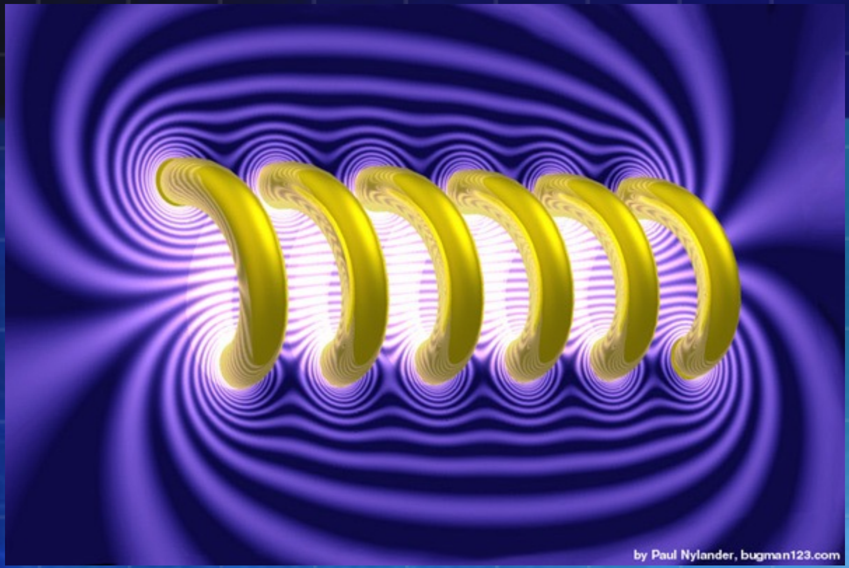

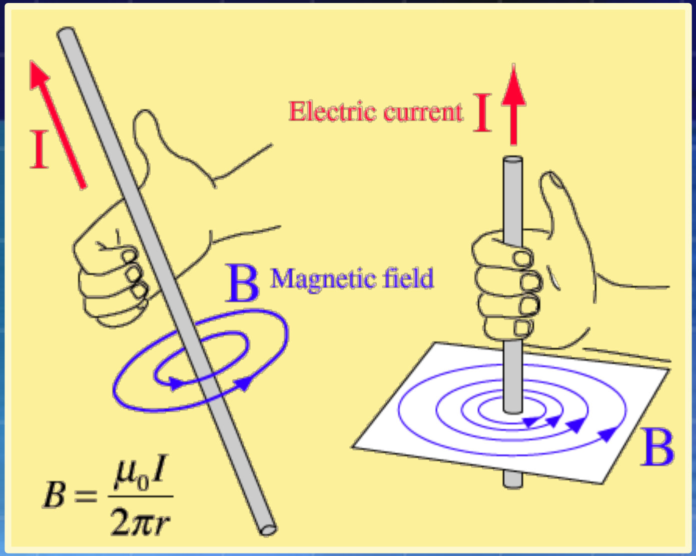

Circuit Lab

Practice #7—Electromagnets and Motors

Mr. Burleson
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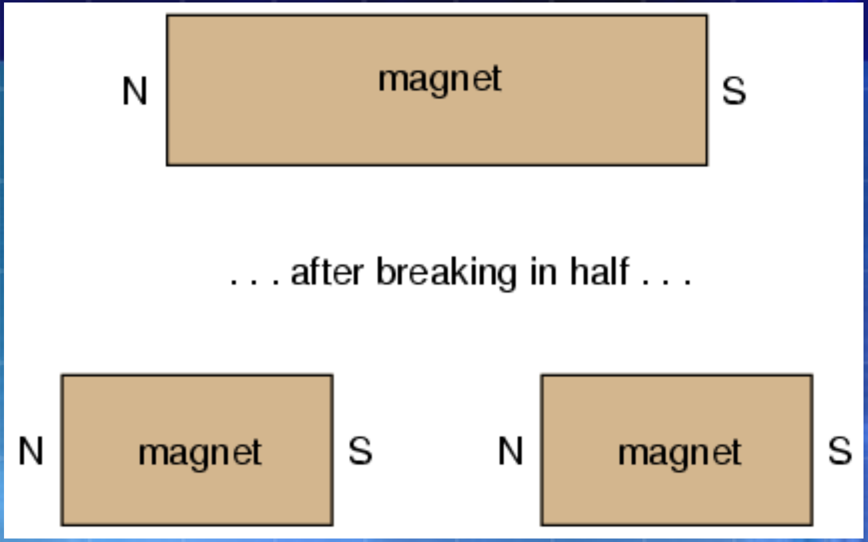
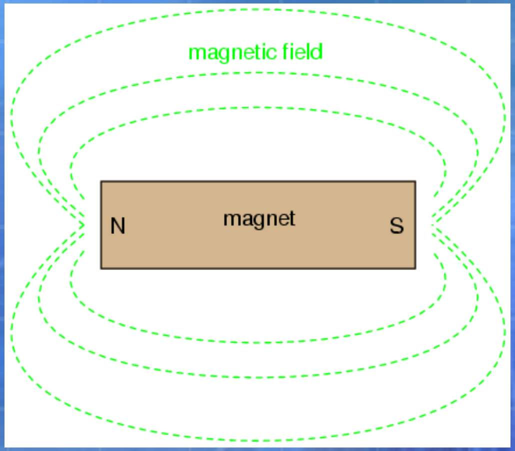
Agenda

- 15 minutes—Grading homework.
- 30 minutes—Learning Lesson of the Day
