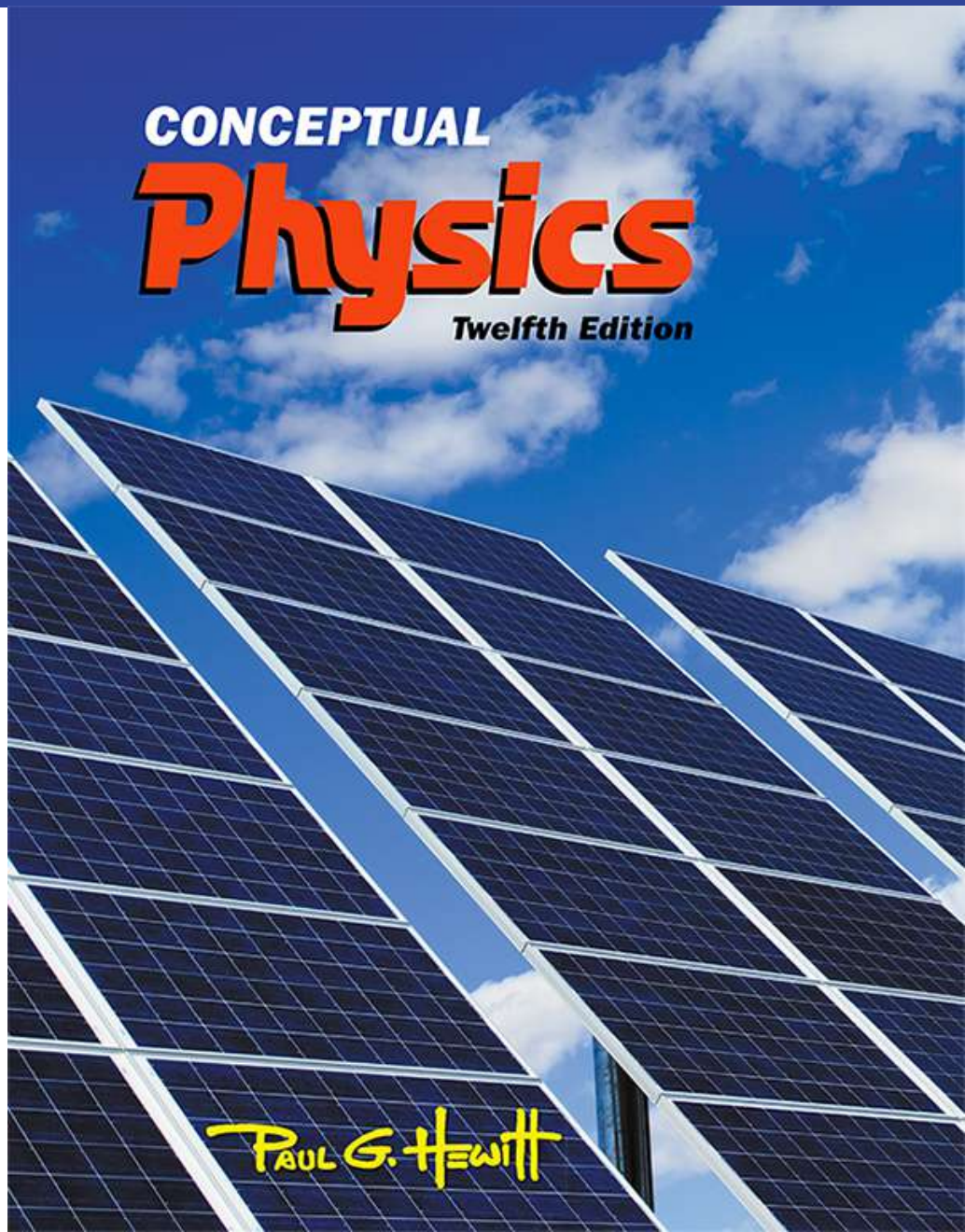
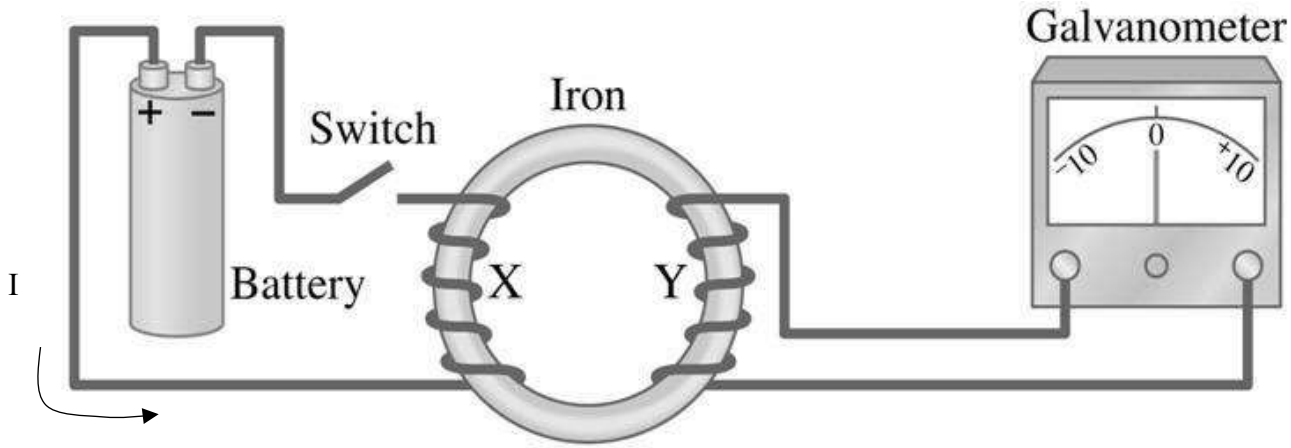
Lecture Outline



Chapter 25: Electromagnetic Induction

Part 1

What did Faraday do?



