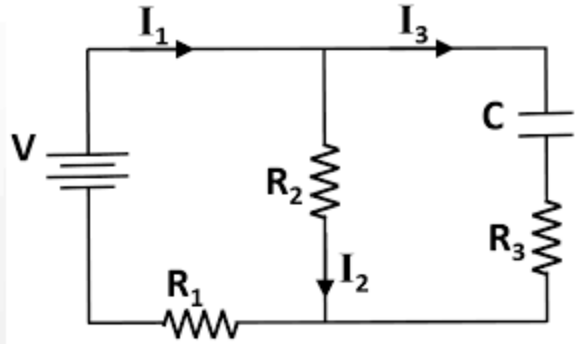

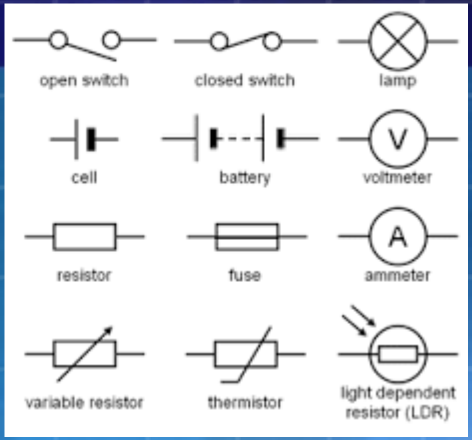

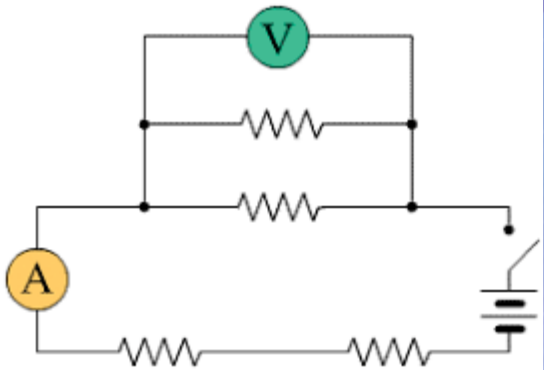

Circuit Lab

Practice #5—Magnets, Voltage Dividers, and Current Dividers

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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

What causes magnetism?

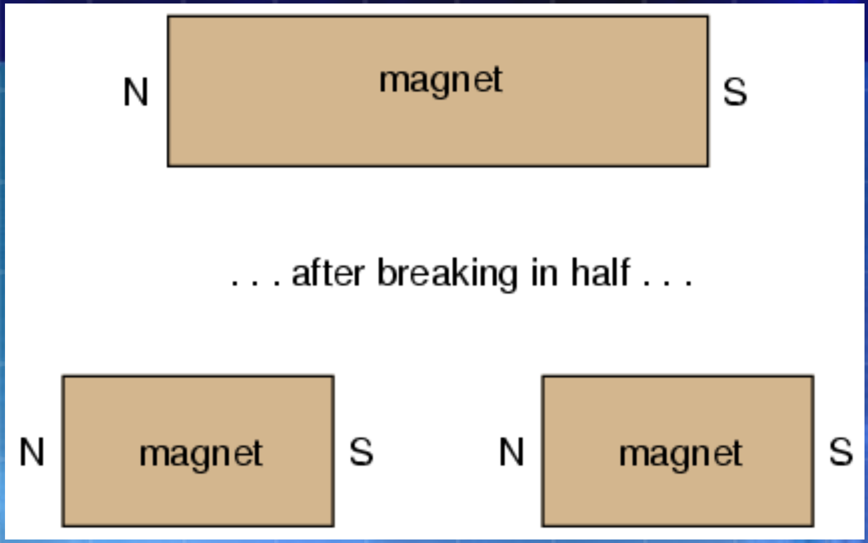
- Magnetism, at its root, arises from two sources:
  - Electric current (moving charges) including electron magnetic moments
    - Electron magnetic dipole moment is the magnetic moment of an electron caused by its intrinsic property of spin. This normally cancels out, but sometimes— either spontaneously, or owing to an applied external magnetic field — each of the electron magnetic moments will be, on average, lined up. Then the material can produce a net total magnetic field, which can potentially be quite strong.
  - Nuclear magnetic moments of atomic nuclei. These moments are typically thousands of times smaller than the electrons' magnetic moments, so they are negligible in the context of the magnetization of materials.

