\varepsilon_{max} = NBA\omega$

Substituting the values: $\varepsilon_{max} = 2$ mV

9. (a) Graph is a straight line passing through origin for both. Slope for 24 mH inductor is twice the slope for 12 mH inductor.

(b) Graph is a parabola opening upwards for both. For same current I , energy stored in 24 mH inductor is twice that in 12 mH inductor.

10. Derive the correct result. $L = \mu n^2 Al$, where $n = \frac{N}{l}$

5 MARKS QUESTIONS

1. (a) State Faraday's law of electromagnetic induction.

(b) Derive an expression for the self-inductance of an air-filled long solenoid of length l and cross-sectional area A having N turns.

(c) A conducting rod of length 50 cm, with one end pivoted, is rotated with angular speed of 60 rpm in a uniform magnetic field of 4.0 mT directed perpendicular to the plane of rotation of rod. Find the emf induced in the rod. (CBSE 2026)

2. (a) State Lenz's law. Give one example to illustrate this law. "The Lenz's law is a consequence of the principle of conservation of energy." Justify this statement.

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

3. (a) Define coefficient of self-induction. Obtain an expression for mutual-inductance of a long solenoid of length 'l', area of cross-section 'A' having 'N' turns.

(b) Calculate the self-inductance of a coil using the following data obtained when an AC source of frequency $\frac{200}{\pi}$ Hz and a DC source is applied across the coil.

AC Source		
S.No	V (Volts)	I (A)
1	3.0	0.5
2	6.0	1.0
3	9.0	1.5

DC Source		
S.No	V (Volts)	I (A)
1	4.0	1.0
2	6.0	1.5
3	8.0	2.0

SOLUTIONS- 5 MARKS QUESTIONS

- (a) Stating Faraday's law
(b) Deriving Expression for self-inductance.
(c) Finding the induced e.m.f $e = 3.14 \text{ mV}$
- State the law. $e = 7.54 \mu\text{V}$

3.

$$\text{For dc part, } R = \frac{V}{I} = 4 \Omega \text{ (in each case)}$$

$$\text{For ac part, } f = \frac{200}{\pi} \text{ Hz}$$

Total impedance

$$Z = 6 \Omega \text{ (in each part)}$$

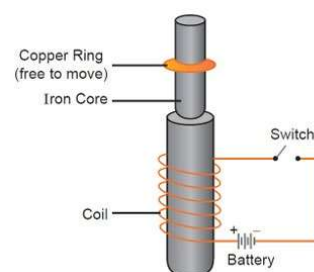
$$X_L = \omega L = 2\pi fL = \sqrt{Z^2 - R^2} = \sqrt{6^2 - 4^2} = \sqrt{20}$$

$$\text{Thus, } 2\pi fL = \sqrt{20}$$

$$\text{or } L = \frac{\sqrt{20}}{2\pi \times \frac{200}{\pi}} = \frac{\sqrt{20}}{400} = \frac{1}{20\sqrt{20}} \text{ H}$$

CASE BASED QUESTIONS

1. Consider the experimental set up shown in the figure. This jumping ring experiment is an outstanding demonstration of some simple laws of Physics. A conducting non-magnetic ring is placed over the vertical core of a solenoid. When current is passed through the solenoid, the ring is thrown off.



(i) The direction of induced current in the ring in jumping ring experiment is such that the polarity developed in the ring is same as that of the polarity on the face of the coil, then ring will jump up due to

- attractive force when the switch is closed in the circuit.
- repulsive force when the switch is closed in the circuit.
- attractive force when the switch is closed in the circuit.
- repulsive force when the switch is closed in the circuit.

(ii) What will happen if the terminals of the battery are reversed and the switch is closed?

- Ring will not be jump.
- Ring will jump again.
- Current will not induced in the ring.
- none of these

(iii) The jumping ring experiment based on which of the following law?

- Lenz's Law
- Faraday's law
- Snell's Law
- both (a) and (b)

(iv) Two identical circular loops A and B of metal wire are lying on a table without touching each other. Loop A carries a current which increases with time. In response the loop B

- (a) remains stationary. (b) is attracted by loop A.
 (c) is repelled by loop A. (d) rotates about its centre of mass with centre of mass fixed.

OR

An emf of 200 V is induced in a circuit when current in the circuit falls from 5 A to 0 A in 0.1 second. The self-inductance of the circuit is

- (a) 3.5 H (b) 3.9 H (c) 4 H (d) 4.2 H

2. Electromagnetic induction is defined as the production of an electromotive force across an electric conductor in the changing magnetic field. The discovery of induction was done by Michael Faraday in the year 1831. Electromagnetic induction finds many applications such as in electrical components which includes transformers, inductors, and other devices such as electric motors and generators. Alternating current is defined as an electric current which reverses in direction periodically. In most of the electric power circuits, the waveform of alternating current is the sine wave.

