# PHYSICS 571 – Master's of Science Teaching

# "Electromagnetism and Light"
# Lecture 4 – Magnetism and Magnetic Induction

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# Outline

Review of magnetic forces and cross products.

Magnetic forces do no Work.

Magnetic Induction

Faradays Law

Examples

- Changing B, constant A
- Changing A, constant B

Generators

- Constant B, rotating A

Rigorous definition of Flux

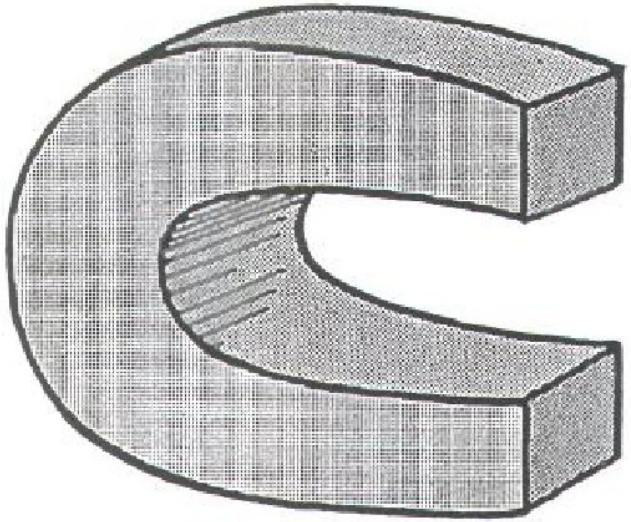
# Magnetic Fields Review
# CHECK YOURSELF

**The source of all magnetism is**

A. electrons rotating around an atomic nucleus.
B. electrons spinning around internal axes.
C. both A and B
D. tiny bits of iron.

# NEXT-TIME QUESTION





Compared to the huge force that attracts an iron tack to a strong magnet, the force that the tack exerts on the magnet is

a) relatively small.

b) equally huge.

# NEXT-TIME QUESTION

CONCEPTUAL Physics

The two iron bars look alike, but only one is a magnet.

How can you determine which is the magnet only by investigating their interaction with each other?

**Exercise 18**

In a cyclotron, protons are subjected to electric and magnetic fields. One field increases the speed of the electrons while the other causes them to follow a curved path. Which is which?

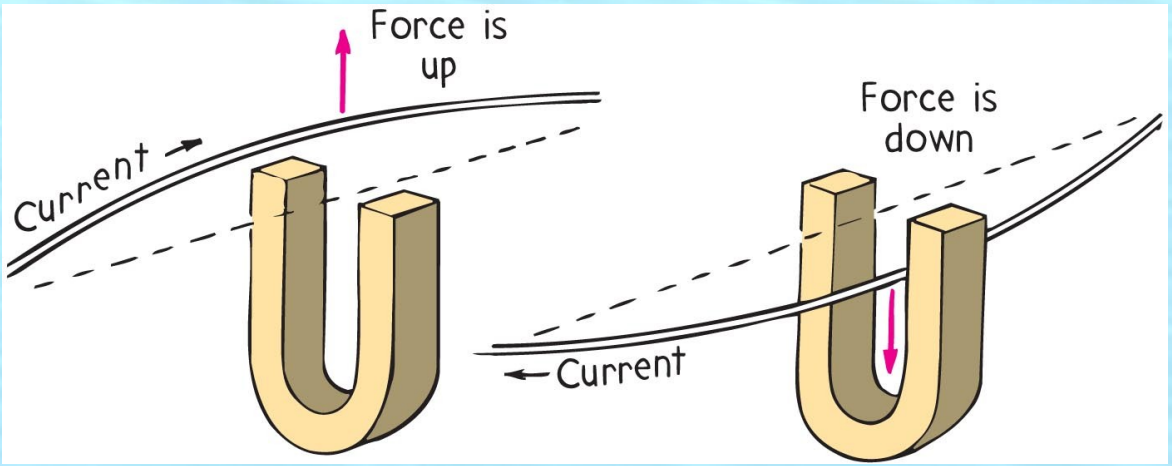
$$\vec{F}_{magnetic} = q\vec{v} \times \vec{B}$$

$$\vec{F}_{electric} = q\vec{E}$$

# Magnetic Force on Moving Charges

Magnetic force on current-carrying wires

- current of charged particles moving through a magnetic field experiences a deflecting force
  - direction is perpendicular to both magnetic field lines and current (perpendicular to wire)
  - strongest when current is perpendicular to the magnetic field lines



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**Exercise 20**

A magnetic field can deflect a beam of electrons, but it cannot do work on the electrons to change their speed. Why?

$$\vec{F}_{\text{magnetic}} = q\vec{v} \times \vec{B}$$

$$W = \vec{F} \cdot \Delta\vec{r}$$

# Exercise 20

A magnetic field can deflect a beam of electrons, but it cannot do work on the electrons to change their speed.  Why?

