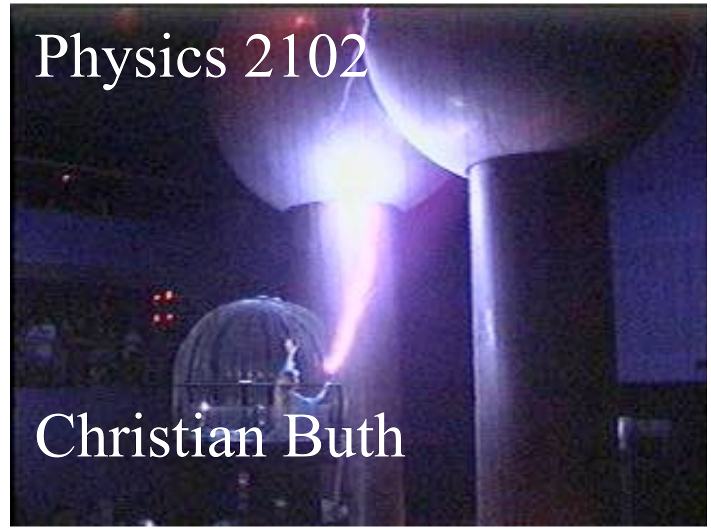


Physics 2102
Lecture 26
Induction 2

03/18/2009

Nikola Tesla

Review

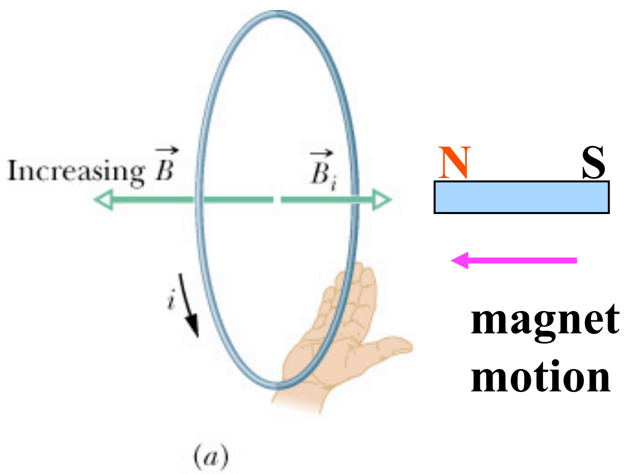
- Magnetic flux: $\Phi_B = \int \vec{B} \cdot d\vec{A}$
- Faradays' law: $\mathcal{E} = -\frac{d\Phi_B}{dt}$

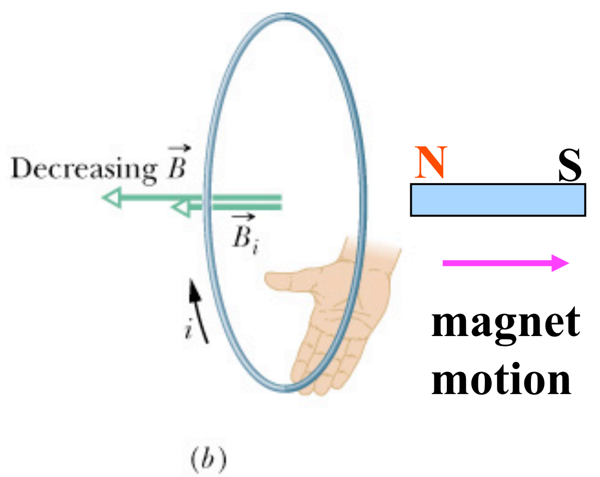
An emf is induced in a loop when the number of magnetic field lines that pass through the loop is changing.

- Negative sign in Faradays' law from **Lenz rule**:

An induced current has a direction such that the magnetic field due to the induced current opposes the change in the magnetic flux that induces the current.