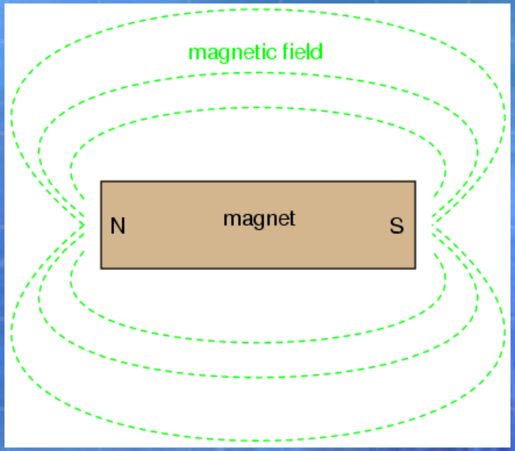
Permanent Magnets

- Over 2500 years ago it was discovered that lodestone or magnetite was attracted to iron
  - It would also orient itself to North-South, creating the first compasses
  - Peter Pergrinus discovered in 1269 that one could make steel “magnetic” by rubbing it against a pole of the lodestone
- These magnetic materials possess two poles of opposite effect (North and South)
  - Like electrical charges Alike Poles Push against each other and Different Poles Pull towards each other.

North and South Poles

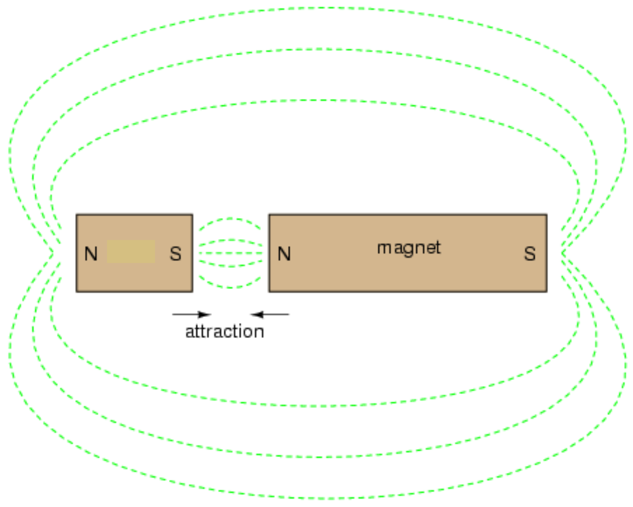
- If you break a magnet in half, it forms two magnets—each with a North and South Pole
- The magnetic field can be displayed by lines drawn from the North Pole to the South Pole