Close switch. Current flows in coil X.

This starts a magnetic field in coil X.

Galvanometer measures a current.

Open switch. Current stops flowing in X.

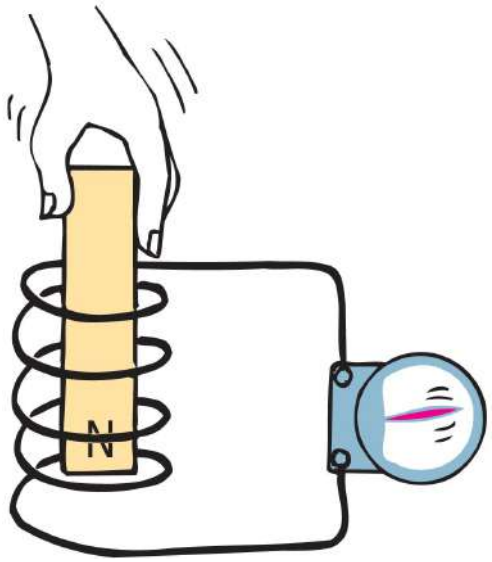
This stopped a magnetic field in coil X

Galvanometer measures a current, again.

No current if switch was left open or closed!

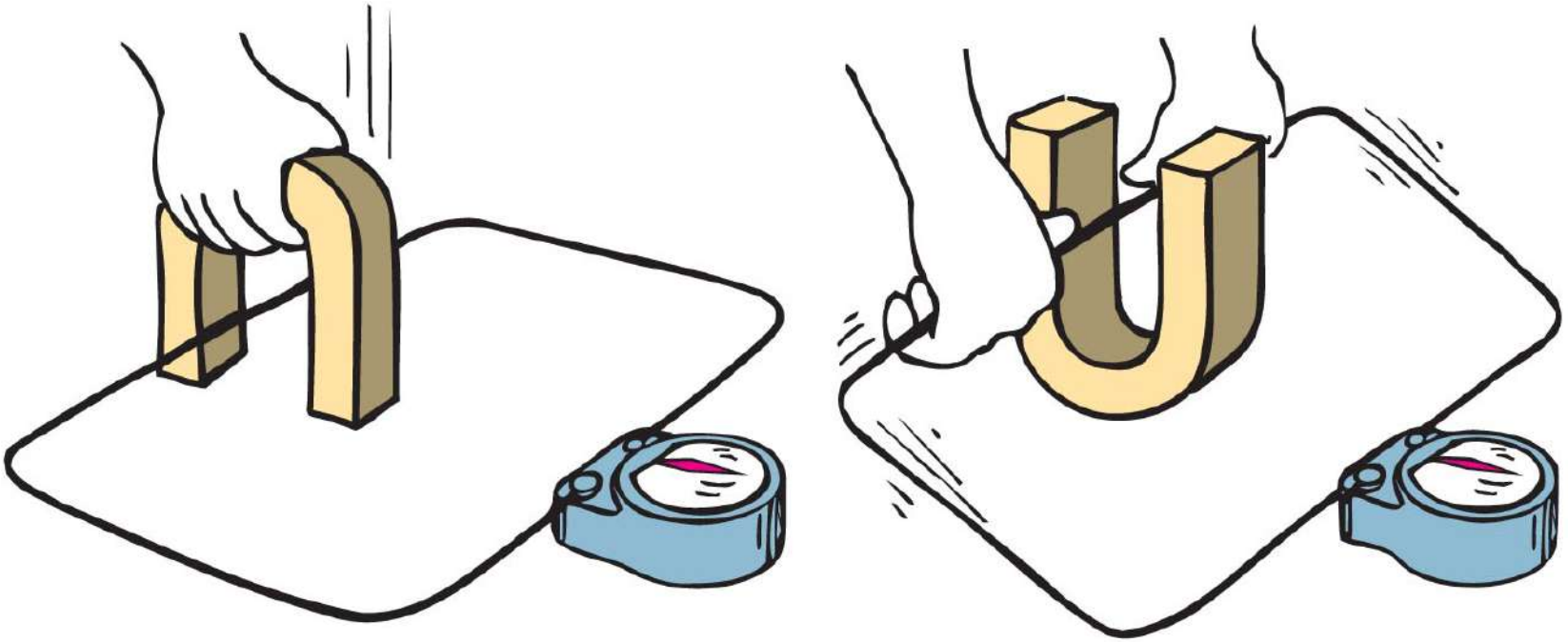
Electromagnetic Induction

- Electromagnetic induction



- Discovered by Faraday and Henry
- Induces (causes) a voltage by changing the magnetic field strength in a coil of wire