# Magnetic Force on Moving Charges
## CHECK YOURSELF

**The reason that an electron moving in a magnetic field doesn't pick up speed is**

A. magnets only divert them.
B. only electric fields can change the speed of a charged particle.
C. the magnetic force is always perpendicular to its motion.
D. all of the above

# Homework 4a

Magnetic Force Worksheet

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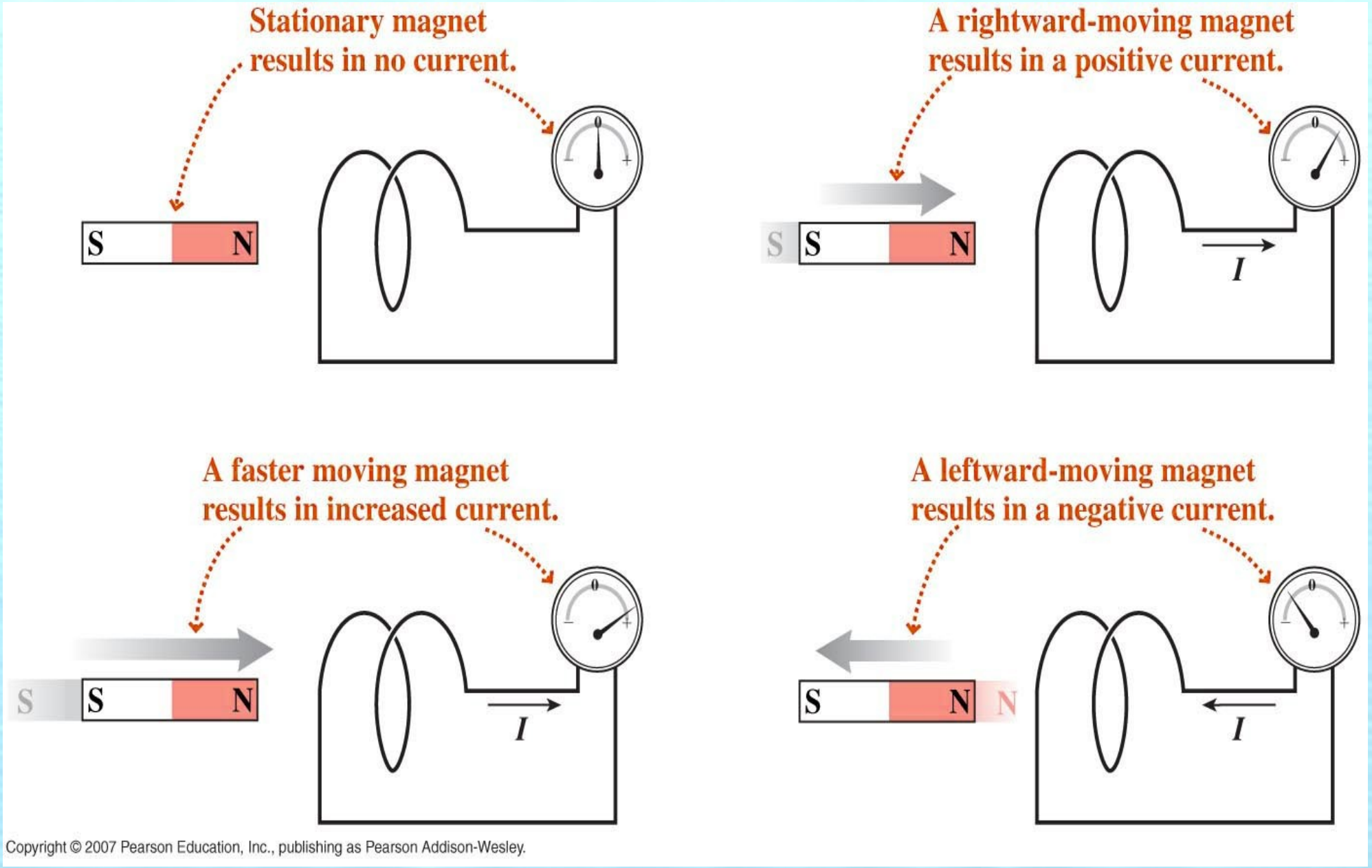
# Electromagnetic Induction



# Electromagnetic Induction

Faraday's law

- States that the induced voltage in a coil is equal to the rate of change of the "Magnetic Flux" through that coil.
  - Thus, the induced voltage in a coil is proportional to the number of loops, multiplied by the rate of B-field change within those loops
- amount of current produced by electromagnetic induction is dependent on
  - resistance of the coil
  - circuit that it connects
  - induced voltage

# Electromagnetic Induction

## Application of Faraday's law

- activation of traffic lights by a car moving over underground coils of wire
- triggering security system at the airport by altering magnetic field in the coils as one walks through
- scanning magnetic strips on back of credit cards
- recording of sound on tape
- electronic devices in computer hard drives, Original iPods
- Generators
- Transformers

# Electromagnetic Induction

It is more difficult to push the magnet into a coil with many loops because the magnetic field of each current loop resists the motion of the magnet.

