

Electromagnetic Induction

AP Physics C: E&M • Unit 13

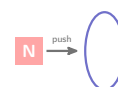
AP Physics C: E&M



Electromagnetic Induction

What we will cover

- 1 Magnetic flux
- 2 Faraday's law and Lenz's law
- 3 Induced currents and forces
- 4 Inductance
- 5 LR and LC circuits



1

Flux & Faraday

Electromagnetic Induction

Flux & Faraday

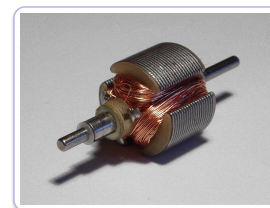
Magnetic flux and Faraday's law

Flux, then Faraday

$$\Phi_B = \int \vec{B} \cdot d\vec{A} = BA \cos \theta$$
$$\varepsilon = -\frac{d\Phi_B}{dt}$$

The minus sign is **Lenz's law** 楞次定律: the induced current **opposes the change** – energy conservation.

Motional emf: $\varepsilon = BLv$, a coil of N turns: $\times N$.



Motor rotor

2

Induced currents

Electromagnetic Induction

Induced currents

Induced currents and forces

The **induced current** 感应电流 (Lenz's law) always creates a **retarding force** 阻碍力 that resists the motion causing it.

- mechanical work $\rightarrow$ electrical energy $\rightarrow$ heat
- **eddy currents** 涡电流 in solid metal damp motion (magnetic braking)



Substation transformer

3 Inductance

Electromagnetic Induction
└ Inductance

Inductance

An **inductor** 电感 resists a **change** in current, creating a **back emf** 反电动势:

Back emf and stored energy

$$\varepsilon = -L \frac{dI}{dt}, \quad U = \frac{1}{2} L I^2$$

Energy density $u = \frac{B^2}{2\mu_0}$ – the magnetic mirror of $\frac{1}{2}\varepsilon_0 E^2$.

Worked example

2 H with I rising at 3 A/s:

$$\varepsilon = L \frac{dI}{dt} = 2 \times 3 = 6 \text{ V}$$

At a steady 4 A: $U = 16 \text{ J}$, and the back emf vanishes.

4 LR & LC

Electromagnetic Induction
└ LR & LC

LR and LC circuits

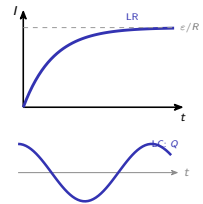
LR: smooth growth

$$\tau = \frac{L}{R}, \quad I = \frac{\varepsilon}{R} (1 - e^{-t/\tau})$$

An inductor blocks current at first, passes it freely later – **opposite** to a capacitor.

LC: oscillation

$$\omega = \frac{1}{\sqrt{LC}}$$



5 Recap

Electromagnetic Induction
└ Recap

Unit 13 – key takeaways

1 Faraday

$\varepsilon = -d\Phi_B/dt$; Lenz opposes the change

2 Induced force

always retarding; eddy currents damp motion

3 Inductance

$\varepsilon = -L dI/dt$; stores $U = \frac{1}{2} L I^2$

4 Circuits

LR grows with $\tau = L/R$; LC oscillates at $1/\sqrt{LC}$

Check yourself

- 1 Write Faraday's law for the induced emf.
- 2 Which law fixes the direction of the induced current?
- 3 At the first instant, how does an inductor behave?
- 4 What sets the oscillation frequency of an LC circuit?



Answers 1. $\mathcal{E} = -d\Phi_B/dt$ 2. Lenz's law 3. it blocks current (open) 4. $\omega = 1/\sqrt{LC}$