- 15 minutes—In Practice quick test on Lesson of the Day
- 25 minutes—Practical testing
- 5 minutes—Sending out homework

North and South Poles

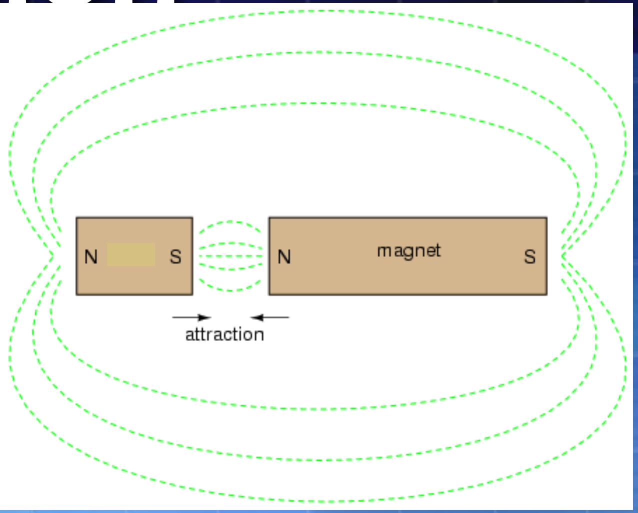
- If you break a magnet in half, it forms two magnets—each with a North and **South** Pole
- The magnetic field can be displayed by lines drawn from the North Pole to the South Pole

