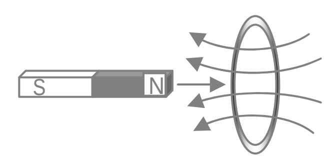
Chapter 5 Faraday's Law

5.1 Faraday's Law of Induction

5.2 Two Kinds of Electromotance

5.3 Mutual Inductance and Self-Inductance

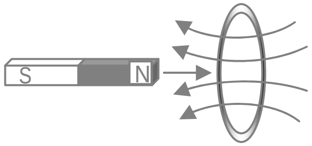
5.4 Transient Process



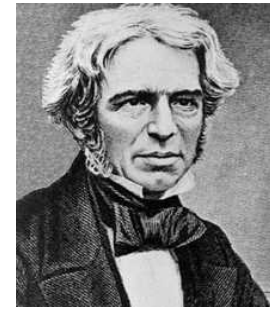
5.1 Faraday's Law of Induction

- Faraday's Law of Induction

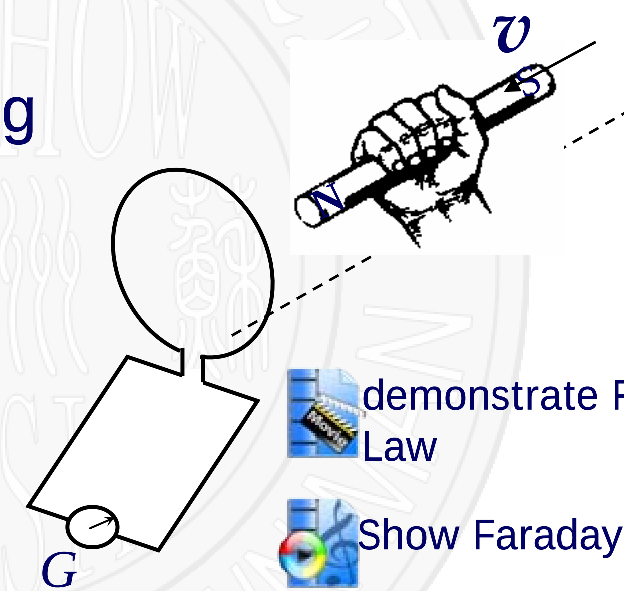
  - 1820, Oersted, Magnetic Field create by Current
  - Can Magnetic Field Create Current ?
  - 1831,Faraday, How to Create Current by Magnet
  - A set of Experiment



5.1 Faraday's Law of Induction



- A set of Experiment
  - Experiment 1. A Bar Magnet Inserting a Loop
    - Pushing into →G Deflecting
    - Keeping Stationary → No G Deflecting
    - Pulling out→ G Deflecting opposite Direction



Galvanometer

demonstrate Faraday's Law

Show Faraday's Law

Show Faraday's Law
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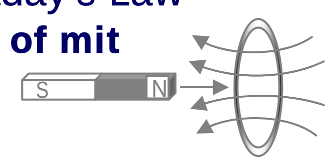
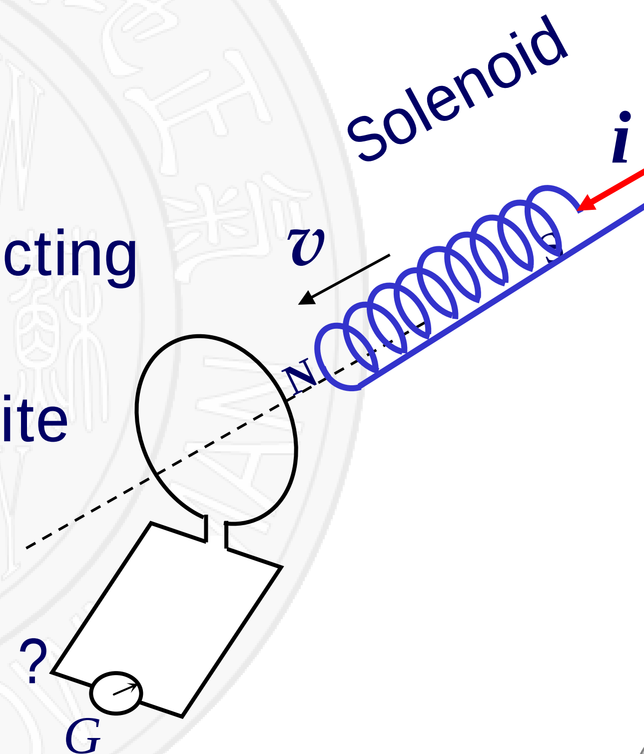