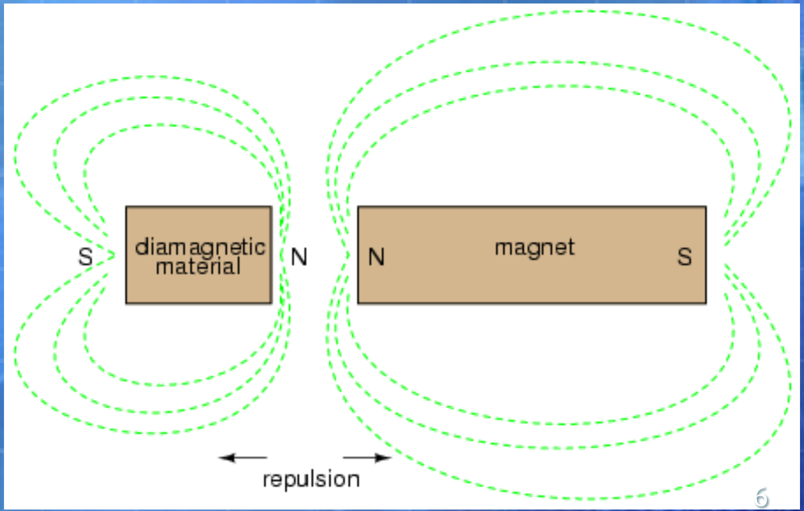




Magnetic Attraction and Repulsion

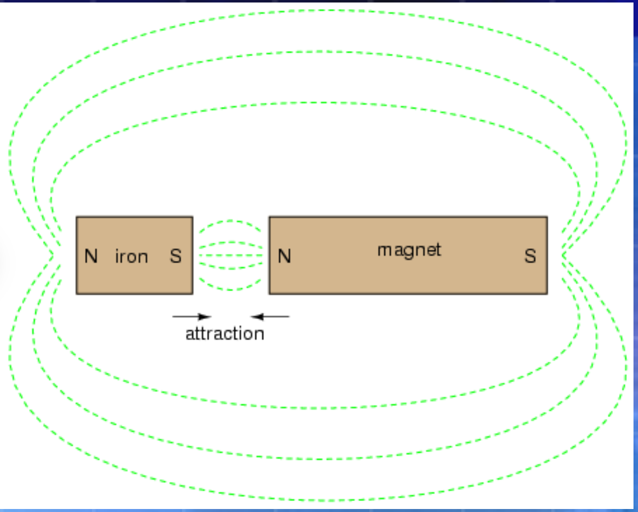
- When magnets are near, the lines of force go from North to South Pole from the two magnets.
  - North Pole would be attracted to the South Pole
  - North Pole would be repulsed from the North Pole





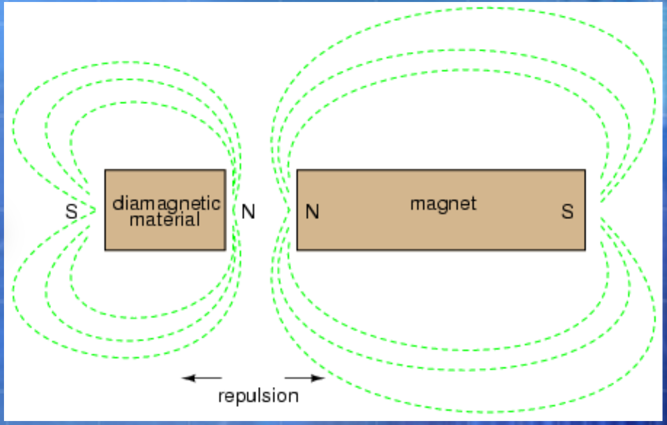
Magnetic Materials

- Magnetic or Ferromagnetic Materials are readily magnetized (its constitute atoms easily orient their electron spins to conform to the external magnetic force)
  - Iron is the main Ferromagnetic material



- Paramagnetic Materials are slightly magnetic,.

- Diamagnetic Materials are materials which tend to exclude magnetic fields and actually slightly repulse a magnet.



Ferromagnetic materials

- Cobalt
- Iron
- Iron Oxide (iron oxide)
- Ferrite (ceramic materials with Iron Oxide)—includes hematite and magnetite
- Nickel
- Chromium (IV) oxide

Curie temperatures for some crystalline ferromagnetic (* = ferrimagnetic) materials[4]

Material	Curie temp. (K)
Co	1388
Fe	1043
Fe_2O_3*	948
$FeOFe_2O_3$*	858
$NiOFe_2O_3$*	858
$CuOFe_2O_3$*	728
$MgOFe_2O_3$*	713
MnBi	630
Ni	627
MnSb	587
$MnOFe_2O_3$*	573
$Y_3Fe_5O_{12}$*	560
CrO_2	386
MnAs	318
Gd	292
Dy	88
EuO	69

Paramagnetic materials

- Tungsten
- Cesium
- Aluminum
- Lithium
- Magnesium
- Sodium

Material	Magnetic susceptibility ($\times 10^{-5}$)
Tungsten	6.8
Cesium	5.1
Aluminium	2.2
Lithium	1.4
Magnesium	1.2
Sodium	0.72

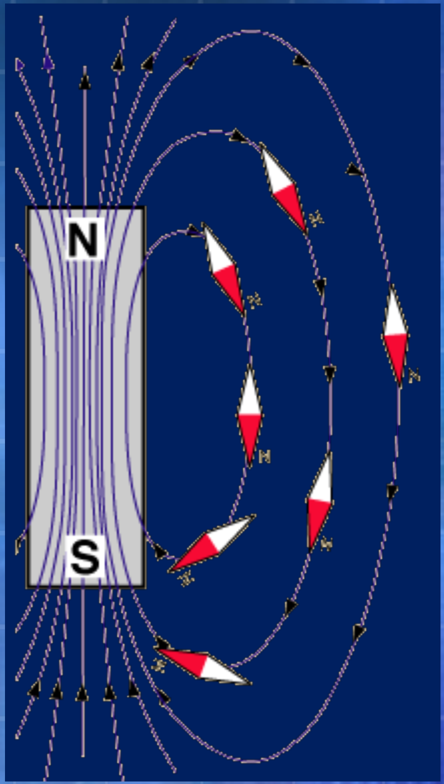
Diamagnetic materials

- Superconductor
- Pyrolytic carbon
- Bismuth
- Mercury
- Silver
- Carbon (diamond)
- Lead
- Carbon (graphite)
- Copper
- Water

