Magnetism Review

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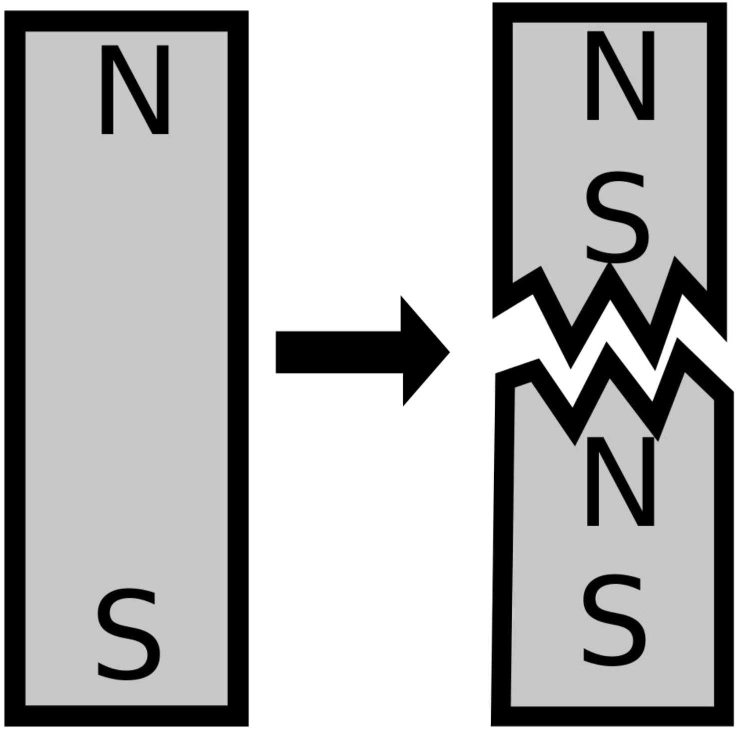
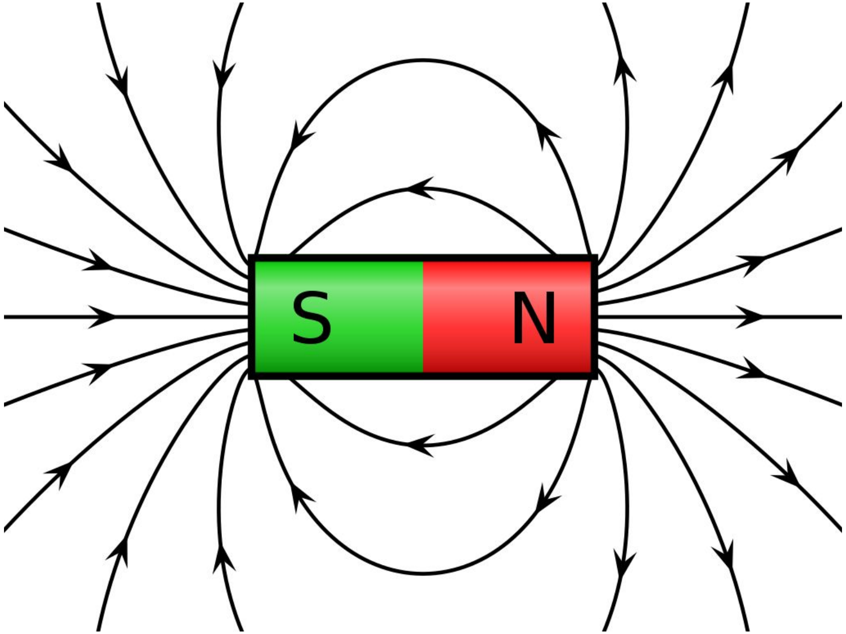
Magnetic Poles

- Every magnet has two poles, a north and south pole
- Like poles repel each other
- Unlike poles attract each other
- North and south poles cannot be separated, there will always be two poles



Magnetic Fields

- Magnetic fields surround magnets
- The shape of a magnetic field is shown by magnetic field lines
- Field lines:
    - Point from north to south
    - Never cross each other
    - The density of the lines are proportional to the depth of the field
- **Magnetic fields are produced by motion of electric charge**