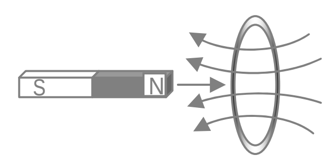
5.1 Faraday's Law of Induction

A set of Experiment

Experiment 2. A Solenoid with current Inserting a Loop

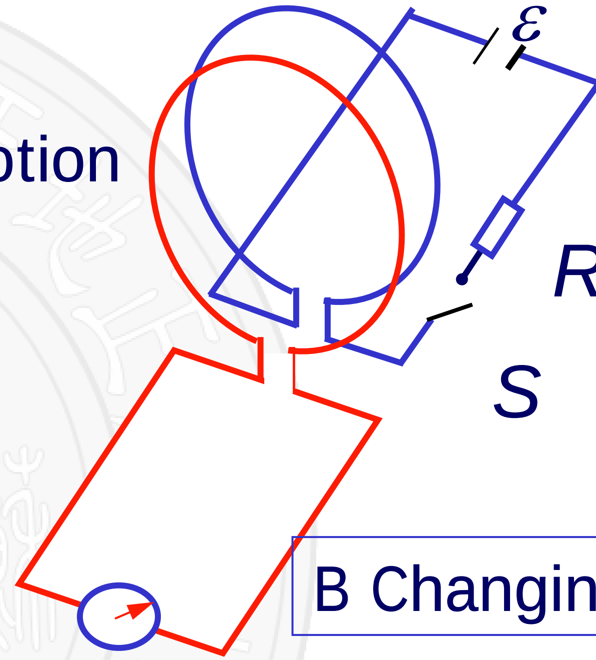
- Inserting →G Deflecting
- Keeping Stationary →No G Deflecting
- Pulling out→ G Deflecting opposite Direction
- Is the Relative Motion Necessary ?





5.1 Faraday's Law of Induction

- A set of Experiment
  - Experiment 3. B Change without Motion
    - Switch Closing → G Deflecting
    - Switch Keep on →No G Deflecting
    - Switch Opening → G Deflecting Opposite Direction
    - Is the Magnetic Field B Change Necessary ?



B Changing

induced emf

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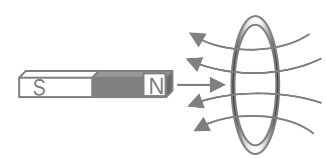
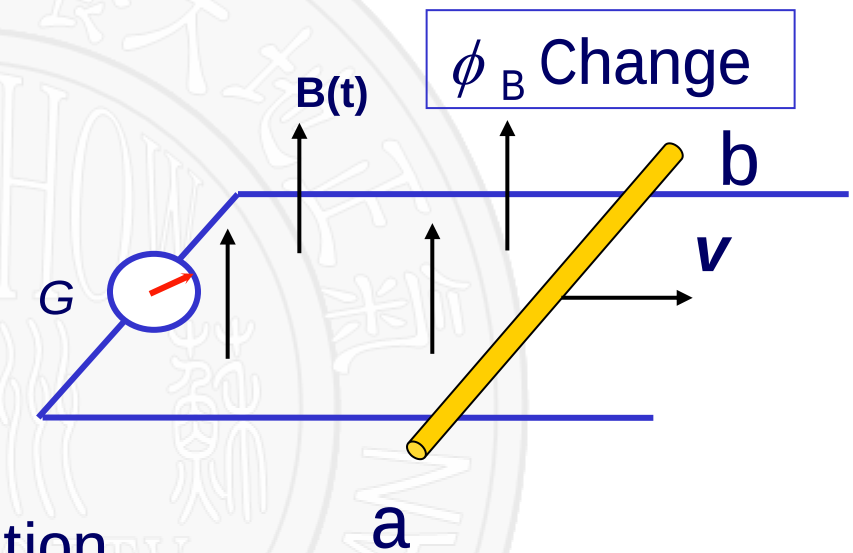