- The fact that magnets "resist change" is called "Lenz's Law".

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    Changing B, constant A
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## Faraday's Law

Changing magnetic fluxes produce electric fields and hence voltages.

$$\int \vec{E} \cdot d\vec{r} = \varepsilon = -\frac{d\Phi_B}{dt} \qquad \varepsilon = \frac{-d\Phi_B}{dt}$$

## Lenz's Law
## (the minus sign in Faraday's law)

Changing fluxes produce currents which would oppose the changing flux.

# Ways to change flux

Let $\vec{B}$ be uniform over the loop. Then

$$\Phi_B = \vec{B} \cdot \vec{A}$$

$$\frac{d\Phi_B}{dt} = \frac{d\vec{B}}{dt} \cdot \vec{A} + \frac{d\vec{A}}{dt} \cdot \vec{B}$$

- Can move loop into stronger or weaker B.
- Can increase/decrease B.
- Can rotate B.
- Can increase/decrease size of loop.
- Can rotate loop.

# Faraday's law, electromagnets, generators etc.

http://phet.colorado.edu/en/simulation/faraday

# Electromagnetic Induction
## CHECK YOUR NEIGHBOR

**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

# Electromagnetic Induction
## CHECK YOUR NEIGHBOR

**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

# Electromagnetic Induction
## 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.

# Ways to change flux

Let $\vec{B}$ be uniform over the loop. Then

$$\Phi_B = \vec{B} \cdot \vec{A}$$

$$\frac{d\Phi_B}{dt} = \frac{d\vec{B}}{dt} \cdot \vec{A} + \frac{d\vec{A}}{dt} \cdot \vec{B}$$

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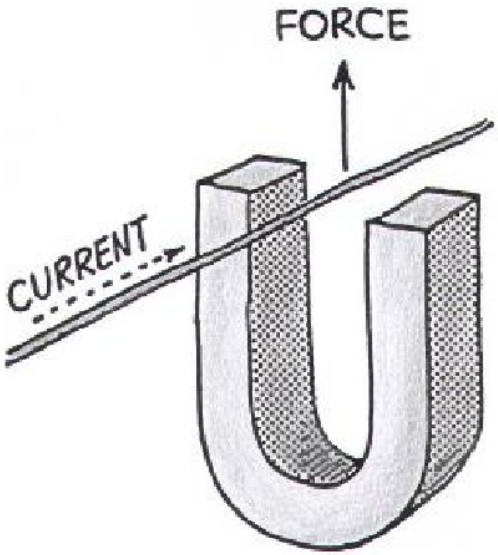
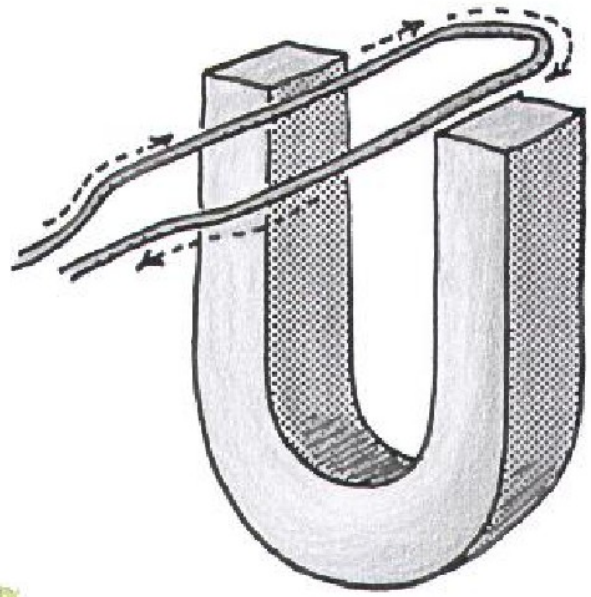
# NEXT-TIME QUESTION

CONCEPTUAL Physics

When current flows in the wire that is placed in the magnetic field shown, the wire is forced upward. If the wire is made to form a loop as shown below, the loop will tend to



a) rotate clockwise.

b) rotate counterclockwise.

c) remain at rest.



Hewitt Drew-it!