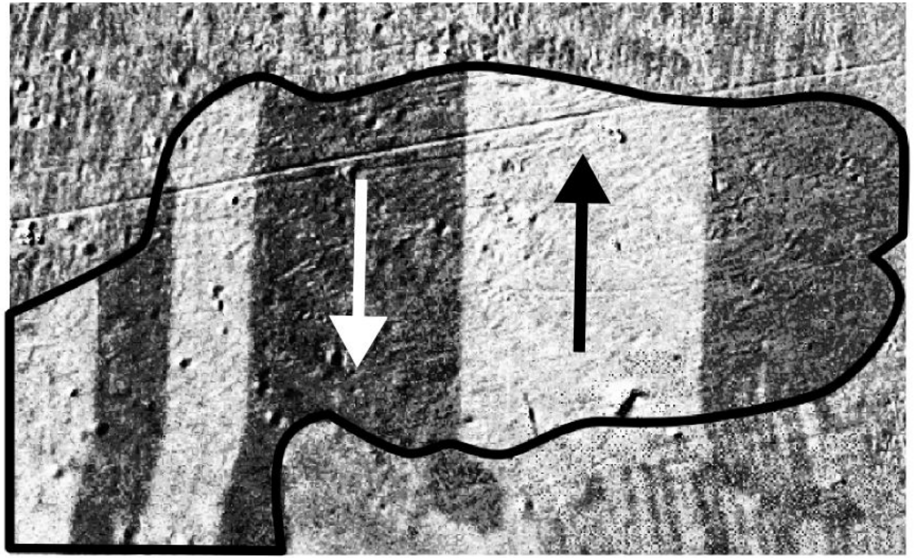


Making Magnetism

- Ferromagnets: materials that show strong magnetic effects
- Those materials include iron, cobalt, nickel, and gadolinium
- A moving charge is surrounded by a magnetic field
  - Charges in motion have both an electric and magnetic field

Magnetic Domains

- Magnetic fields of individual iron atoms are strong
- Interactions between iron atoms that are next to each other cause them to line up in large clusters called magnetic domains