5.1 Faraday's Law of Induction

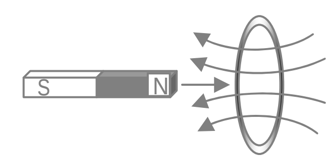
- Experiment 4. Motion only, No B Change

  - Moving ab →G Deflecting
  - Stop →No G Deflecting
  - Moving other Direction
  →G Deflecting Opposite Direction



5.1 Faraday's Law of Induction

- The Following cases can produce electricity
  - Case 1. A Bar Magnet Inserting a Loop
  - Case 2. A Solenoid with current Inserting a Loop
  - Case 3. B Change without Motion
  - Case 4. Motion only, No B Change
  - What is the natural reason to produce electricity?



5.1 Faraday's Law of Induction

There will be an induced emf in the loop as long as the magnetic flux through the loop is changed.

Faraday's Law of Induction

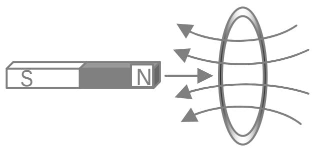
- The induced emf ε in a circuit is equal to the rate of B flux.

$$\varepsilon = -\frac{\mathrm{d}\phi_B}{dt}$$

- N turns, every turn has same the flux ϕ_B

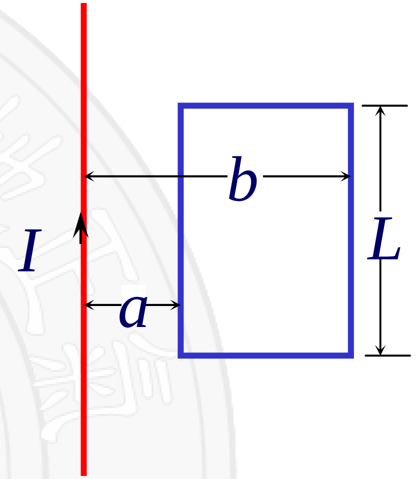
$$\varepsilon = -N\frac{\mathrm{d}\phi_B}{dt}$$

- $N\phi_B$ —Flux Linkages



5.1 Faraday's Law of Induction

Example 5.1 A rectangular Coil with N turns is placed parallel to a infinite line with changing current I sharing a same plane with coil,



$$I = I_0 \cos \omega t$$

What is the emf in the coil?

Solution:

The Field B is

$$B = \frac{\mu_0 I}{2\pi r}$$

The flux of B through the coil one turn

5.1 Faraday's Law of Induction

$$\phi_B = \int_a^b \boldsymbol{B}\cdot d\boldsymbol{S} = \int_a^b \frac{\mu_0 \boldsymbol{I}}{2\pi r}\cdot L d\boldsymbol{r} = \frac{\mu_0 \boldsymbol{I}}{2\pi}\cdot L\ln\frac{b}{a}$$

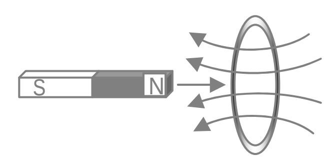
The flux linkages of B through the coil with N turns

$$\psi_B = N\phi_B = N\frac{\mu_0 \boldsymbol{I}}{2\pi}\cdot L\ln\frac{b}{a}$$

According to Faraday's Law ,the emf is

$$\varepsilon = -\frac{d\psi_B}{dt} = -\frac{\mu_0 NL}{2\pi}\cdot\ln\frac{b}{a}\cdot\frac{dI}{dt}$$

$$= \frac{\mu_0 NL}{2\pi}\cdot\ln\frac{b}{a} I_0\omega\sin\omega t$$



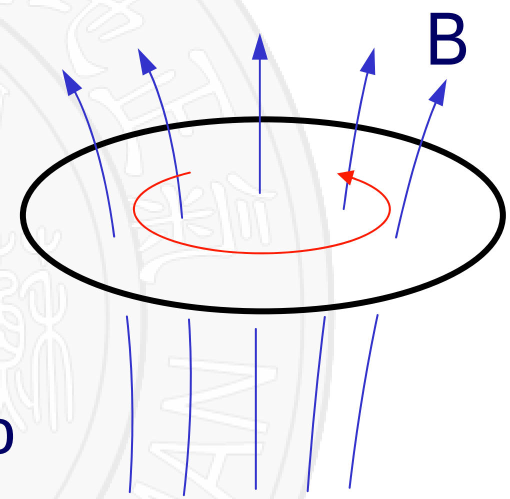
5.1 Faraday's Law of Induction

◈ Faraday's Law of Induction

✸ How to Determine the Direction of induction Current ?