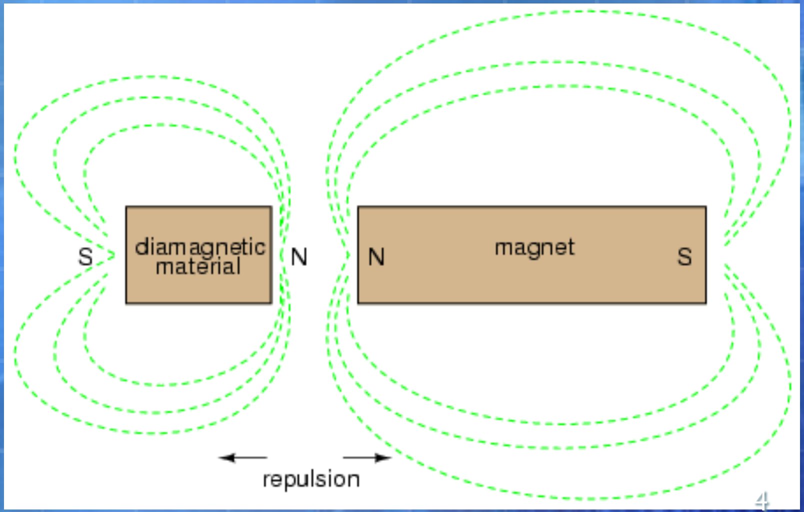




Magnetic Attraction and Repulsion

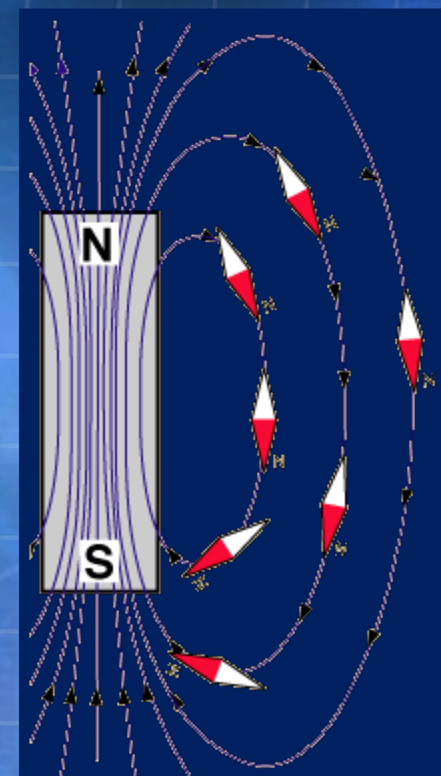
- When magnets are near, the lines of force go from North to South Pole from the two magnets.
  - North Pole would be attracted to the South Pole
  - North Pole would be repulsed from the North Pole





Magnetic Compass

- A compass is a navigational instrument that measures directions using a free floating magnetic and the Earth's magnetic field to point towards the Magnetic North Pole.
  - Magnetic North Pole is not quite at the geographical North Pole and it moves
  - Magnetic North Pole is actually a South Pole of Earth's magnetic field—allowing the North Pole of the compass to be attracted.
  - Compasses become useless near the Poles



- Invented first by the Chinese during the Han Dynasty. Europe invented the dry compass around 1300.

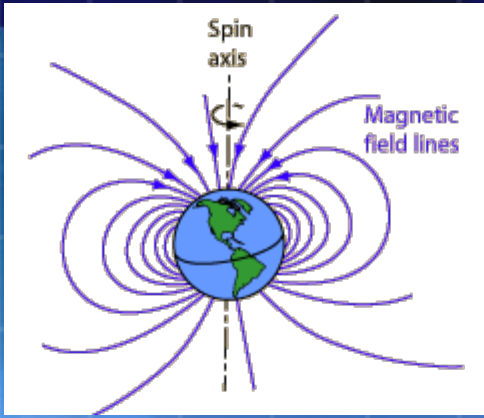
Earth's Magnetic Field

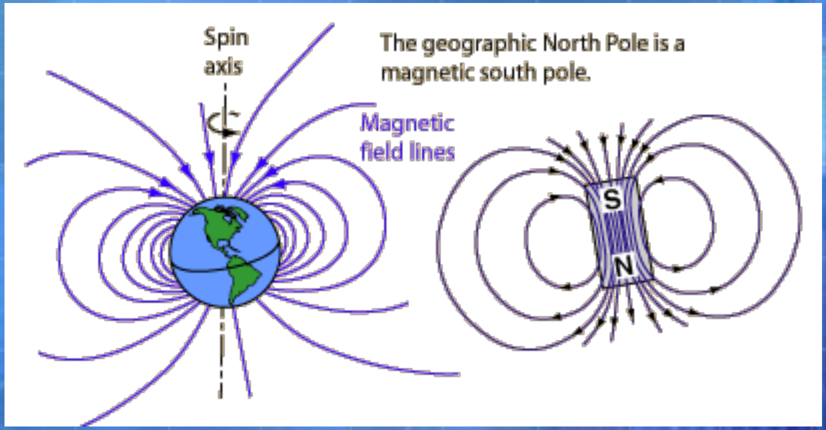
- The Earth's magnetic field is similar to that of a bar magnet tilted 11 degrees from the spin axis of the Earth.