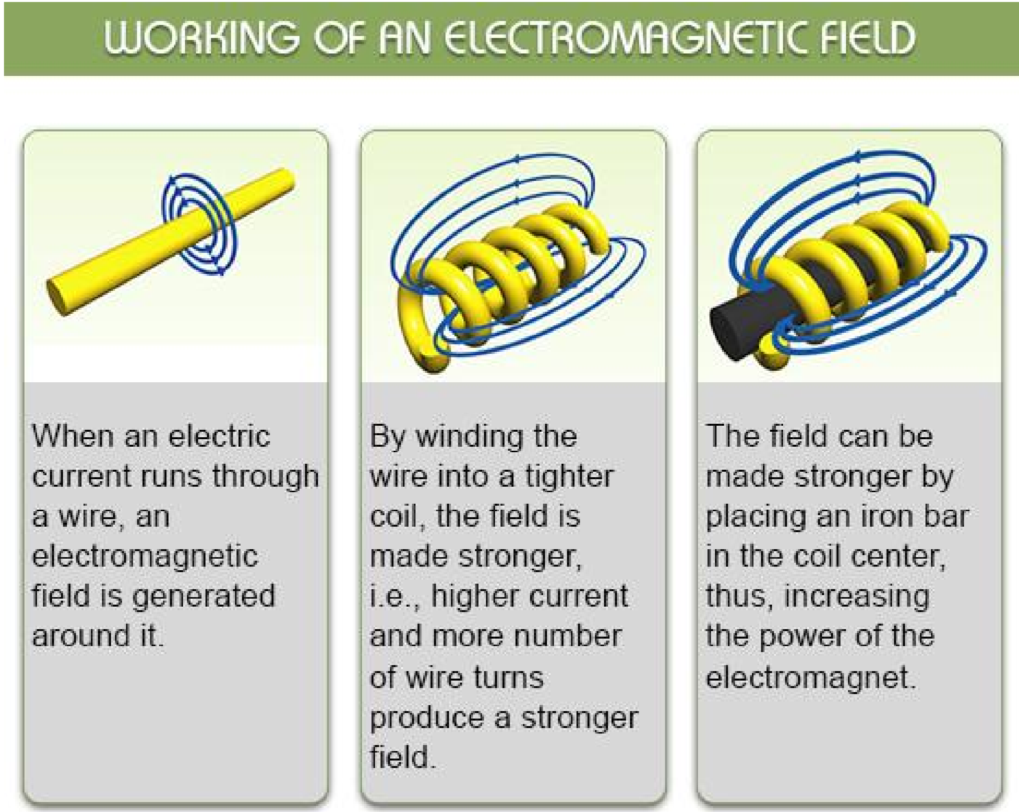


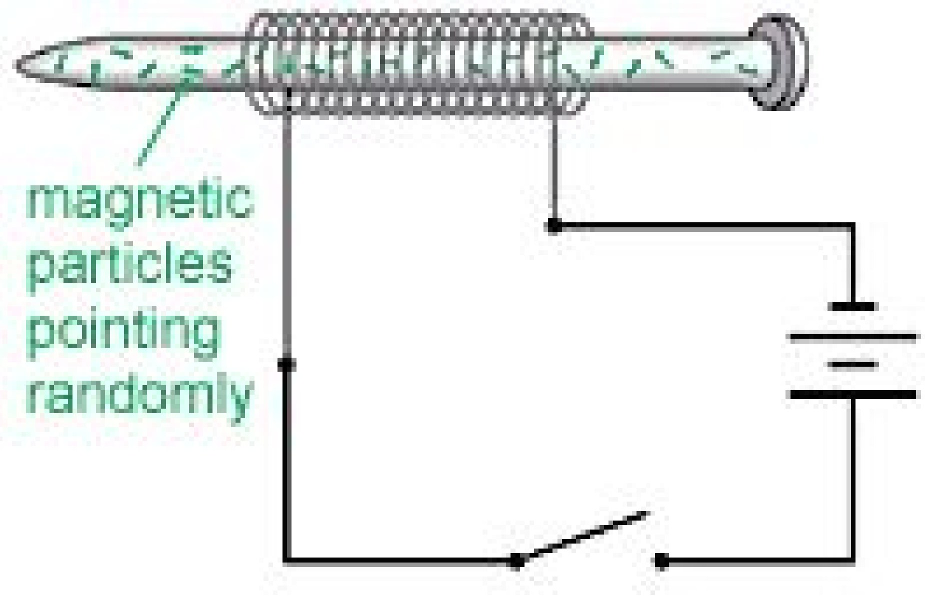
Magnetism and Electric Current

- ❖ Looping a current carrying wire increases the magnetic field.
- ❖ The field will be more concentrated in the center of the loop.
- ❖ Stacking multiple loops concentrates the field even more.

Electromagnets

- ❖ Electromagnet: a magnet that runs on electricity.
- ❖ The strength can be changed by the amount of electric current that flows through it.
- ❖ Make the electromagnet stronger by:
  - ➢ Increasing the current
  - ➢ Increasing the number of turns
  - ➢ Putting in a soft iron core





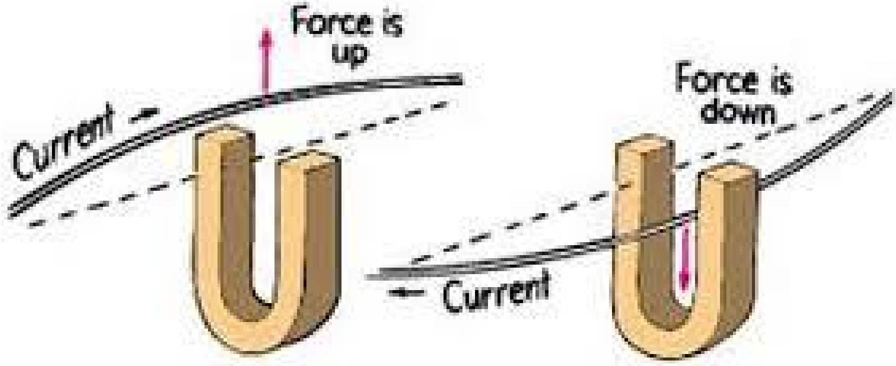
The magnetic particles in a soft iron nail will line up with the magnetic field when the current is switched on.

Superconductors

- ❖ Superconducting materials have less interaction between atoms and current, so the moving charges lose much less energy.
- ❖ This means they can conduct much larger electric currents than ordinary wire.

Magnetic Forces on Electric Current

- ❖ An electric current exerts a force on a magnet.
- ❖ Opposite is also true because of Newton’s Third Law
  - ➢ A magnet exerts a force on a current carrying wire.



Magnetic Force on Electric Current continued...