Electromagnetic Induction, Continued-1

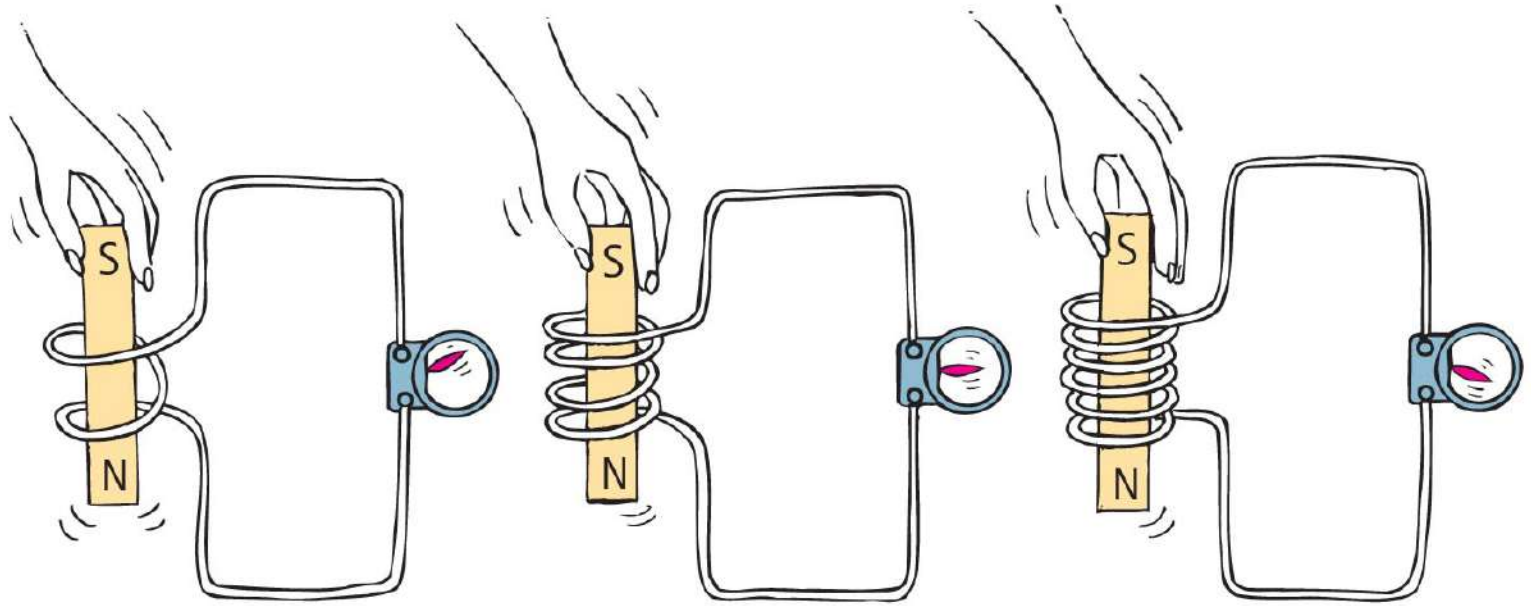


- Voltage is induced in the wire loop whether the magnetic field moves past the wire or the wire moves through the magnetic field.

Electromagnetic Induction, Continued

- Electromagnetic induction (continued)
  - Induced voltage can be increased by
    - increasing the number of loops of wire in a coil.
    - increasing the speed of the magnet entering and leaving the coil.
      - Slow motion produces hardly any voltage.
      - Rapid motion produces greater voltage.

Electromagnetic Induction, Continued-2



- When a magnet is plunged into a coil with twice as many loops as another, twice as much voltage is induced. If the magnet is plunged into a coil with 3 times as many loops, 3 times as much voltage is induced.

The coil repels the magnet!

You push magnet.

Magnetic field changes.

Current is induced in wires.

Wire coils become a magnet.

Coil magnet repels you.

Why? Magnetic inertia.

→ It resists changes

→ More coils → more repulsion

FIGURE 25.4
It is more difficult to push the magnet into a coil that has more loops because the magnetic field of each current loop resists the motion of the magnet.

Faraday's Law
CHECK YOUR NEIGHBOR

The resistance you feel when pushing a piece of iron into a coil involves

A. repulsion by the magnetic field you produce.
B. energy transfer between the iron and coil.
C. Newton's third law.
D. resistance to domain alignment in the iron.

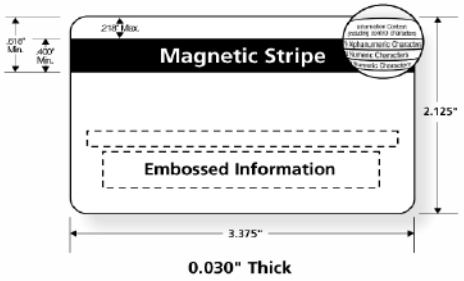
Faraday's Law
CHECK YOUR ANSWER

The resistance you feel when pushing a piece of iron into a coil involves

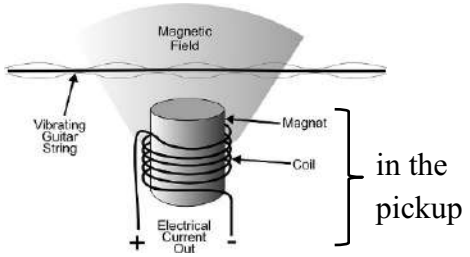
A. repulsion by the magnetic field you produce.

Examples of electromagnetic induction:

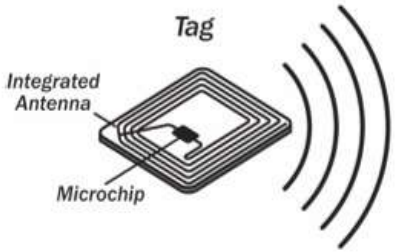
- Credit/debit cards at ATM



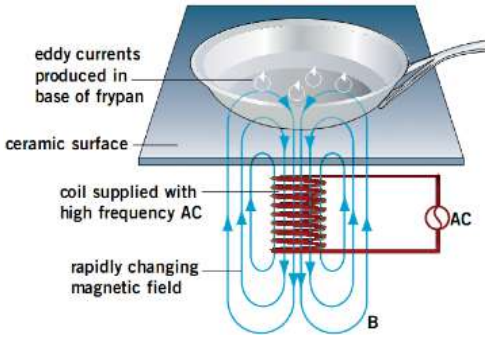
- Electric guitar



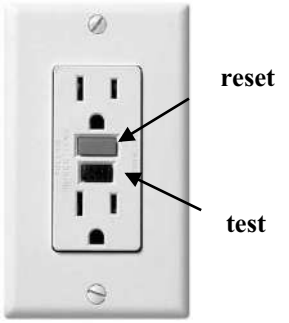
- security systems

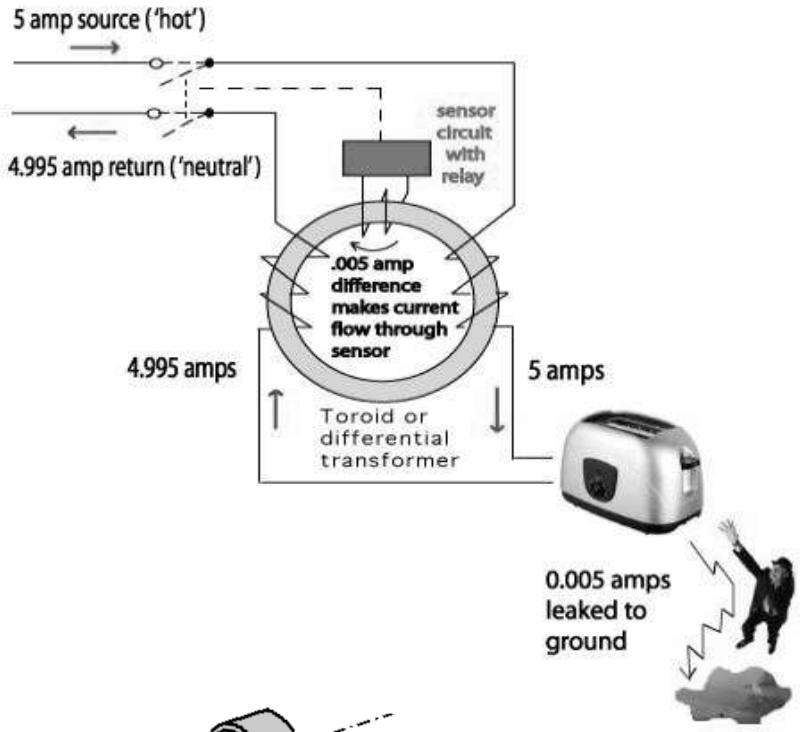


- Induction stove

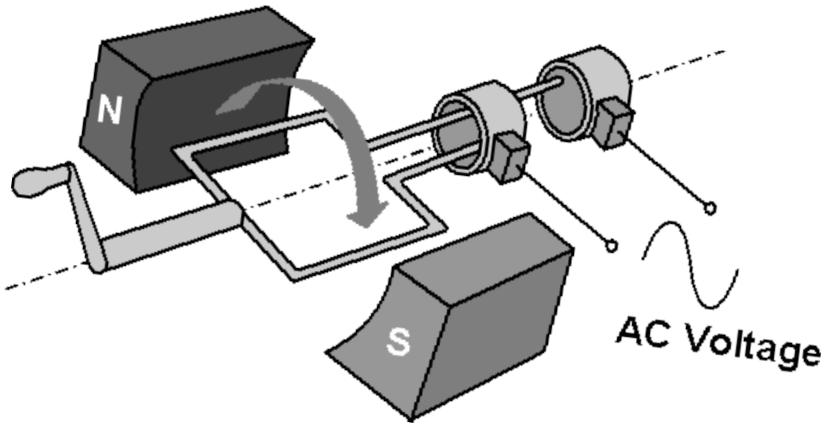


GFI switches:





Generators:



- computer hard drive (magnetic storage)
- Phonograph needle:
- Car activating traffic lights