Notable diamagnetic materials[2]

Material	χ_v (10^{-5})
Superconductor	-10^5
Pyrolytic carbon	−40.0
Bismuth	−16.6
Mercury	−2.9
Silver	−2.6
Carbon (diamond)	−2.1
Lead	−1.8
Carbon (graphite)	−1.6
Copper	−1.0
Water	−0.91

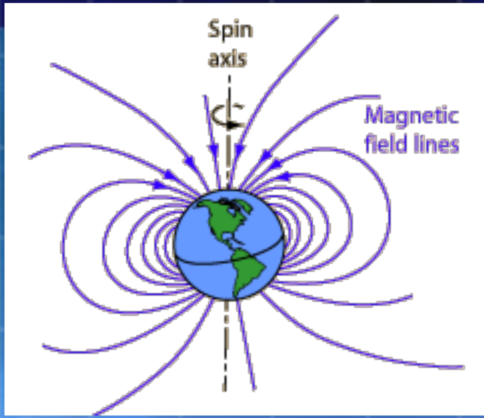
Magnetic Compass

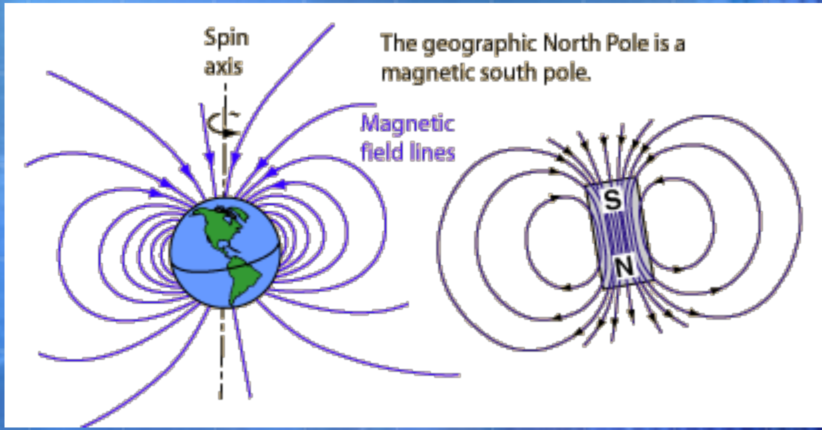


- A compass is a navigational instrument that measures directions using a free floating magnetic and the Earth's magnetic field to point towards the Magnetic North Pole.
  - Magnetic North Pole is not quite at the geographical North Pole and it moves
  - Magnetic North Pole is actually a South Pole of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

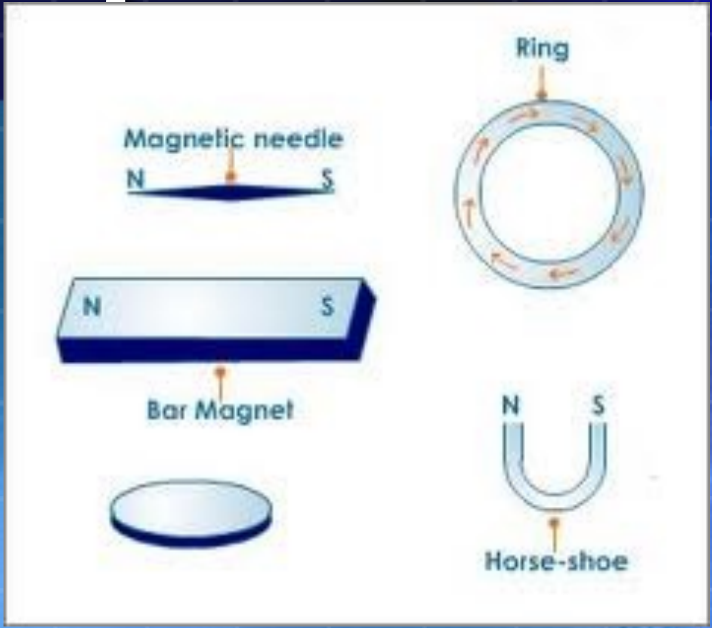
- The Earth's magnetic field is similar to that of a bar magnet tilted 11 degrees from the spin axis of the Earth.
- Magnetic fields surround electric currents, so we surmise that circulating electric currents in the Earth's molten metallic core are the origin of the magnetic field.
- Rock specimens 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.