Opposition to Flux Change



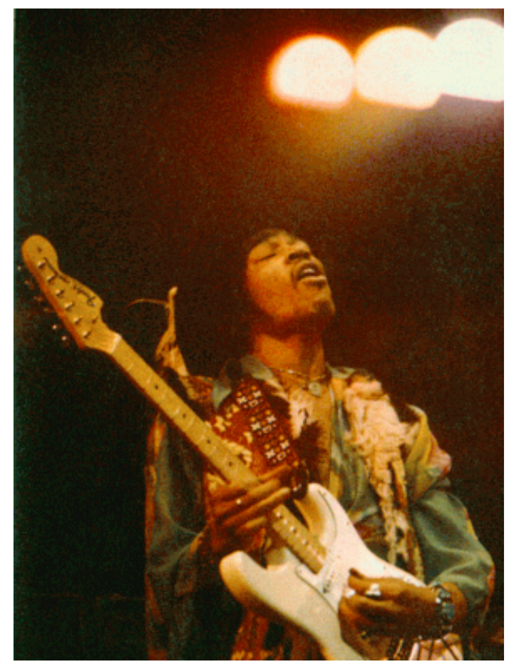


- **Approaching**; field / flux **increase**
- **Counterclockwise** induced current; net field: $\vec{B} - \vec{B}_i$
- Induced current tries to **prevent** flux from increasing
- **Retreating**; field / flux **decrease**
- **Clockwise** induced current; net field: $\vec{B} + \vec{B}_i$
- Induced current tries to **prevent** flux from decreasing

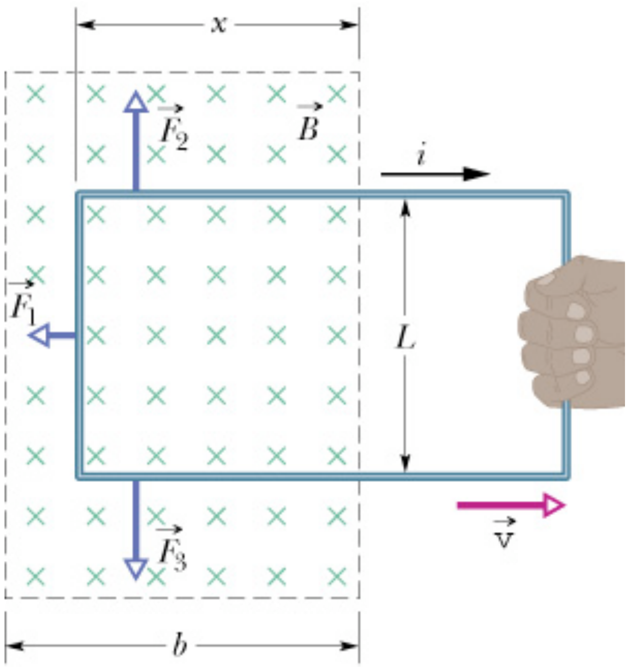
Some interesting applications

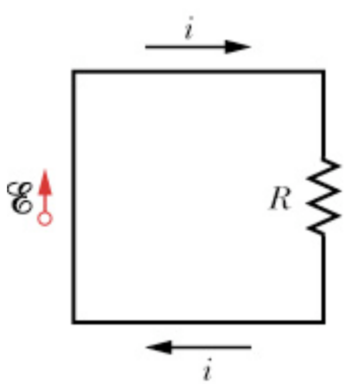
MagLev train relies on Faraday's Law: currents induced in non-magnetic rail tracks create induction and supply the train with energy; magnets in the track repel the moving magnets, result: levitation! A linear motor provides propulsion

Guitar pickups also use Faraday's Law -- a vibrating string modulates the flux through a coil hence creating an electrical signal at the same frequency.