- Faraday's law
  - the induced voltage in a coil is proportional to the

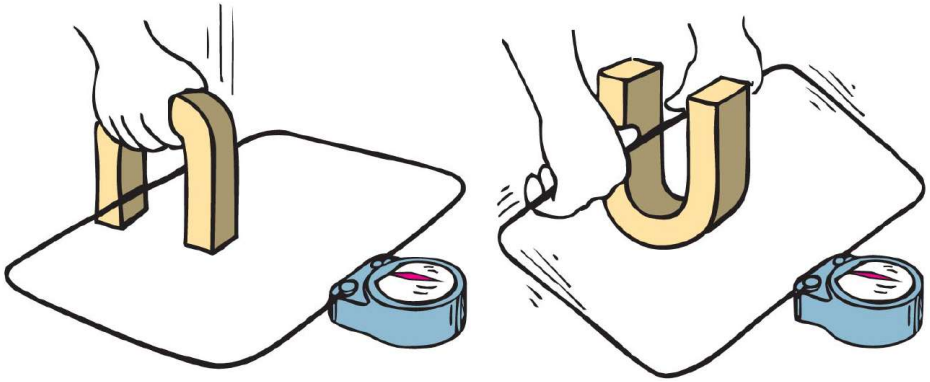
  1) number of loops,

  2) the cross-sectional area of the loops,

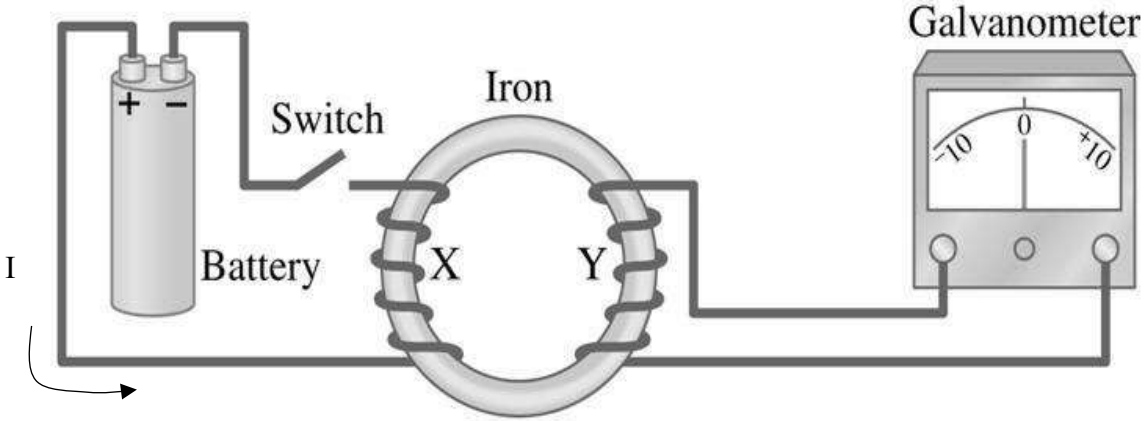
  3) the rate at which the magnetic field changes within those loops.

- Voltage induced in a wire requires **changing magnetic field** in the loop by 3 ways:

1) moving the loop near a magnet
2) moving a magnet near a loop,



3) changing the current in a nearby loop.



1. What important discovery did physicists Michael Faraday and Joseph Henry make?

2. What must change in order for electromagnetic induction to occur in a wire coil?

3. State Faraday's law.

4. What are the three ways in which voltage can be induced in a loop of wire?

Remember Ohm's Law: current = $\frac{voltage}{resistance}$

Amount of current produced by electromagnetic induction is dependent on

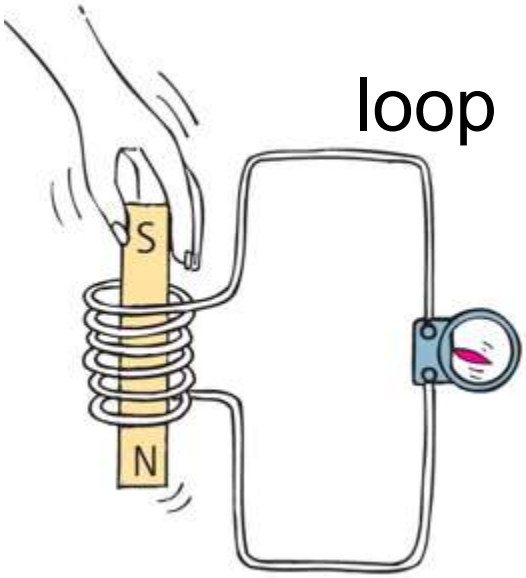
- induced voltage
- resistance of the coil,
- circuit that it connects

Ex: metal vs. plastic loops

Voltage same for both!

metal loop → current

plastic loop → no current



Faraday's Law
CHECK YOUR NEIGHBOR, Continued

More voltage is induced when a magnet is thrust into a coil

A. more quickly.
B. more slowly.
C. Both A and B.
D. Neither A nor B.

Faraday's Law
CHECK YOUR ANSWER, Continued

More voltage is induced when a magnet is thrust into a coil

A. more quickly.

Faraday's Law
CHECK YOUR NEIGHBOR, Continued-1

Not only is voltage induced when a magnet is thrust into a coil of wire but _____ is also induced.

A. current
B. energy
C. power
D. None of the above.

Faraday's Law
CHECK YOUR ANSWER, Continued-1

Not only is voltage induced when a magnet is thrust into a coil of wire but _____ is also induced.

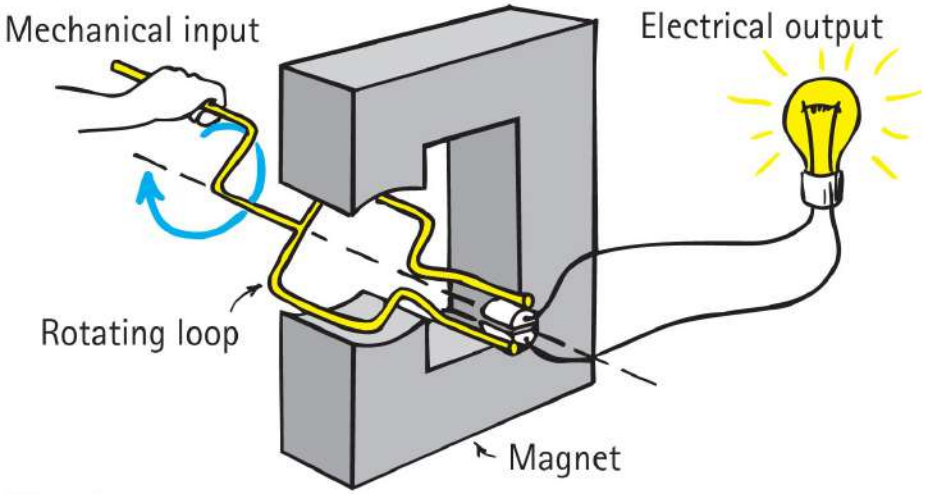
A. current

Comment:

Don't say *energy* or *power,* which are conservation-of-energy no-no's! Energy can be transferred but not created by induction.