- Magnetic fields surround electric currents, so we surmise that circulating electric currents in the Earth's molten metallic core are the origin of the magnetic field.

- Rock specimens of different age in similar locations have different directions of permanent magnetization. Evidence for 171 magnetic field reversals during the past 71 million years has been reported.

- Interaction of the terrestrial magnetic field with particles from the solar wind sets up the conditions for the aurora phenomena near the poles.



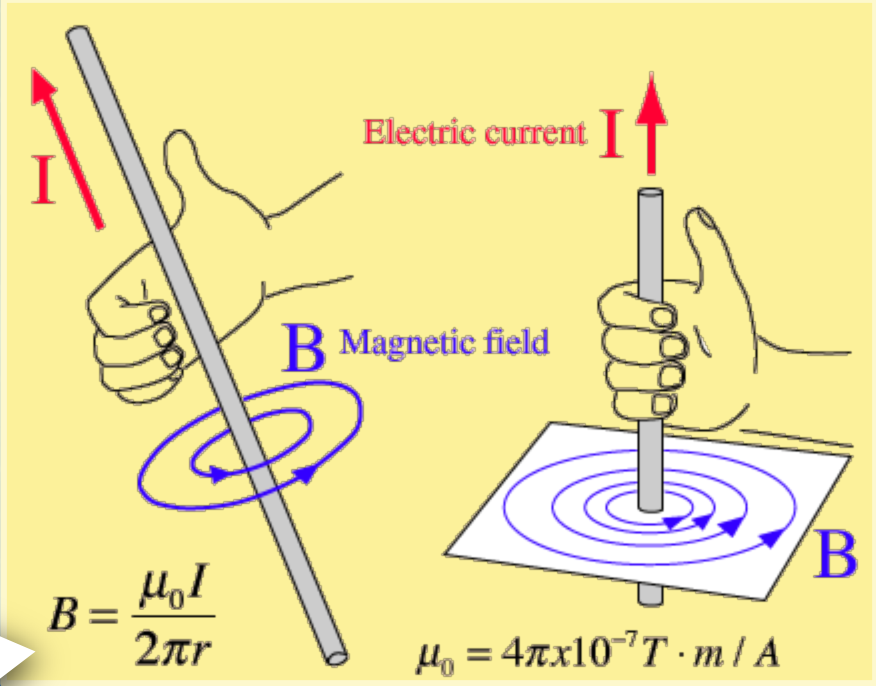


Magnet Shapes

- All have a North Pole and a South Pole
- Different shapes for different purposes

Magnetic Field of Current

- Current going through a wire causes a magnetic field going around it in a "right hand rule"
  - Point your right thumb in the direction of the current.
  - The magnetic field (B) goes around the wire like your right hand fingers
  - See the formula for B