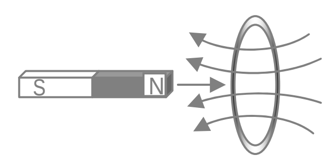
- The Minus in Faraday's Law

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



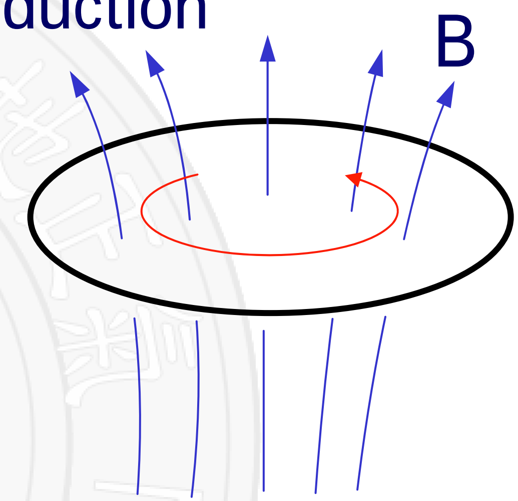
- Choose a direction of the loop, to determine the flux of B

- Choose Counterclockwise, $\phi>0$



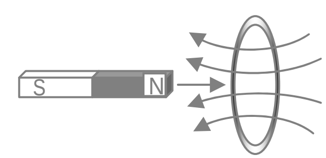
Faraday's Law of Induction

- How to Determine the Direction of induction Current ?



  - If B is increased, $d\phi > 0$, $\varepsilon < 0$, it means that the direction of ε is in the opposite direction of chosen direction of the loop, and inversely.

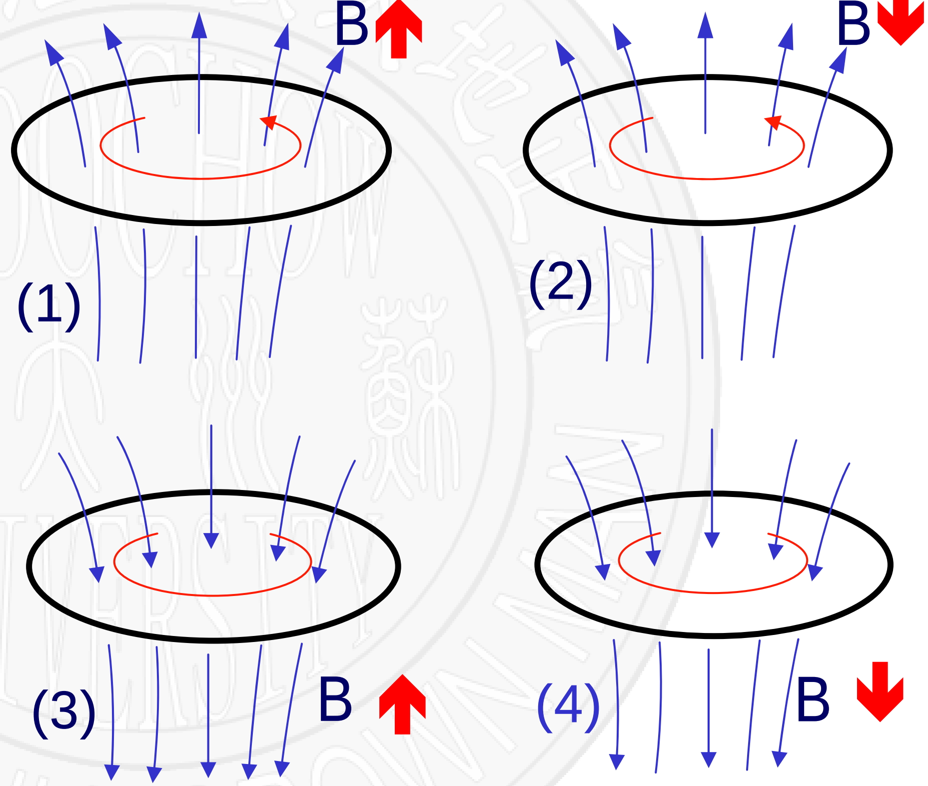
  - You can choose Clockwise, and try again



5.1 Faraday's Law of Induction

✸ How to Determine the Direction of induction Current ?