Induction and Energy Transfers





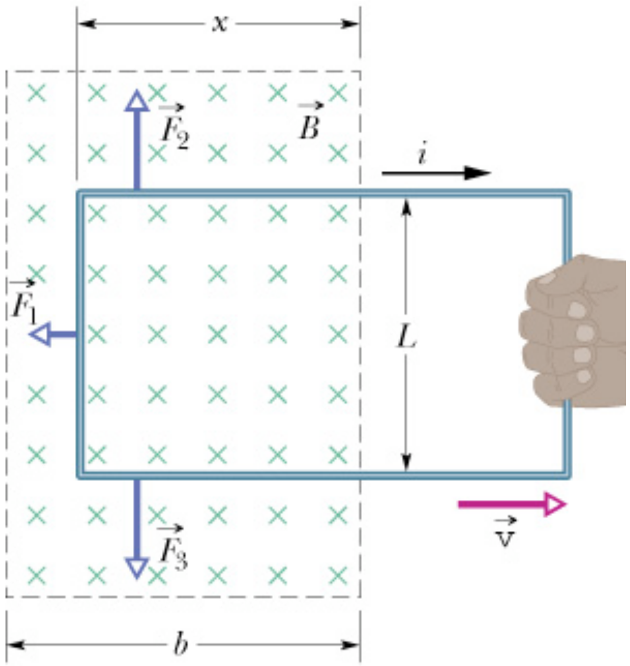
- Lenz's rule: induced current **opposes** external agent
- External agent **must do work**
- Work converted into **thermal energy** in resistance
- Lenz's rule different formulation of **energy conservation**

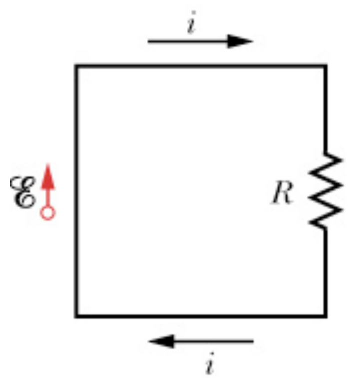
$$\Phi_B = BA = BLx$$

$$|EMF| = \frac{d\Phi_B}{dt} = BL\frac{dx}{dt} = BLv$$

$$i = \frac{|EMF|}{R} = \frac{BLv}{R}$$

Thermal and Mechanical Energy





- **Dissipation** of thermal energy:

$$P_{th} = i^2 R = \frac{B^2 L^2 v^2}{R}$$

- **Mechanical power** on loop:

$$\vec{F}_1 = i\vec{L} \times \vec{B}$$

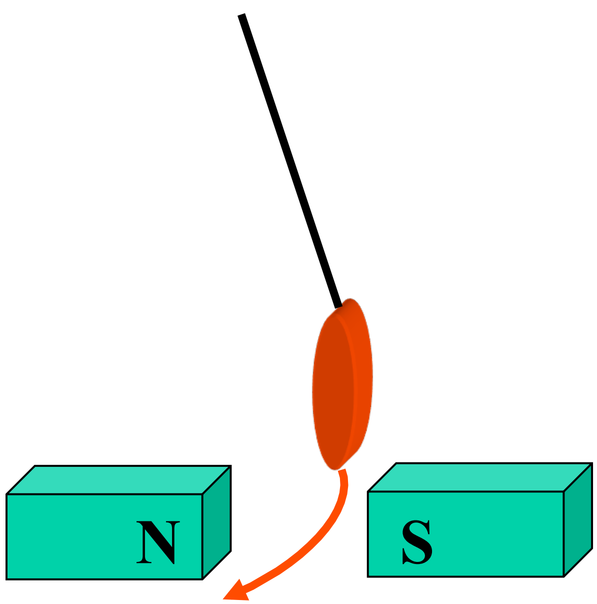
$$F_1 = iLB = \frac{B^2 L^2 v}{R}$$

$$P_{mech} = F_1 v = \frac{B^2 L^2 v^2}{R}$$

- Mechanical energy is fully **converted** into thermal energy

Another Experimental Observation

- Drop a non-magnetic pendulum (copper or aluminum) through an inhomogeneous magnetic field
- What do you observe? Why? (Think about energy conservation!)



Pendulum had kinetic energy
What happened to it?
Isn't energy conserved??

Summary

- Lenz's rule different formulation of **energy conservation**
- Thermal energy and mechanical energy are **equal** when pulling a conducting loop through a magnetic field
- A pendulum in magnetic fields is slowed down due to induced **eddy currents**