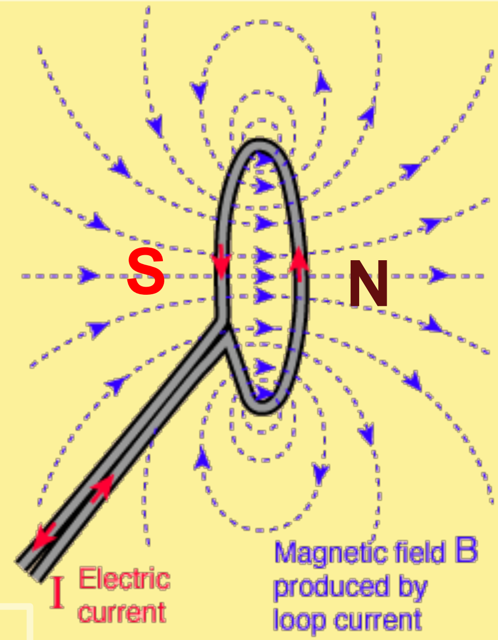
$$B = \frac{\mu_0 I}{2\pi r}$$

$$\mu_0 = 4\pi x 10^{-7} T \cdot m / A$$

Permeability of free space

Magnetic Field of Current Loop

- Current going through a wire loop causes a magnetic field that is concentrated in the inside of the loop
  - Have your right hand fingers follow the current
  - The magnetic flux (B) goes through the loop with your right thumb
  - See the formula for B for center of the loop



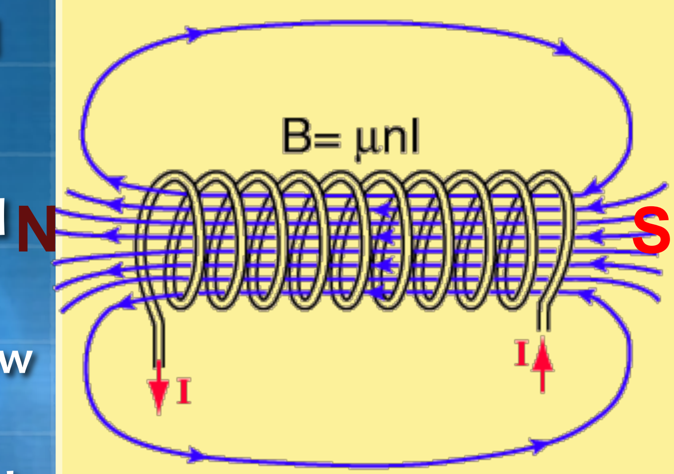
$$B = \frac{\mu_0 I}{2R}$$

$$\mu_0 = 4\pi x 10^{-7} T \cdot m / A$$

Permeability of free space

Magnetic Field of Solenoid

- Current going through a multiple wire loops causes a magnetic field similar to a bar magnet.
- The magnetic field is concentrated inside the loops.
  - Have your right hand fingers follow the current
  - The magnetic flux (B) goes through the loop with your right thumb
  - See the formula for B for center of the solenoid
    - µ is the permeability
    - n is the turn density (turns/M)
    - I is the current



The magnetic field is concentrated into a nearly uniform field in the center of a long solenoid. The field outside is weak and divergent.

$$\mu_0 = 4\pi x10^{-7} T \cdot m / A$$

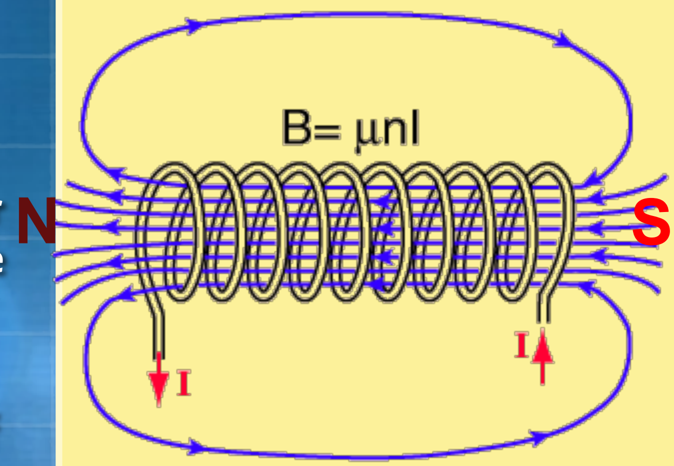
$B = \mu n I$

Permeability of free space

Iron cores have a much higher (~200x) permeability than free space or air, and make better solenoids.