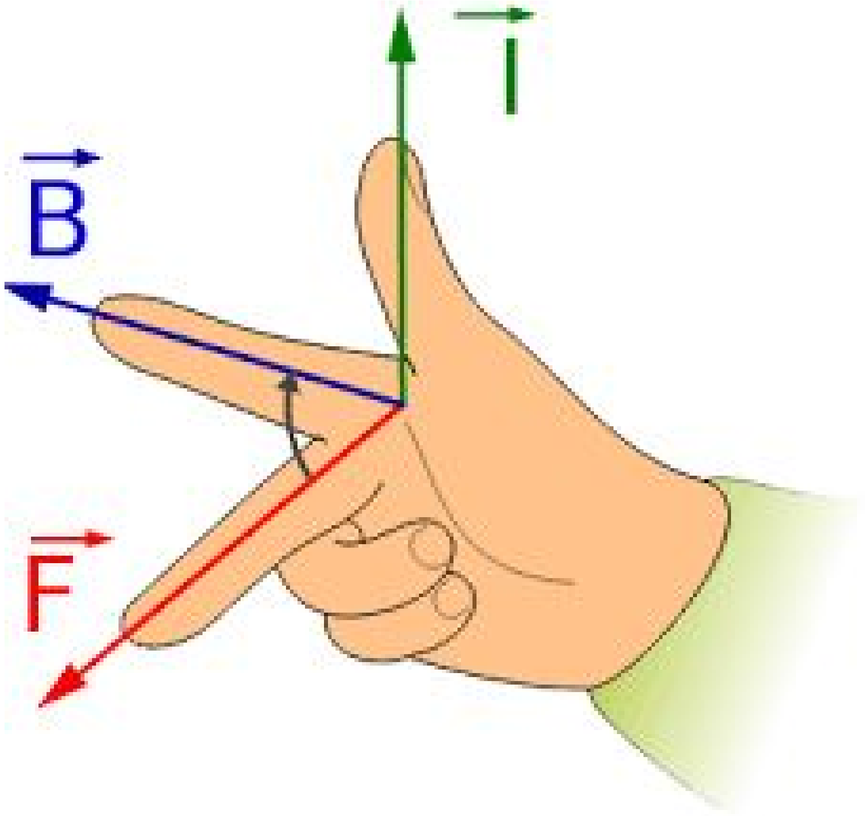
- This force on electric current due to a magnetic field depends on…
  - **Strength of the magnetic field** (B: measured in Teslas)
  - **Current in the wire** (I: measured in Amperes)
  - **Length of the wire in the magnetic field** (ℓ: measured in meters)
  - **Angle the wire makes with the magnetic field** (sinθ)

$$F_B = I\ell B \sin\theta$$

*as you increase the strength of the magnetic field, current in the wire, length of the wire, and/or angle the wire makes with the magnetic field, the force increases.

Right Hand Rule Part 2

-The magnetic force is always perpendicular to both the direction of the current and the direction of the magnetic field.
-Magnetic fields exert a force on electric current (on moving charge)



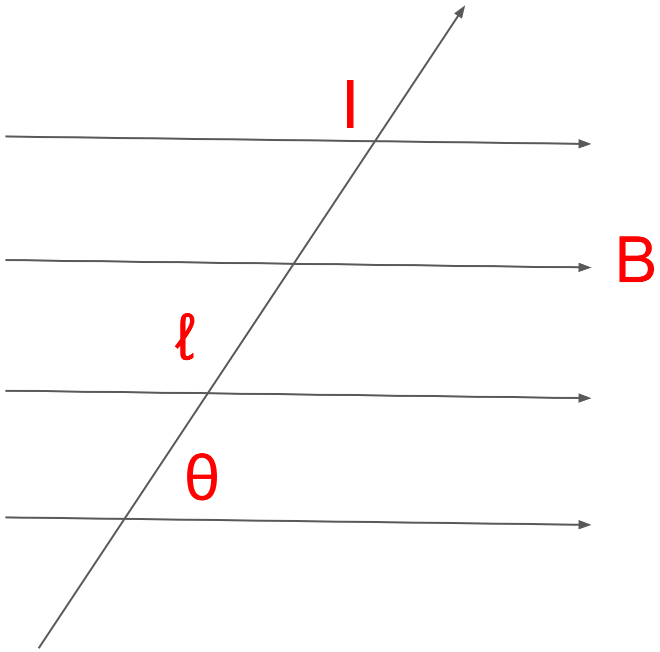
Magnetic Force on Moving Charges

The magnitude of the force on a moving charge due to a magnetic field depends on 4 quantities:

1. Strength of the magnetic field: **B**

2. Charge of the particle: **q**

3. Velocity of the particle: **v**
4. Angle the velocity makes with the magnetic field: **θ**



Magnetic Force on Moving Charges

Put calculator in degree mode!

$$F = qvB \sin\theta$$

F: force (Newtons, N)

q: charge (Coulombs, C)

v: velocity (meters/sec, m/s)

B: magnetic field (Teslas, T)

Θ:angle measure (degrees)