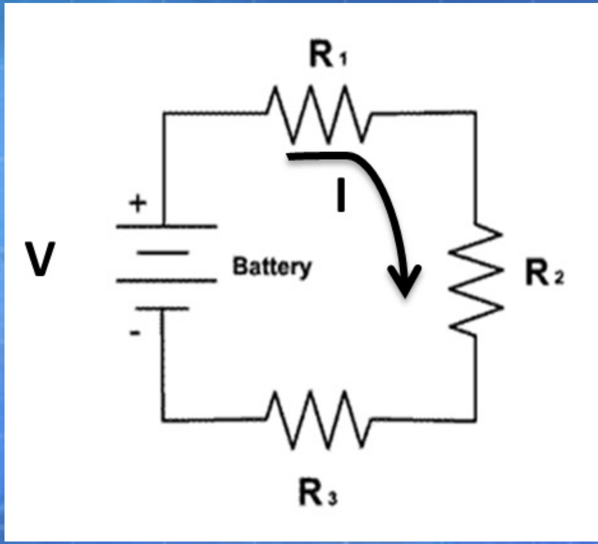
Magnet Shapes

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



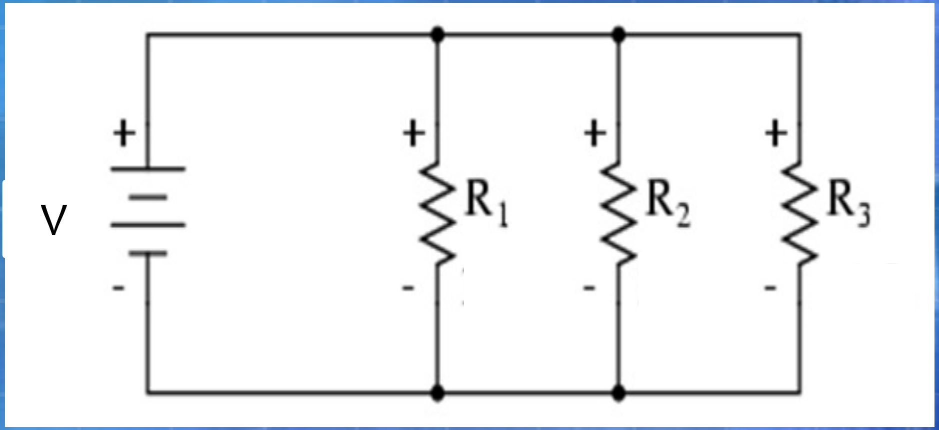
Voltage Divider

- A Series Circuit acts as a voltage divider
- Voltage is split between resistors
- The Voltage summed across all resistors equals the Source Voltage
- V_{source} = the source voltage
- $R_{total} = R_1 + R_2 + R_3$
- $I = V_{source}/R_{total}$
- $V_{R1} = I\,R_1$, $V_{R2} = I\,R_2$, $V_{R3} = I\,R_3$
- Combining the two equations
  - $V_{R1} = V_{source}\,R_1/R_{total}$
  - $V_{R2} = V_{source}\,R_2/R_{total}$
  - $V_{R3} = V_{source}\,R_3/R_{total}$
- <u>Voltage Divider Formula</u>
  - $V_{RX} = V_{source}\,R_X/R_{total}$