Magnetic Field of Electromagnet

- An electromagnet is just a solenoid
  - The core material's permeability can dramatically increase the strength of the electromagnet or solenoid.
  - The number of turns over the length or turn density can dramatically affect the strength of the electromagnet or solenoid.
  - See the formula for B for center of the electromagnet
    - μ is the permeability
    - n is the turn density (turns/m)
      - For example if you have 100 turns per 0.01m, n = 100/0.01 = 10,000 turns/m
    - I is the current



The magnetic field is concentrated into a nearly uniform field in the center of a long solenoid. The field outside is weak and divergent.

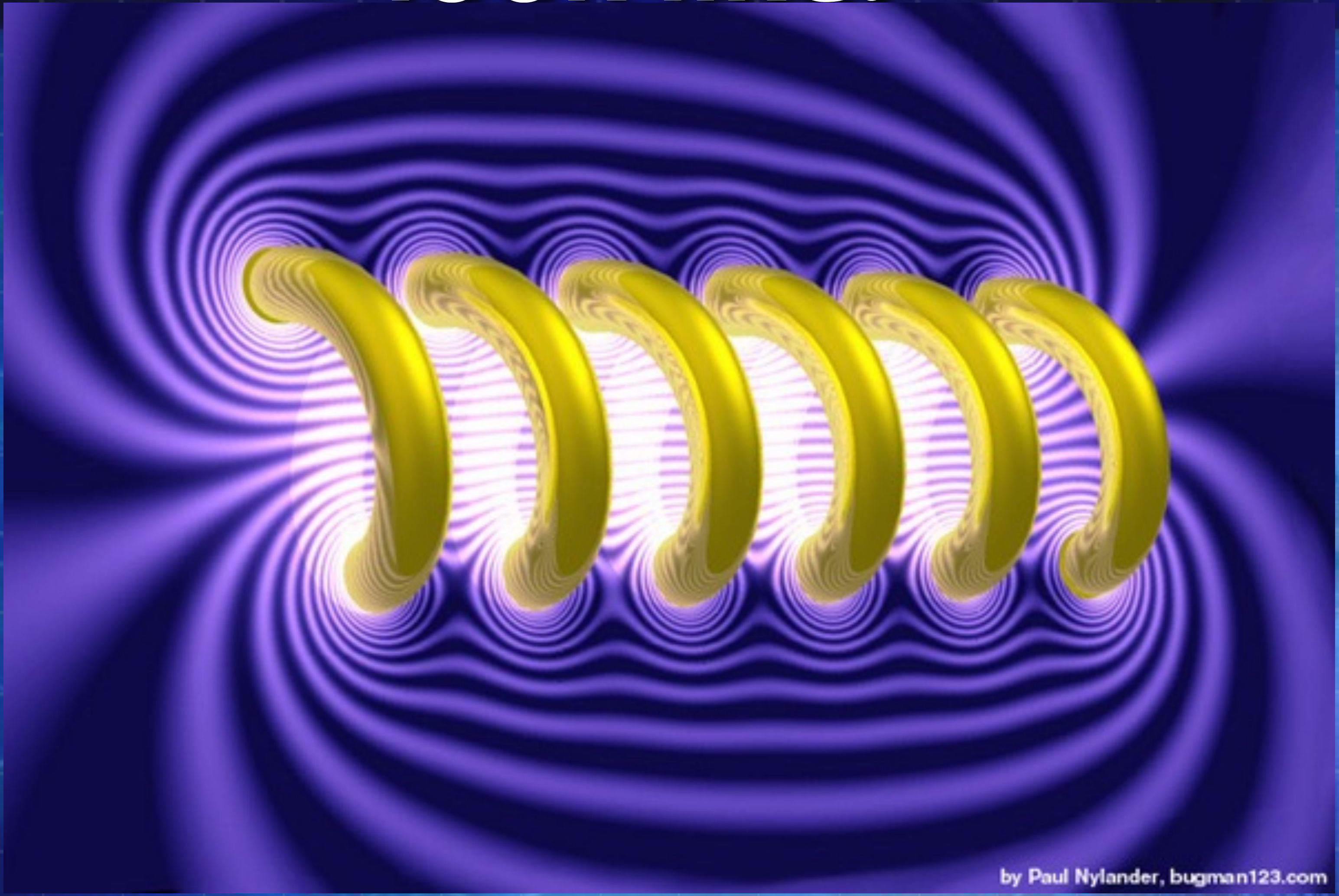
$$\mu_0 = 4\pi x 10^{-7} T \cdot m / A$$

$$B = \mu n I$$

Permeability of free space

Iron cores have a much higher (~200x) permeability than free space or air, and make better solenoids.