Applicable Equations

$$F_B = qvB\sin\theta$$

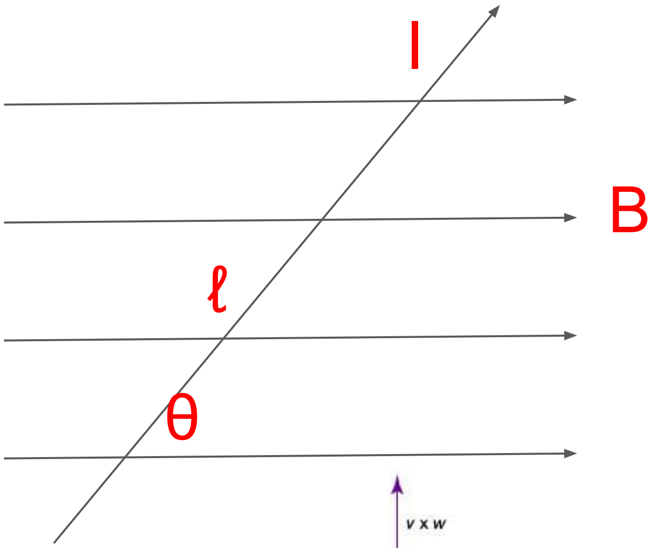
$$F_B = I\ell B \sin\theta$$

$$F_B = q(\ell/t)B\sin\theta$$

$$F_B = qvB\sin\theta$$

Example 1: Right Hand Rule

A wire carrying a 20-A current has length ℓ = 15 **cm** between the pole faces of a magnet at an angle θ = 60º. The magnetic field is approximately uniform at 0.80 T. What is the force on the wire?

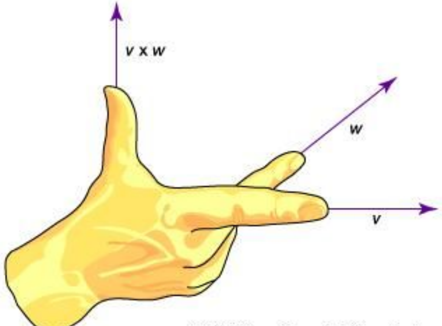


- $F_B = I\ell B \sin\theta$

  $=(20)(.15)(.8)\sin(60)$

Answer: FB = 2.1 N into the board

(use right hand rule, you are trying to find Force, so use your middle finger to determine direction)



Example 2: Right Hand Rule

A proton having a speed of 6.0×106 m/s in a magnetic field feels a force of 9.0 ×10-14 N toward the west when it moves vertically upward. When moving horizontally in a northerly direction, it feels zero force. What is the magnitude and direction of the magnetic field in this region?

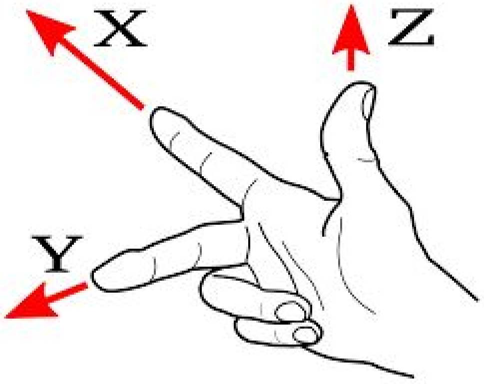
$F_B = qvB\sin\theta$

9.0×10-14=(1.6×10-19)(6.0×106)**B**sin90

9.6×10-13**B**= 9.0×10-14

B=0.09

- Answer: B = 0.09 T north (or into the board)



Right Hand Rule, part 2.5

-Only works for positive charges

-For negative charges, either remember that the force will be in the opposite direction of whatever the right hand rule yields OR use your left hand

-In other words, direction changes when using electrons instead of proton (opposite direction)

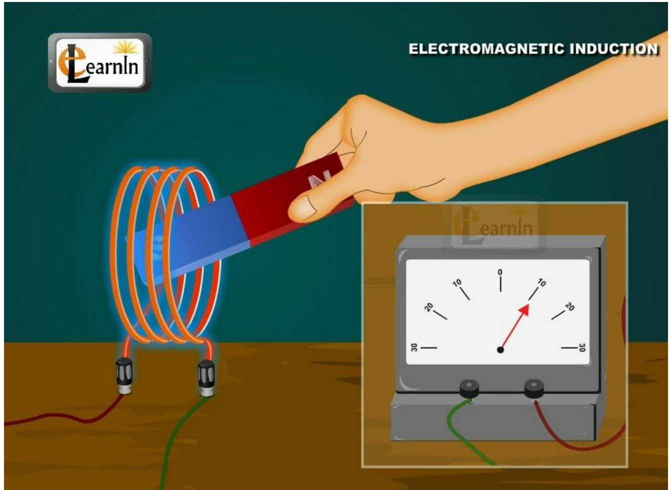
Electromagnetic Induction

Was discovered by Michael Faraday and Joseph Henry

-Basic Idea: Magnetism can produce an electric current in a wire

-(A changing magnetic field will produce a charge)

-Is dependent on the relative motion of the conductor with respect to the magnetic field



