Physics 102

Lecture 19. Ref: ch. 23.

- Faraday's Law of Induction.

The induced emf for a coil of N loops

$$\mathcal{E} = -N \cdot \frac{\Delta \Phi}{\Delta t} = -N \frac{d\Phi}{dt}.$$

Φ — flux of each loop.

i.e. The time-rate of change in Φ determines $\mathcal{E}$.

(Not Φ itself).

"$-$" — Lenz's Law : Induced current always opposes the change that caused it.

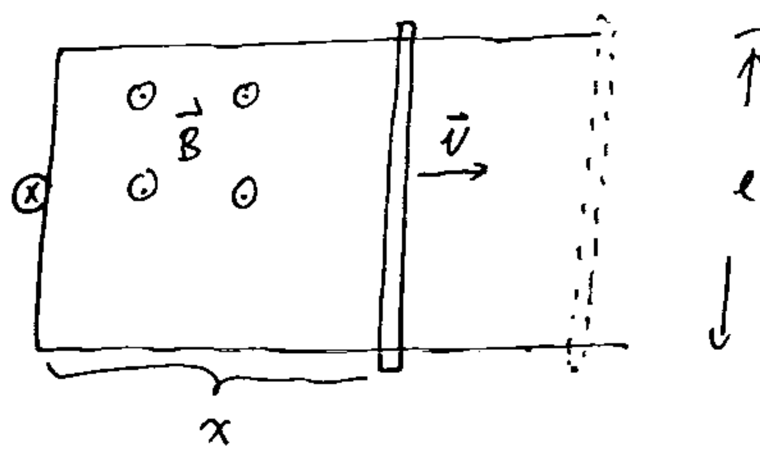
- e.g. A conducting rod slides on two wires

$N = 1$. (# of loops)

$\Phi = B \cdot A \cdot \cos\theta$

$= B \cdot A$

$= B \cdot l x$.



In time interval Δt:

$\Delta \Phi = Bl \cdot \Delta x = Bl \cdot v \cdot \Delta t$.

Induced emf:

$$\mathcal{E} = -N\frac{d\Phi}{dt} = -\frac{B\ell \cdot v \cdot \delta t}{\delta t} = -B\ell v.$$

Magnitude:

$$|\mathcal{E}| = B\ell v.$$

direction of induced current:

Method 1: $\vec{F} = q\vec{v} \times \vec{B}$ RHR. ↓ I.

Method 2: Lenz's law.

when the rod moves to the right,

Φ increases. ($\because$ B = const, A — increased).

Then, the induced current should produce a $\vec{B}$-field that will partly cancel the original field. so that the total B is weaker, and so is Φ.

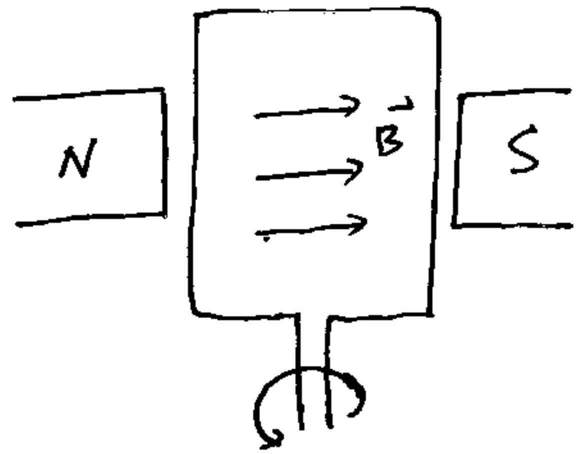
Electric field inside the rod:

$\because$ $\mathcal{E} = V = E\ell$. (voltage across the rod).

$$E = \frac{\mathcal{E}}{\ell} = Bv.$$

direction of $\vec{E}$: by RHR. $q\vec{v} \times \vec{B}$

- Electric generator



Flux:

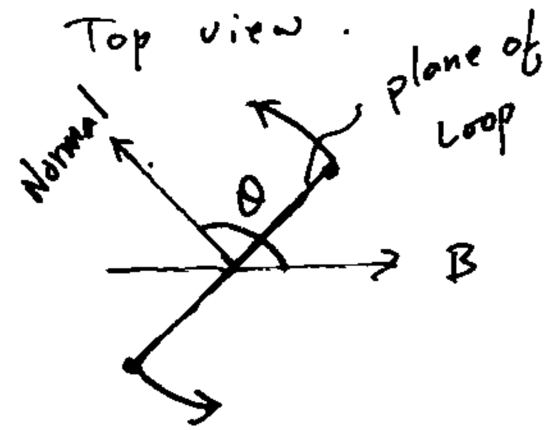
$\Phi = B \cdot A \cdot \cos\theta$.

$\theta = \omega t$.

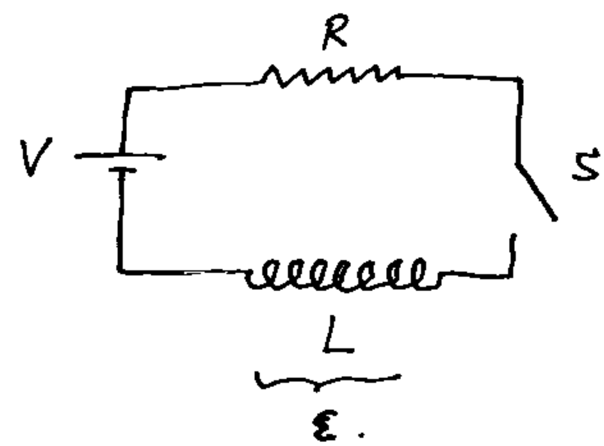
$\therefore \Phi = BA \cdot \cos(\omega t)$.

$\mathcal{E} = -N \frac{d\Phi}{dt} = -NBA \cdot \omega \cdot \overset{(-)}{} \sin(\omega t)$

$\therefore \mathcal{E} = NBA \cdot \omega \cdot \sin(\omega t)$



- Self Inductance



Induced emf:

$|\mathcal{E}| = N \cdot \left|\frac{\Delta\Phi}{\Delta t}\right| = \underbrace{N \cdot \left|\frac{\Delta\Phi}{\Delta I}\right|}_{L} \cdot \left|\frac{\Delta I}{\Delta t}\right|$

$= L \cdot \frac{\Delta \Phi}{\Delta t}$

Inductance of the coil:

$L = N \cdot \left|\frac{\Delta\Phi}{\Delta I}\right|$. unit: Henry.

- Inductance of a solenoid.

$$\boxed{L = \mu_0 n^2 A \ell} = \mu_0 \cdot \frac{N^2}{\ell^2} \cdot A \cdot \ell = \frac{\mu_0 N^2 A}{\ell}.$$

n — # of turns per unit length.

N — Total # of turns. (in length ℓ)

Why?

field inside a solenoid with a current I:

$$B = \frac{\mu_0 N I}{\ell}.$$

flux: $\Phi = B \cdot A = \frac{\mu_0 N I A}{\ell}$

Self inductance:

$$L = N \cdot \frac{\Delta \Phi}{\Delta I} = N \cdot \frac{d\Phi}{dI}$$

$$= \frac{\mu_0 N^2 A}{\ell}$$

$$= \frac{\mu_0 N^2 A}{\ell \cdot \ell} \cdot \ell$$

$$= \mu_0 n^2 A \cdot \ell.$$

Next: finish. R-L circuit.

#44. 77. 79.

- RL circuits. p.768.

  ① circuit diagram.

  ② time const. $\tau = \frac{L}{R}$.

  ③ $I \sim t$.

  ④. formula.

- Energy stored in a solenoid. p.770.

next: #44. 77. 79.