🌟 ELECTROMAGNETIC INDUCTION (EMI) – Class 12 Physics

Designed exactly as requested: **simple language, visuals, mnemonics, solved numericals, past-year questions, exam tricks, quick notes, and predicted questions.**

⭐ 1. THEORY IN SIMPLE WORDS (WITH VISUALS)

🌈 1.1 What is Electromagnetic Induction (EMI)?

Electromagnetic Induction = *the production of electric current or emf when magnetic flux changes.*

Visual Analogy:

Think of magnetic flux like **water passing through a loop**.
If the water amount changes → the loop feels it → current is created.

```
Changing Magnetic Field
     ↓
  Loop → Induced EMF → Induced Current
```

🌈 1.2 Magnetic Flux (Φ)

Flux = amount of magnetic field passing through a surface.

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

Where
B = magnetic field
A = area
θ = angle between field and normal

Visual:

```
More field lines → more flux
Tilt coil → fewer lines pass → flux decreases
```

🌈 1.3 Faraday's Laws

1st Law:

Whenever magnetic flux linked with a coil changes, an emf is induced.

2nd Law:

Induced emf ∝ rate of change of flux.

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

Negative sign → **Lenz's Law** (opposes cause).

🌈 1.4 Lenz's Law

Induced current always opposes the change in flux that produces it.

Analogy → "Nature says: STOP THE CHANGE!"

Visual:

```
Push magnet in coil → coil generates opposite field to resist it
Pull magnet out → coil reverses field to oppose removal
```

🌈 1.5 Fleming's Right-Hand Rule

(For direction of induced current)

```
Thumb → Motion
First finger → Field
Second finger → Current
```

Mnemonic: **"Mo-F-F-Cu"**
(MOtion-FieLd-CUrrent)

🌈 1.6 Motional EMF

When a conductor moves in a magnetic field:

$$\varepsilon = Blv$$

(B = field, l = rod length, v = velocity)

Visual:

```
Rod moves across field → charges pushed → emf created
```

🌈 1.7 Eddy Currents

Currents induced in bulk metal pieces (not a coil).

Effect:

- Causes heating (e.g., induction stove)
- Causes damping (e.g., speedometer)

🌈 1.8 Self Induction (L)

A coil opposes change in its own current.

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

L = inductance (Henry, H)

🌈 1.9 Mutual Induction (M)

One coil induces emf in another coil.

$$\varepsilon = -M\frac{di}{dt}$$

Transformers work on this principle.

⭐ 2. KEY FORMULAS & CONCEPTS (TABLE + MNEMONICS)

🌈 Formula Bank

Concept	Formula	Meaning
Magnetic flux	$\Phi = BA\cos\theta$	Field lines passing
Faraday's law	$\varepsilon = -d\Phi/dt$	emf ∝ change of flux
Motional emf	$\varepsilon = Blv$	moving rod
Induced current	$I = \varepsilon/R$	Ohm's law
Self-induction	$\varepsilon = -L\, di/dt$	coil opposes its own current
Energy stored in inductor	$U = \frac{1}{2}LI^2$	magnetic energy

🌈 Mnemonics

💡 Flux formula (BAcosθ)

B+A+cos = "B-Angle-cos"

💡 Lenz's Law

"Lenz = Law of Opposition"

💡 Right-hand rule

"Mo-F-F-Cu": Motion–Field–Current

⭐ 3. SOLVED NUMERICAL PROBLEMS

⭐ Type 1: Using Faraday's Law

Q1: Flux changes from 0.5 Wb to 0.2 Wb in 0.1 s. Find induced emf.

$$\varepsilon = \frac{\Delta\Phi}{\Delta t}$$

$$= \frac{0.5 - 0.2}{0.1} = 3V$$

⭐ Type 2: Motional EMF

Q2: A rod of length 0.5 m moves at 4 m/s in a 0.2 T field. Find emf.

$$\varepsilon = Blv = 0.2 \times 0.5 \times 4 = 0.4V$$

⭐ Type 3: Self Induction

Q3: Current in coil changes at 5 A/s, inductance = 2 H.
Find induced emf.

$$\varepsilon = -L\frac{di}{dt} = -2 \times 5 = -10V$$

(Negative = opposite direction.)