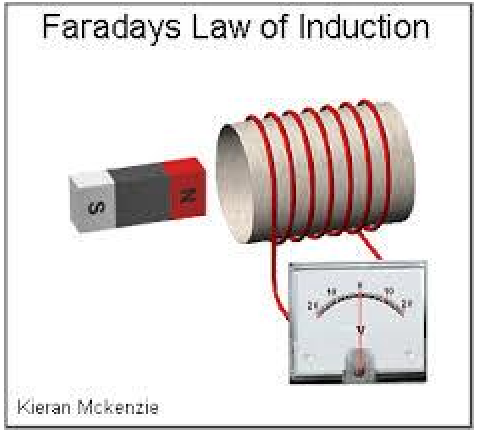
- **Factors of Voltage Magnitude:**

1) **The faster the wire moves through the magnetic field the greater the voltage**

2) **The number of loops in the wire that the magnetic field passes through**
   ****Doubling the number of loops doubles the voltage induced**

Pusing magnets through wire with more loops require more force to do so

Faraday's & Lenz's Laws



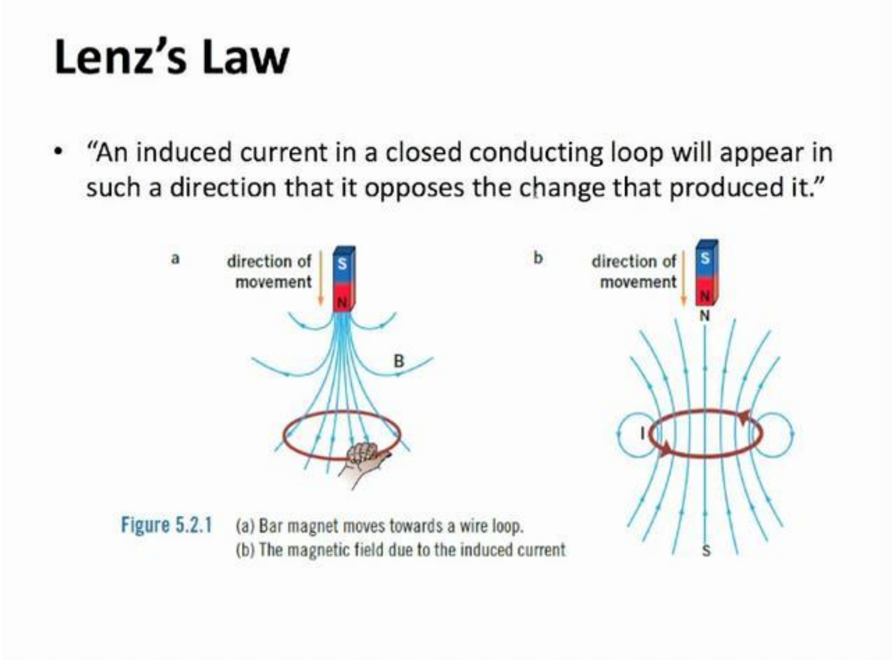
Factors of Voltage Magnitude:

1) **Strength of the magnetic field**
2) **Cross-sectional area of the coil**

Magnetic flux = Magnetic field x cross-sectional area

$$\Phi = B \square A = BA \sin\theta$$ **(measured in webers (Wb))**

Faraday’s & Lenz’s Laws



Faraday’s Law of Induction: $V = N\Delta\Phi/\Delta t$

V is the voltage induced

N= # of loops

$\Delta\Phi/\Delta t$ is the change in flux per time

LENZ’S LAWS

• An induced voltage always gives rise to a current whose magnetic field opposes the original magnetic field which produced it

• Try to push the magnet into the coil and current will counterclockwise, creating a magnetic field that repels the incoming magnet • Try to pull the magnet out of the coil and current will run clockwise, creating a magnetic field that attracts the outgoing magnet

Example 3

A circular, 50-loop coil of wire has a radius of 17cm. It is exposed to a perpendicular magnetic field which grows at a steady rate of .76T/s.What is the induced voltage, and in what direction will current flow?

Direct current is a flow of charge always in one direction. Alternating current is a flow of charge back and forth, changing its direction many times in one second. **Batteries** produce DC current, while the **outlets** in our homes use AC current.