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

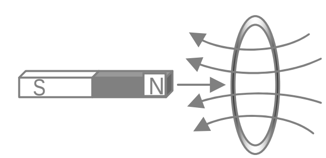


▲ If B⬇,CCW of Loop

$\phi>0$, $d\phi<0$

$$\varepsilon = -\frac{d\phi_B}{dt} > 0$$

What's Meaning?



5.1 Faraday's Law of Induction

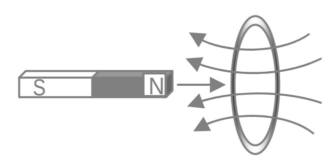
- Lenz's Law

  It is bothered to determine the direction of induction current by Faraday's law, are there any shortcut way ?

- The field of induced current always opposes the change of the field producing induction current

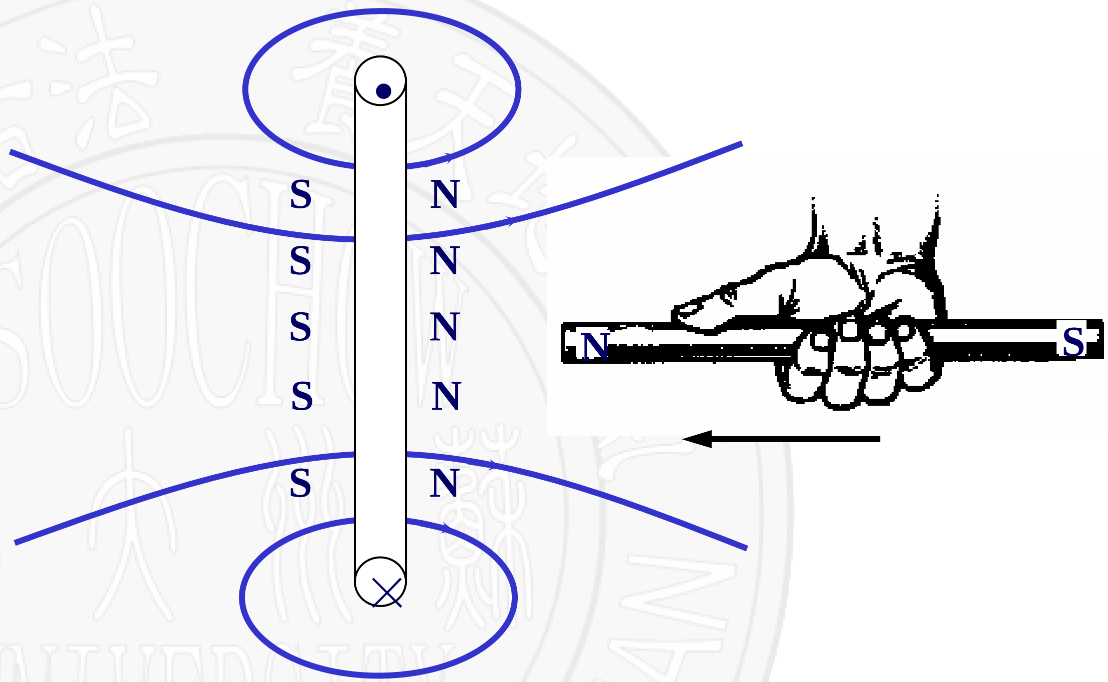
- The effect of induced current always resists the reason producing induction current.

- Lenz's Law obeys the conservation law of energy.



5.1 Faraday's Law of Induction

Lenz's law Obey the conservation law of energy



If we move the magnet toward the loop, the induced current points as shown, setting up a magnetic field that oppose the motion of the magnet.