⭐ Type 4: Energy Stored in Inductor

Q4: L = 3 H, I = 2 A. Find energy.

$$U = \frac{1}{2}LI^2 = 0.5 \times 3 \times 4 = 6J$$

⭐ 4. PAST-YEAR BOARD QUESTIONS (SOLVED)

(Based on 2015–2024 trend)

✔ Q1

State Faraday's laws of electromagnetic induction.
(2 marks frequently asked)

✔ Q2

Explain Lenz's law using conservation of energy.

Ans:
Opposition ensures no *free energy* is created → satisfies conservation of energy.

✔ Q3

A rod of length l moves with velocity v in magnetic field B. Derive emf expression.

(Important derivation)

✔ Q4

Define self-inductance and mutual inductance.

✔ Q5

Write uses of eddy currents.
(Asked many times)

✔ Q6

Numerical on:

- motional emf
- rate of flux change

- inductance energy

⭐ 5. QUICK REVISION NOTES (1–2 PAGES)

🌈 Must-Remember Points

- Changing flux → induced emf
- Static flux → NO emf
- $\varepsilon = -\, d\Phi/dt$ (heart of chapter!)
- Lenz's law → direction
- Motional emf = B l v
- Eddy currents cause heating & damping
- Self induction opposes change in current
- Mutual induction → basis of transformers

🌈 Flux Behavior Table

If B ↑	Φ ↑	emf direction opposes B ↑
If A ↑	Φ ↑	emf tries to decrease area
If θ changes	Φ changes	emf tries to restore original orientation

---

🌈 Inductor Behavior

- Inductor **opposes change of current**
- Works like *magnetic inertia*
- Stores energy in magnetic field

🌈 Identifying Lenz Direction

Flowchart:

```
1. Identify cause (B increasing? decreasing?)
2. Ask: what would oppose it?
3. Draw direction of counter field
4. Use right-hand rule → current direction
```

⭐ 6. PREDICTED / LIKELY QUESTIONS (2025 Boards)

💡 Short Answer (Most likely)

- Define magnetic flux.
- State Faraday's law.
- What is Lenz's law?
- Explain eddy currents with uses.
- Write formula for motional emf.

💡 Long Answer

- Derive $\varepsilon = -d\Phi/dt$.
- Derive motional emf formula.
- Explain self & mutual induction.
- Draw graph of flux vs time and find emf.

💡 Numerical

- Rate of change of flux problems
- Motional emf (Blv)
- Self-inductance emf
- Energy stored in inductor

⭐ 7. EXAM TIPS & SCORING TRICKS

✔ Tip 1

In derivations:
Always mention negative sign = Lenz's law.

✔ Tip 2

In numericals:
Convert mT → T, cm → m (common mistake).

✔ Tip 3

For direction questions:
Use **step-by-step Lenz flowchart**.

✔ Tip 4

Eddy current uses = guaranteed 2 marks.

✔ Tip 5

Draw coil arrows clearly; examiners love neat diagrams.

⭐ 8. VISUAL & KID-FRIENDLY MEMORY TOOLS

🎨 Visual: “Flux as Field Water”

```
More field lines → More flux
Less field lines → Less flux
```

🎨 Visual: Lenz’s Law

```
CAUSE == CHANGE
INDUCED CURRENT == ANTI-CHANGE
```

🎨 Visual: Motional EMF

```
Rod moving in field = charge pushed to one end
(q pushed → emf appears)
```

🎨 Visual: Inductor

```
Inertia for Current
(Doesn’t let current change suddenly)
```