Ch 21: Electromagnetic Induction

- If electric currents produce magnetic fields, can magnetic fields produce electric currents?
  - Yes!
- Discovered independently by
  - Joseph Henry (American)
  - Michael Faraday (English)

Joseph Henry

- Lived from 1797 to 1878
- Premier American scientist after Ben Franklin
- Albany native
- Attended & then taught at Albany Academy
  - conducted experiments in his spare time!
- Invited to Princeton and stayed there
  - now endowed chair of physics department
  - Joseph Henry Laboratories
- First Secretary of the Smithsonian Institute
- One of first members of National Academy of Science

Induced EMF

- Faraday observed deflection when switched was opened and closed
  - changing B field induces current

Induced EMF

- Magnet moves up, current in circuit
- Magnet moves down, current in circuit
- No movement, no current in circuit
Faraday’s Law of Induction

- The induced emf depends on the:
  - area of loop
  - how fast B field is changing
  - change in magnetic flux, \( \Phi_B \)

**Faraday’s Law of Induction**

\[
Emf = -\frac{\Delta \Phi_B}{\Delta t}
\]

where

\( \Phi_B = B\cdot A = BA \cos \theta \)

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Ch 21: Problem 5

- A 12.0-cm-diameter loop of wire is initially oriented perpendicular to a 1.5-T magnetic field. The loop is rotated so that its plane is parallel to the field direction is 0.20 s. What is the average induced emf in the loop?
**More practice**

- What is the direction of the induced current in the circular loop due to the current in the wire?

![Diagram of circular loop and current](image)

**Ch 21: Problem 2**

- The rectangular loop shown is pushed into the magnetic field which points inward. In what direction is the induced current?

![Diagram of rectangular loop](image)

**EMF Induced in a Moving Conductor**

- Area inside loop is increasing as rod moves to right
  \[ \Delta A = l \Delta t \]

- A changing B field induces an electric field \( (E = \frac{F}{q}) \)

**Electric Generators**

- Faraday's law of induction
  \[ E_{mf} = N \frac{\Delta \phi}{\Delta t} = N B \Delta A \]

- Electric generators
  \[ E_{mf} = N B q \]
Ch 21: Problem 20

A simple generator is used to generate a peak output voltage of 24.0 V. The square armature consists of windings that are 6.0 cm on a side and rotates in a field of 0.420 T at a rates of 60.0 rev/s. How many loops of wire should be wound on the square armature?

Transformers

- Step-Up Transformer
  - $V_s > V_p$
- Step-Down Transformer
  - $V_s < V_p$
- Conservation of energy requires
  - $P_p = P_s$
  - $I_p V_p = I_s V_s$

$$\frac{I_s}{I_p} = \frac{N_p}{N_s}$$

- $\Delta B/\Delta t$ in primary induces $V_s$ in secondary coil
- Works for AC only
- DC voltages don’t have changing B field

Ch 21: Problem 31

A transformer has 320 turns in the primary coil and 120 in the secondary coil. What kind of transformer is this, and by what factor does it change the voltage? By what factor does it change the current?
Inductance

- \[ Emf_2 = -M \frac{\Delta I_1}{\Delta t} \]
- \[ Emf_1 = -M \frac{\Delta I_2}{\Delta t} \]

- where \( M \) = mutual inductance
- Units of inductance = **Henry**
- \( 1 \text{ H} = 1 \text{ \Omega s} \)

Self-Inductance

- Changing current passes through a coil
- Produces changing B flux
- Which induces an emf
- Induced emf opposes change in flux

\[ Emf = -L \frac{\Delta I}{\Delta t} \]

Ch 21: Problem 39

- If the current in a 180-mH coil changes steadily from 25.0 A to 10.0 A in 350 ms, what is the magnitude of the induced emf?