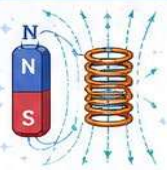
- (i). How to increase the energy stored in an inductor by four times?
 (a) By doubling the current (b) This is not possible
 (c) By doubling the inductance (d) By making current $\sqrt{2}$ times
 (ii). Consider an inductor whose linear dimensions are tripled and the total number of turns per unit length is kept constant, what happens to the self-inductance?
 (a) 9 times (b) 3 times (c) 27 times (d) 13 times
 (iii). Lenz law is based on which of the following conservation?
 (a) Charge (b) Mass (c) Momentum (d) Energy
 (iv). What will be the acceleration of the falling bar magnet which passes through the ring such that the ring is held horizontally and the bar magnet is dropped along the axis of the ring?
 (a) It depends on the diameter of the ring and the length of the magnet
 (b) It is equal due to gravity (c) It is less than due to gravity
 (d) It is more than due to gravity

Answer:

1. (i) (b) The direction of induced current in the ring is such that the polarity developed in the ring is same as that of the polarity on the face of the coil, hence it will jump up due to repulsive force.
 (ii) (b) The polarity of the induced current in the ring will get reversed on changing the terminals of the battery, so the ring will jump again. (iii) (d)
 (iv) (c) Opposite currents are induced in loops, so loops repel each other.

OR (c) Self inductance, $L = 4 \text{ H}$

2. (i). (a) By doubling the current (ii). (c) 27 times (iii). (d) Energy (iv). (c)



ELECTROMAGNETIC INDUCTION

CLASS 12 PHYSICS – FORMULA SHEET



CBSE SYLLABUS



NEP 2020 ALIGNED



QUICK REVISION



EXAM READY



1 MAGNETIC FLUX (Φ)

★ MOST IMPORTANT

$$\Phi = BA \cos \theta$$

For N turns:

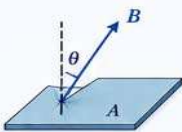
$$\Phi = NBA \cos \theta$$

Φ = Magnetic Flux (weber, Wb)

B = Magnetic field (tesla, T)

A = Area (m^2)

θ = Angle between B and normal to area



2 FARADAY'S LAWS OF INDUCTION

For a single turn:

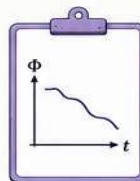
$$\varepsilon = - \frac{d\Phi}{dt}$$

For N turns:

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

ε = Induced EMF (volt)

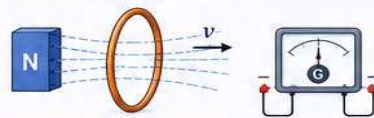
$\frac{d\Phi}{dt}$ = Rate of change of flux



3 LENZ'S LAW

★ MOST IMPORTANT

The induced EMF (or current) is in such a direction that it opposes the change in magnetic flux that produces it.



Nature opposes change.
That is Lenz's Law.

4 MOTIONAL EMF (ε)

★ MOST IMPORTANT

(i) Straight Conductor

$$\varepsilon = B\ell v$$

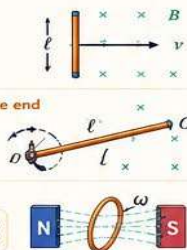
(ii) Rotating Rod about one end

$$\varepsilon = \frac{1}{2} B\omega \ell^2$$

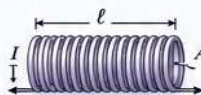
(iii) Rotating Coil (N turns)

$$\varepsilon = NBA\omega \sin(\omega t)$$

B = Magnetic field (T), ℓ = Length (m), v = Velocity (m/s),
 ω = Angular velocity (rad/s), N = Number of turns



5 SELF INDUCTANCE (L)



$$L = \frac{\Phi}{I}$$

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

$$\text{Solenoid: } L = \frac{\mu_0 N^2 A}{\ell}$$

L = Self inductance (henry, H)

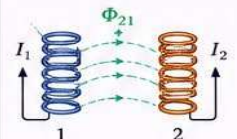
Φ = Magnetic flux (weber)

I = Current (ampere)

$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$

N = Number of turns, A = Area (m^2), ℓ = Length (m)

6 MUTUAL INDUCTANCE (M)



$$M = \frac{\Phi_{21}}{I_1}$$

$$\varepsilon_2 = -M \frac{dI_1}{dt}$$

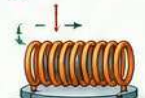
M = Mutual inductance (henry, H)

Φ_{21} = Flux in coil 2 due to current in coil 1

Note:

Mutual inductance depends on size, shape, distance between coils and core.