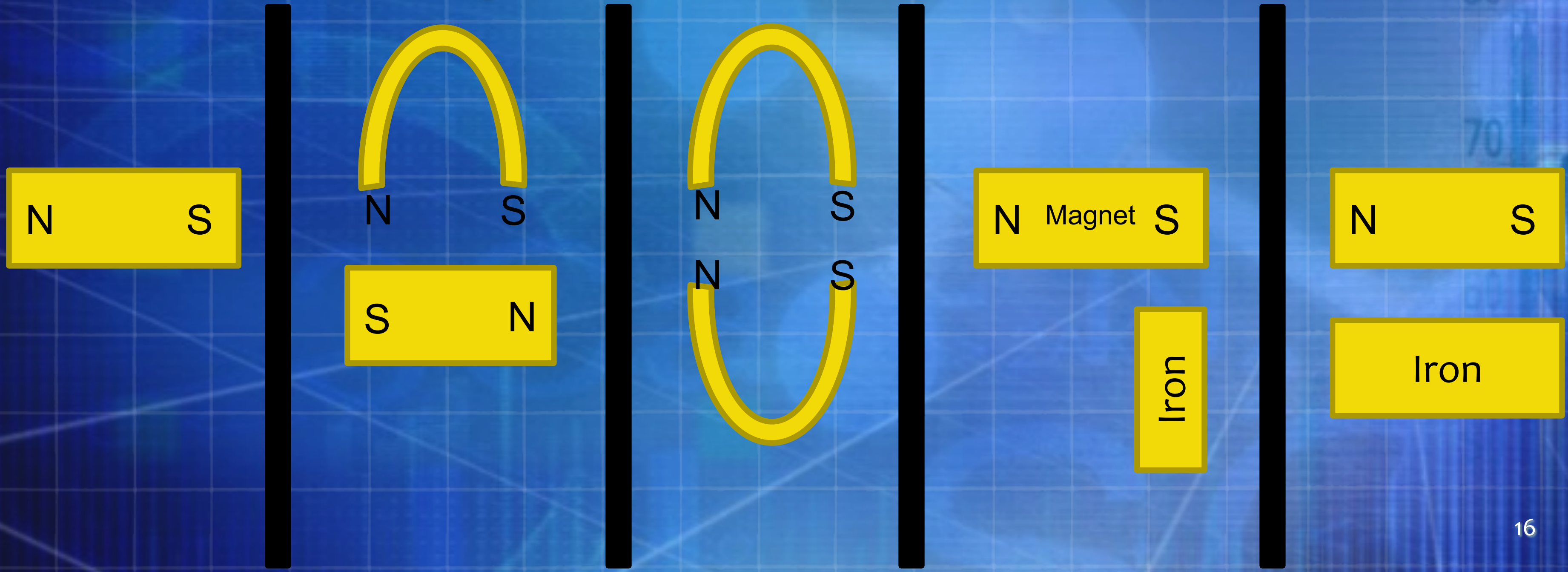
Current Divider

- Current is split between resistors (electrons are split between all branches)
- $1/R_{total} = 1/R_1 + 1/R_2 + 1/R_3$
- R_{total} is always less than the smallest single resistance
- $I_{total} = V_{source}/R_{total}$
- $I_{R1} = V/R_1$, $I_{R2} = V/R_2$, $I_{R3} = V/R_3$
- Combining the two equations
  - $I_{R1} = I_{total}\ R_{total}/R_1$
  - $I_{R2} = I_{total}\ R_{total}/R_1$
  - $I_{R3} = I_{total}\ R_{total}/R_1$
- <u>Current Divider Formula</u>
  - $I_{RX} = I_{total}\ R_{total}/R_X$



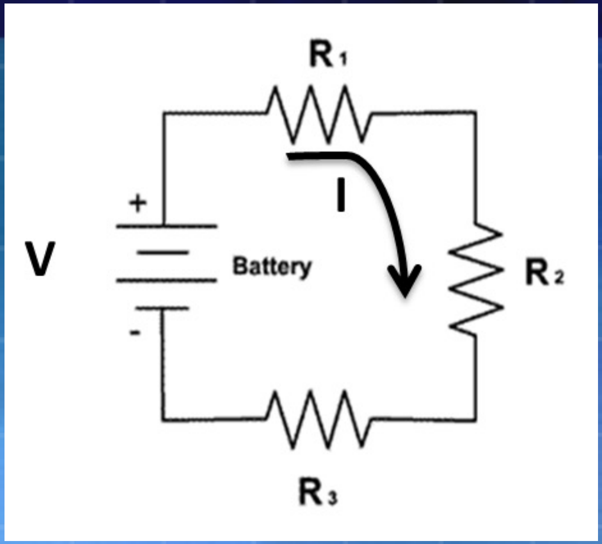
In Practice Quiz

- What are magnetic materials? Two examples?
- What are paramagnetic materials? Two examples?
- What are diamagnetic materials? Two examples?
- Draw magnetic lines for the following magnets, show attraction or repulsion