What does the field look like?



Lorentz Force Law

- Force is applied on all charged particles by both magnetic and electric fields
- The Force of the Electric field is equal to $F_{elect} = qE$ and is in the direction of the Electric field
- The Force of the Magnetic Field is equal to $F_{mag} = qv\ x\ B$ and is in the direction diagonal to the magnetic field and the moving charge
  - if the charge isn't moving there is no magnetic force
  - If the charge is moving in the line of the magnetic field there is no magnetic force

Electric field in N/C or volts/m.

$$\vec{E} = \frac{\vec{F}}{q}$$

electric force in Newtons

charge in Coulombs

Since the measured electric field can depend upon your reference frame, a more general definition of the electric field comes from the Lorentz force law. The electric field can be defined as the electromagnetic force per unit charge in the rest frame of the charge.

$$\vec{F} = \underbrace{q\vec{E}}_{\text{Electric force}} + \underbrace{q\vec{v}\ x\ \vec{B}}_{\text{Magnetic force}}$$

A charge that is moving relative to the source will experience part of the force as a magnetic force.

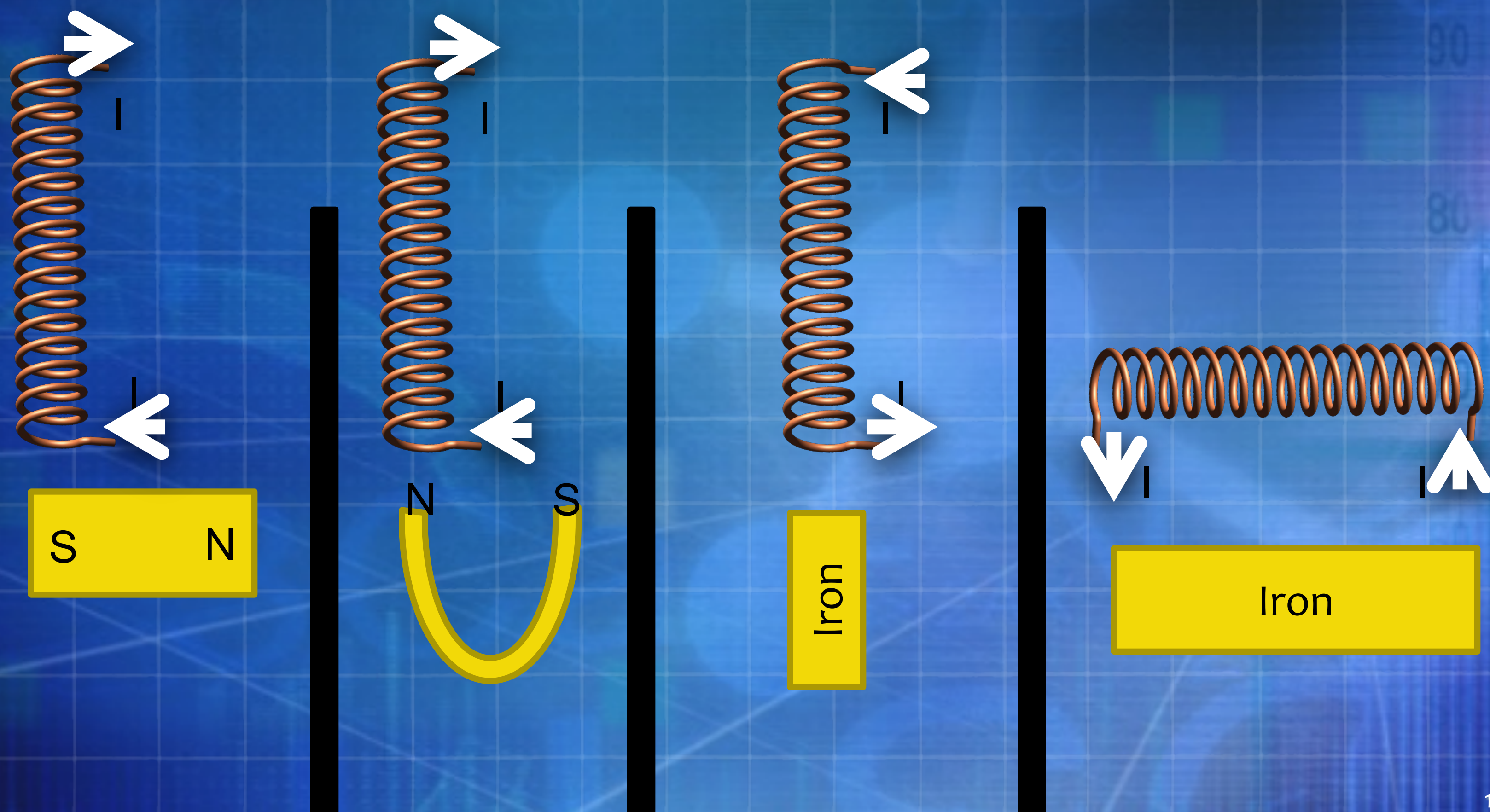
Lorentz force law

What are electric motors?

- Motors that turn flowing electric current into mechanical motion/work
- They are the opposite of generators, which turn mechanical motion/work into flowing electrical power.
- To make one you need a magnetic field and flowing current. Like with an electromagnet, the more turns the more powerful the magnetic field.
- The moving part is the Rotor
- The stationary part is the Stator
- If you reverse the polarity (voltage/current), the motor will run in revers

In Practice Quiz

- Draw the field lines and indicate attraction or repulsion



In Practice Quiz

- What is the magnetic field strength B for a solenoid with the following parameters?