7 ENERGY IN INDUCTOR



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

Energy Density

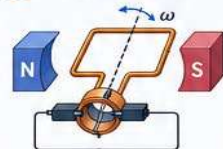
$$u = \frac{B^2}{2\mu_0}$$

U = Energy stored (joule, J)

u = Energy density (J m^{-3})

B = Magnetic flux density (tesla, T)

8 AC GENERATOR



Peak EMF:

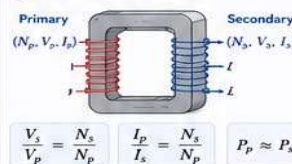
$$\varepsilon_0 = NBA\omega$$

Instantaneous EMF:

$$\varepsilon = NBA\omega \sin(\omega t)$$

N = Number of turns, B = Magnetic field (T)
 A = Area (m^2), ω = Angular speed (rad/s)

9 TRANSFORMER



Primary (N_p, V_p, I_p) Secondary (N_s, V_s, I_s)

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} \quad \frac{I_p}{I_s} = \frac{N_s}{N_p} \quad P_p \approx P_s$$

Efficiency:

$$\eta = \frac{\text{Output Power}}{\text{Input Power}} \times 100\%$$

$$S = V_{rms} I_{rms}$$

$$P = V_{rms} I_{rms} \cos \phi$$

$$Q = V_{rms} I_{rms} \sin \phi$$

$$\tan \phi = \frac{Q}{P}$$

$$S^2 = P^2 + Q^2$$

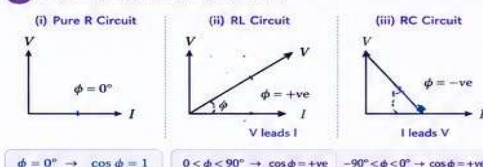
Ideal Transformer

- No power loss
- $P_p = P_s$
- $\eta = 100\%$

10 COMPARISON TABLE

Property	Resistance (R)	Inductive Reactance (X_L)	Capacitive Reactance (X_C)
Formula	R	$X_L = \omega L$	$X_C = \frac{1}{\omega C}$
Cause	Opposition in pure resistor	Self inductance	Capacitance
Depends on	—	f, L	f, C
Phase (V w.r.t. I)	In phase	V leads I by 90°	I leads V by 90°
Unit	ohm (Ω)	ohm (Ω)	ohm (Ω)

11 PHASOR DIAGRAMS (KEY CASES)

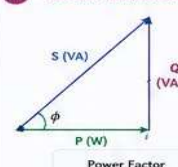


$$\phi = 0^\circ \rightarrow \cos \phi = 1$$

$$0 < \phi < 90^\circ \rightarrow \cos \phi = +ve$$

$$-90^\circ < \phi < 0^\circ \rightarrow \cos \phi = +ve$$

12 POWER TRIANGLE



$$S = V_{rms} I_{rms}$$

$$P = V_{rms} I_{rms} \cos \phi$$

$$Q = V_{rms} I_{rms} \sin \phi$$

$$\tan \phi = \frac{Q}{P}$$

$$S^2 = P^2 + Q^2$$

$$\text{Power Factor} = \cos \phi = \frac{P}{S}$$

13 IMPORTANT CONDITIONS

- ✓ Resonance (LCR Series): $X_L = X_C$ or $\omega_0 = \frac{1}{\sqrt{LC}}$
- ✓ At resonance: $\phi = 0$, $Z = R$ (minimum), I = maximum
- ✓ Power factor unity at resonance.
- ✓ Net inductive: $X_L > X_C \rightarrow \phi > 0$ (V leads I)
- ✓ Net capacitive: $X_C > X_L \rightarrow \phi < 0$ (I leads V)

14 MEMORY TRICKS

- “L Leads, C Cheats”
In inductor (L), Voltage leads Current.
In capacitor (C), Current leads Voltage.
- “N over P – Voltage; P over S – Current”
 $\frac{V_s}{V_p} = \frac{N_s}{N_p}$ | $\frac{I_p}{I_s} = \frac{N_s}{N_p}$
- “Flux First, EMF Next”
Change in Flux ($d\Phi/dt$) gives rise to EMF.
- “Oppose the Change”
Lenz's Law – Nature opposes change.

15 COMMON MISTAKES

- ✗ Using peak values in power formula.
- ✗ Forgetting negative sign in Faraday's law.
- ✗ Confusing phase relations in RL and RC circuits.
- ✗ Ignoring units (H, Wb, T, Ω).
- ✗ Wrong transformer turn ratio.

16 PYQ TIPS

- Very important topics in CBSE PYQs:
- Lenz's Law & direction of induced current
- EMF in moving/rotating conductors
- Self & mutual inductance problems
- AC generator & transformer formulas
- Power & power factor in AC circuits

Practice NCERT Examples & Previous Years' Questions!

SYMBOLS & THEIR MEANINGS

Φ : Magnetic Flux (Wb)	V_{rms} : RMS Voltage (V)
ε : Induced EMF (V)	I_{rms} : RMS Current (A)
I : Current (A)	ω : Angular Frequency (rad s^{-1})
V : Voltage (V)	f : Frequency (Hz)

SI UNITS

Flux (Φ)	: Weber (Wb)
Inductance (L, M)	: Henry (H)
Resistance (R, X)	: Ohm (Ω)
Capacitance (C)	: Farad (F)
Magnetic field (B)	: Tesla (T)

CONSTANTS

π	= 3.1416
μ_0	= $4\pi \times 10^{-7} \text{ H m}^{-1}$
1 T	= 1 Wb A^{-1}
1 F	= 1 C V^{-1}

CONCEPT CLEAR.
FORMULAS STRONG.
SUCCESS LONG!
KEEP CALM &
CRACK THE EXAM!