Electric Generators and Motors

Electric Generators

-converts mechanical
Energy into electric
Energy

Building an Electric Generator

-an electric generator can be made by plunging a magnet into and out of a coil of wire

magnet *Enters* *→ the strength of the field increase*

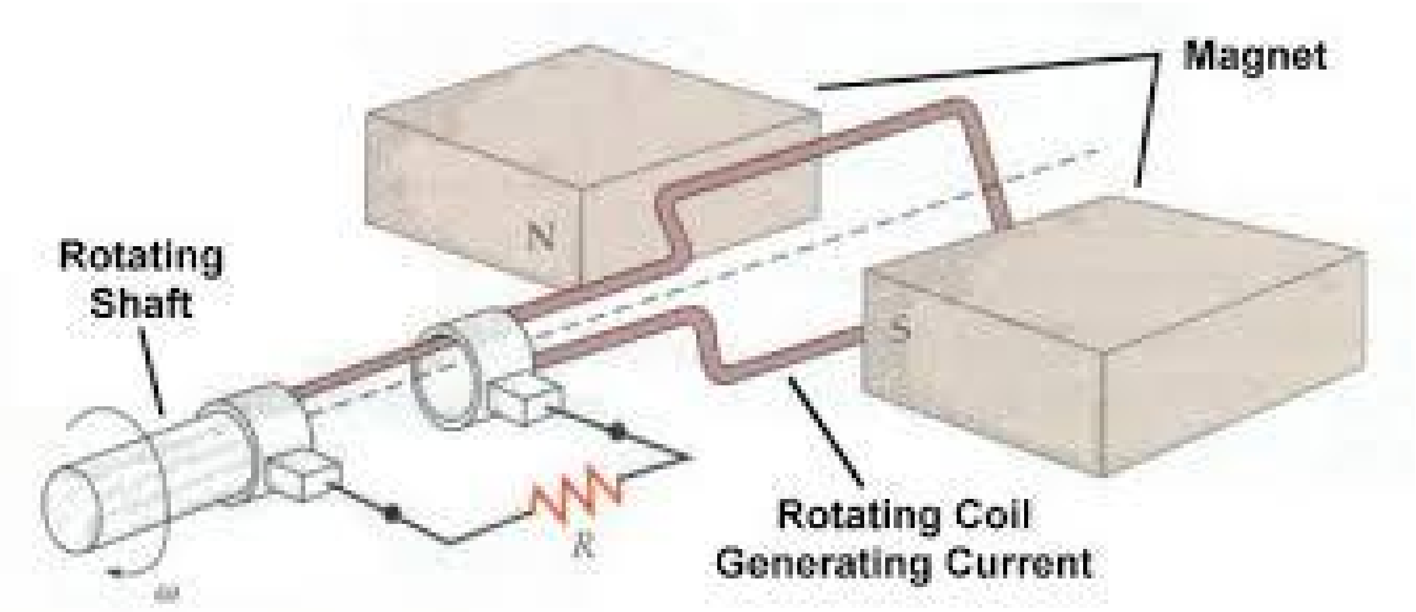
Magnet *exists* *→ The strength of the field goes away*

-the frequency of the changing field creates a voltage

A More Practical Way

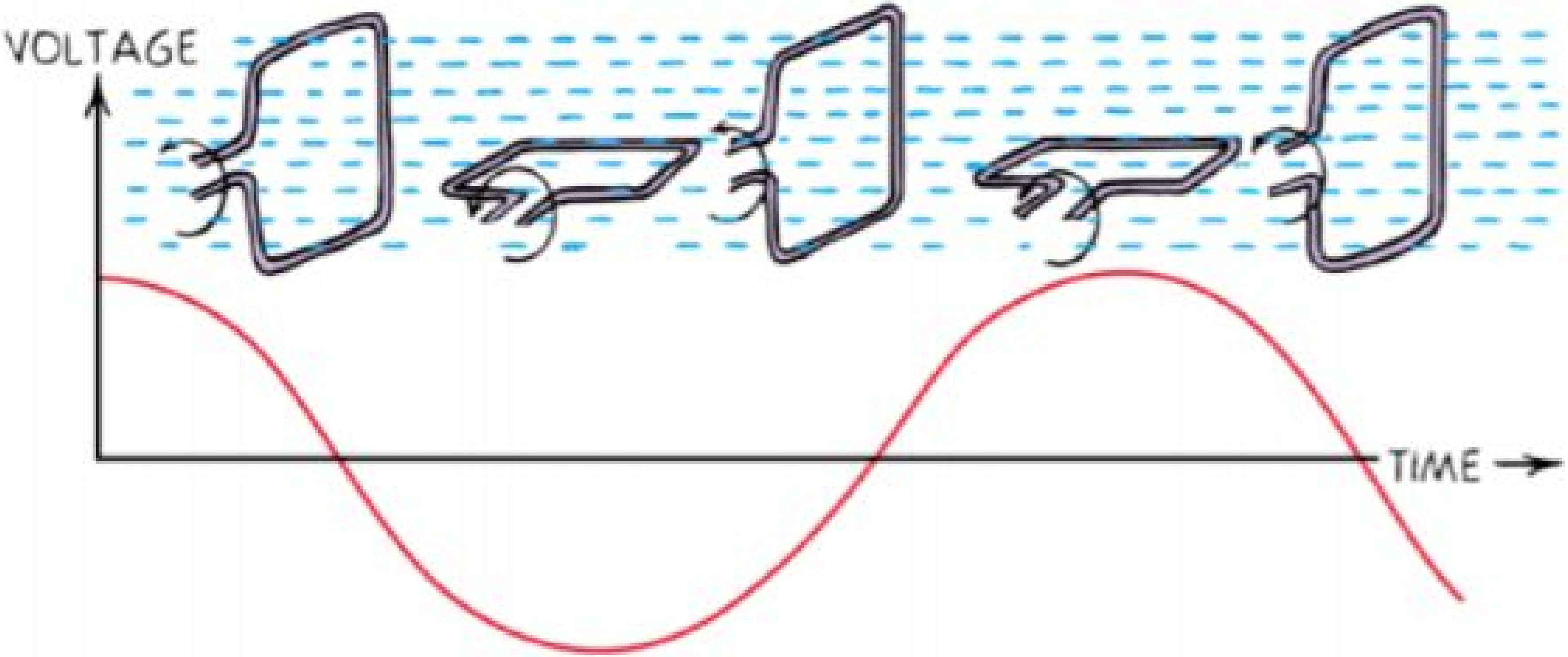
-Rotate a coil in a stationary magnetic Field
-loop is perpendicular to the field→ the maximum amount of field lines can pass through it
-loop is parallel to the field→ the minimum amount of field lines can pass through it
-When the loop rotates the direction and Direction of the voltage and current change