  - n =10,000
  - I = 0.05A
  - Air core
- What is the magnetic field strength if the air core is replaced by an iron core?

In Practice Quiz

- What is the magnetic field strength B for a solenoid with the following parameters?
  - n =10,000
  - I = 0.1A
  - Air core
- What is the magnetic field strength if the air core is replaced by an iron core?
- How did it compare to the one with 0.05A current?

In Practice Quiz

Science Olympiad
Exploring the World of Science

- What is the magnetic field strength B for a solenoid with the following parameters?
  - n =20,000
  - I = 0.05A
  - Air core
- What is the magnetic field strength if the air core is replaced by an iron core?
- How did it compare to the one with 10,000 turn density?

Practical

- Create a circuit operating the DC motor and a switch
  - What is the voltage across the motor while stopped?
  - What is the voltage across the motor while running?
  - What direction is the current flowing?
- What happens if you reverse the polarity of the battery?
  - What is the voltage across the motor while running?
  - What direction is the current flowing?

Practical (cont)

- Create a solenoid (make sure you have a load in series) and see what happens when you put current to it
  - Using the compass determine the North Pole and South Pole of the solenoid.
- Put the iron core inside the solenoid to make an electromagnet and see what happens when you put current to it.
  - Using the compass determine the North Pole and South Pole of the solenoid.
- Which is a stronger magnet?

Homework

- Describe how to make an electric buzzer/bell using a DC power source and draw one.
  - http://www.youtube.com/watch?v=JjTzAXX8dS8
- Describe how to make a telegraph using a DC power source and draw one
- Complete the circuit problems from the Homework Generator
  - Level 1 Magnetism
  - Level 4 Combination
  - Level 5 Combination