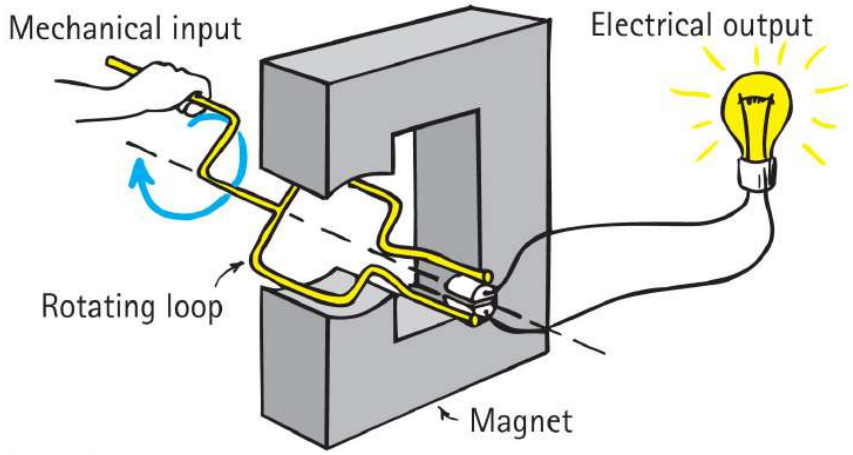
Generators and Alternating Current

- Generator
  - Opposite of a motor
  - Converts mechanical energy into electrical energy via coil motion
  - Produces alternating voltage and current



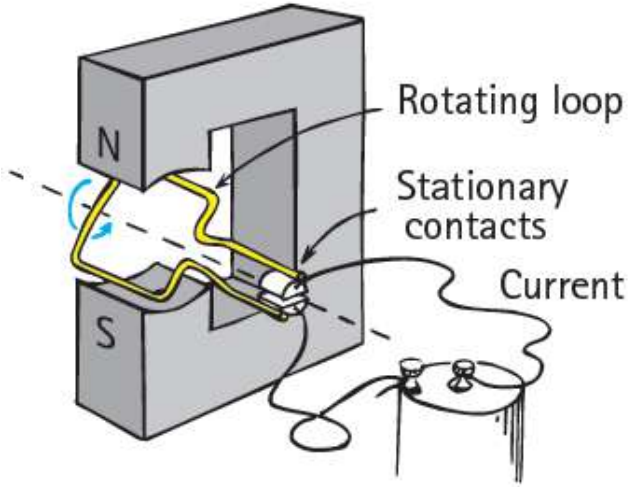
Compare generator to motor:

generator:



Transforms mechanical to electrical energy.

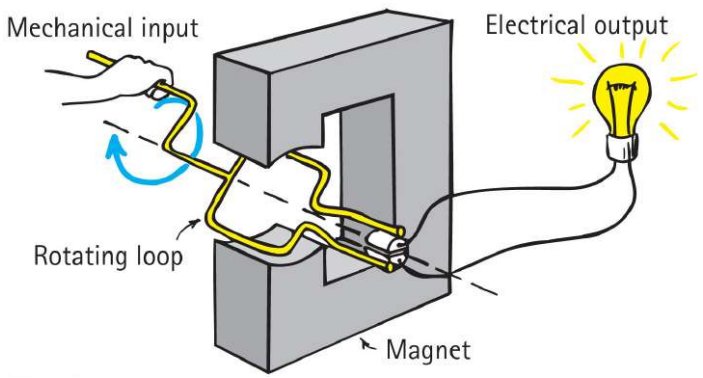
motor:



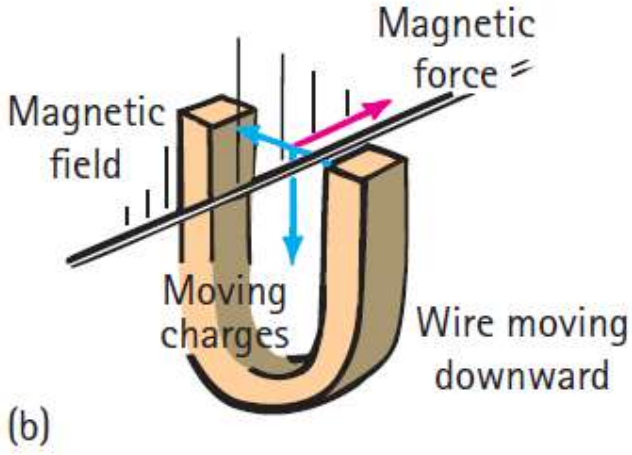
Transforms electrical to mechanical energy.

NOTICE: Both have a magnet and a coil.

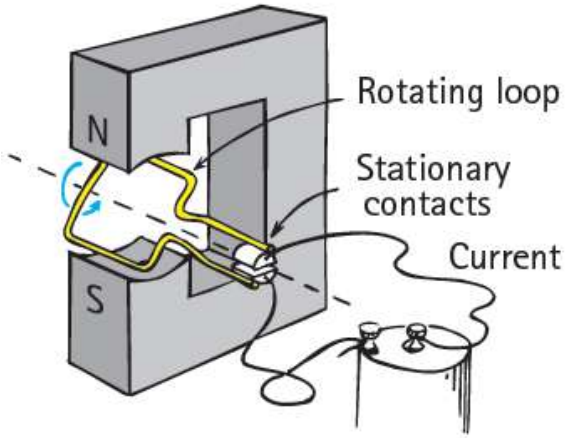
generator:



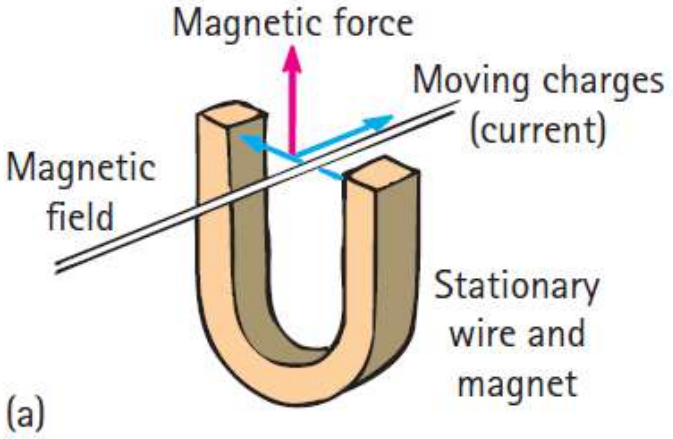
based on the generator effect:



motor:

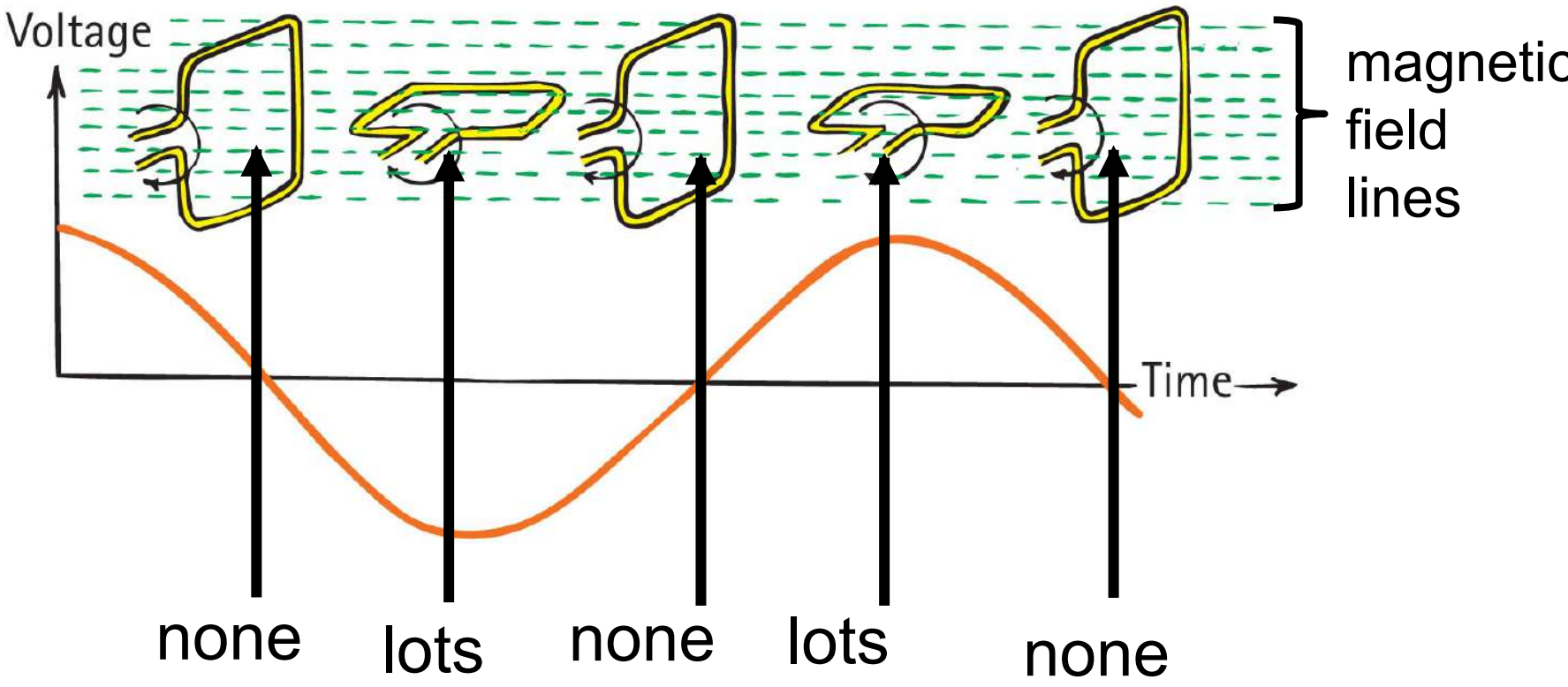


based on the motor effect



Generators and the Faraday Law

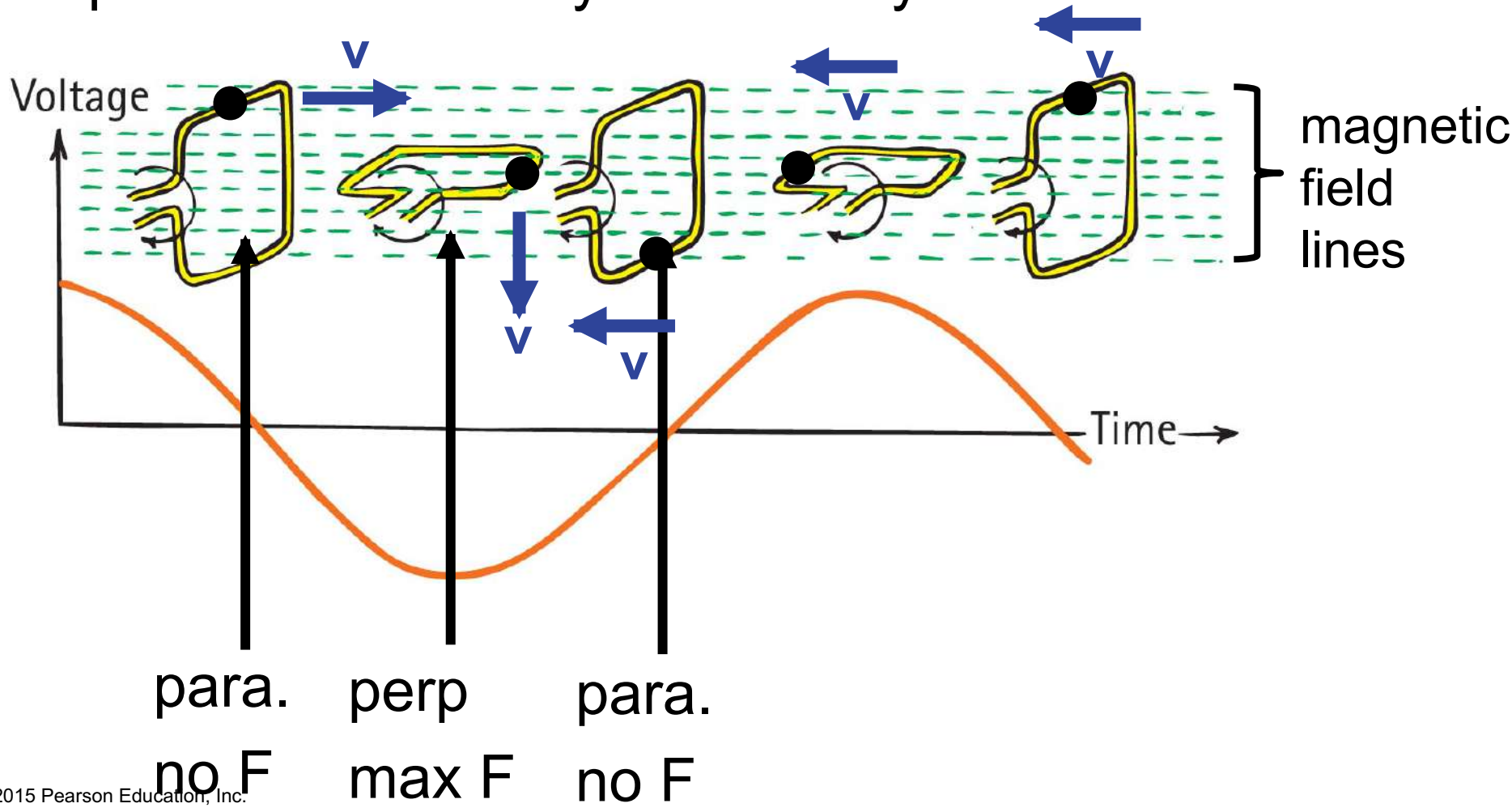
- The induced voltage depends on the rate at which the magnetic field is changing in the loop:



Voltage is caused by forces on charges

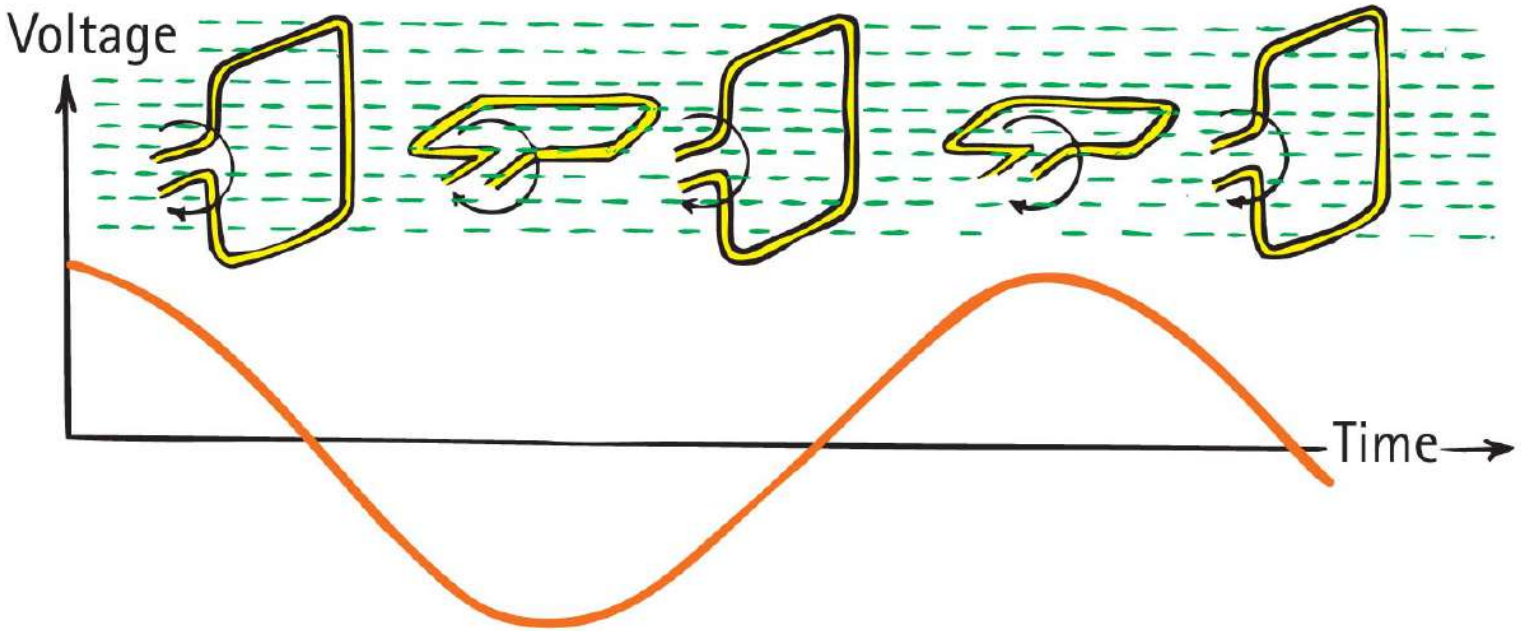
Look at the force F acting on a point in the wire.

The point has a velocity v shown by blue arrows.



Generators Produce Alternating Current

- The frequency of alternating voltage induced in a loop is equal to the frequency of the changing magnetic field within the loop.



5. How does the frequency of induced voltage relate to how frequently a magnet is plunged in and out of a coil of wire?

6. What are the basic differences and similarities between a generator and an electric motor?

7. Is the current that is produced by a common generator ac or dc?

8. What is the common frequency of ac in homes in the United States?