Electric Generator



Electric Generators

-To turn the coil you can attach the generator to a turbine that can be rotated by natural resources like wind, water, or steam


VOLTAGE
TIME

Electric Motor

-Converts Electrical Energy into Mechanical Energy
-a motor is a generator run in reverse

Motors and Generators Together at Work

-cars use Devices that function both as a motor and a generator

-It acts as a motor when the device draws current from a battery when extra power is needed to accelerate or go uphill

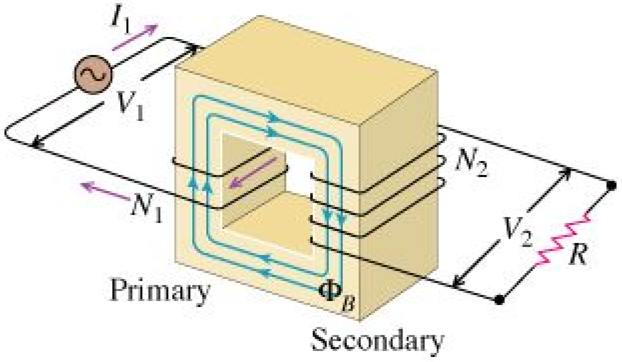
-It acts as a generator the car breaks and causes the wheels to exert a torque on the device, recharging the battery

Transformers

Transformers are used to increase or decrease voltage

More About Transformers

Transformers contain two coils which are known as the *primary* coil and the *secondary* coil



What Is It?

A transformer transfers energy from one coil to the other.

- A step-up transformer is when the secondary coil has more loops than the first coil

- A step-down transformer is when the primary coil has more loops than the secondary coil
- The rate at which energy is transferred is the power
- P = IV = ISVS

Example 4

A transformer in a portable radio reduces 150-V to 15 V. The radio draws 300 mA.

- What is the current in the primary?
- How much power is transferred?

6 Common Mistakes/Misconceptions

1.) If you want to use the right hand rule part 2 and you have a negative charge, you don't have to use your left hand. You can just use your right hand but make your answer opposite at the end
2.) Leaving the calculator in radian instead of degree mode.
3.) Mixing up which variables belong to which finger for the right hand rule. (Remember FBI)
4.) Switching/misplacing the primary vs secondary coils when calculating transformers.
5.) Neglecting to convert all units to SI.
6.) Confusing the V (Voltage) for v (velocity).

Practice Multiple Choice #1

Faraday's Law predicts the _____________ of the induced voltage.

a.) electromagnetic induction

b.)direction

c.) magnitude

Practice Multiple Choice #2

Lenz's Law predicts the ____________ of the induced voltage.

a.) direction

b.) magnitude

c.) velocity

Practice Multiple Choice #3

True or false? An electric motor is just a generator but run in reverse.

a.) True

b.) False

Practice Multiple Choice #4

In a step up transformer the _________ coil has more loops than the ________ coil

a.) secondary, primary

b.) primary, secondary

Practice Multiple Choice #5

The strength of the magnetic field (B) depends on

a.) how much current passes through the wire (I)

b.) how far you are from the wire (r)

c.) both a and b

Works Cited

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