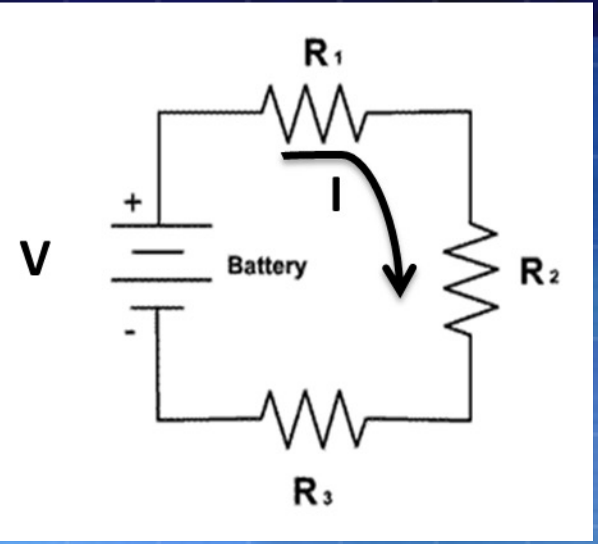
In Practice Quiz

- $V = 100$ V
- $R_1 = 100\Omega$
- $R_2 = 220\Omega$
- $R_3 = 680\Omega$
- What is the voltage drop across each resistor?



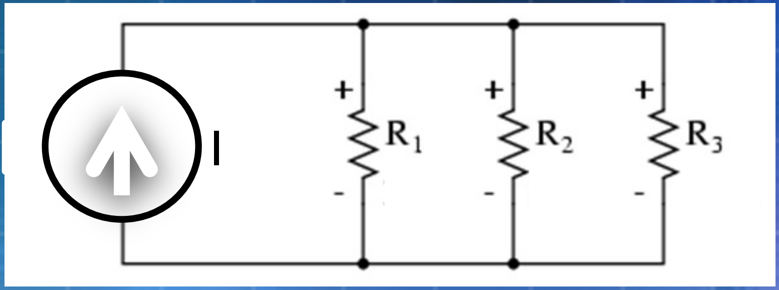
In Practice Quiz

- $V = 25\ V$
- $R_1 = 1k\Omega$
- $R_2 = 8.2k\Omega$
- $R_3 = 3.3k\Omega$
- What is the voltage drop across each resistor?



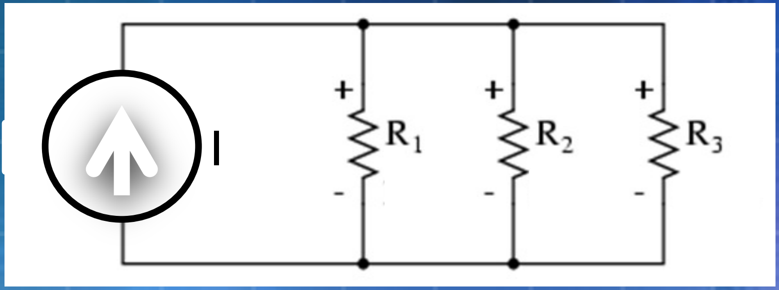
In Practice Quiz

- $I = 10A$
- $R_1 = 680\Omega$
- $R_2 = 330\Omega$
- $R_3 = 220\Omega$
- What is the total resistance?
- What is the current through each resistor?



In Practice Quiz

- $I = 4$ mA
- $R_1 = 2.2k\Omega$
- $R_2 = 4.4k\Omega$
- $R_3 = 4.4k\Omega$
- What is the total resistance?
- What is the current through each resistor?



Practical

- Using the compass determine the North Pole and South Pole of each magnet.
- Using the compass draw the magnetic field lines of the Earth on a piece of paper.
- Measure the voltage across the series circuit total and across each resistor.
- Measure the voltage across the parallel circuit in total and across each resistor. Measure the resistance across the circuit and determine the total current and current across each resistor.

Homework

- What happens when a permanent magnet is put under high heat? Why?
- What can happen if you drop a permanent magnet and it hits the floor or you hit it with a hammer? Why?
- What would happen if you put a refrigerator magnet on a completely Aluminum refrigerator?
- What would happen on a stainless steel refrigerator?
- Solve the combination circuit problems
  - Level 3 Combination
  - Level 4 Combination
  - Level 5 Combination
- Use the voltage divider and current divider formulas to solve the homework problems.