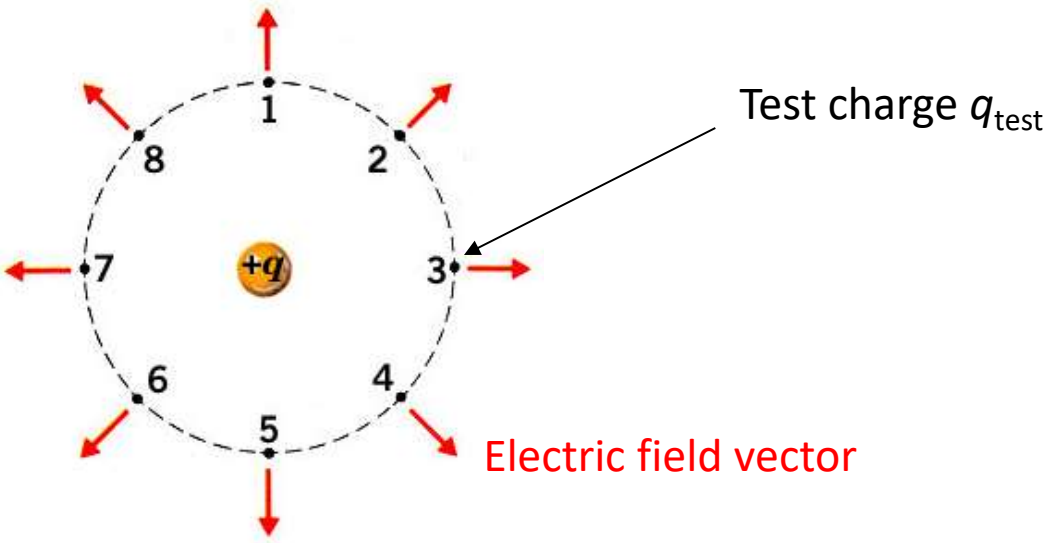
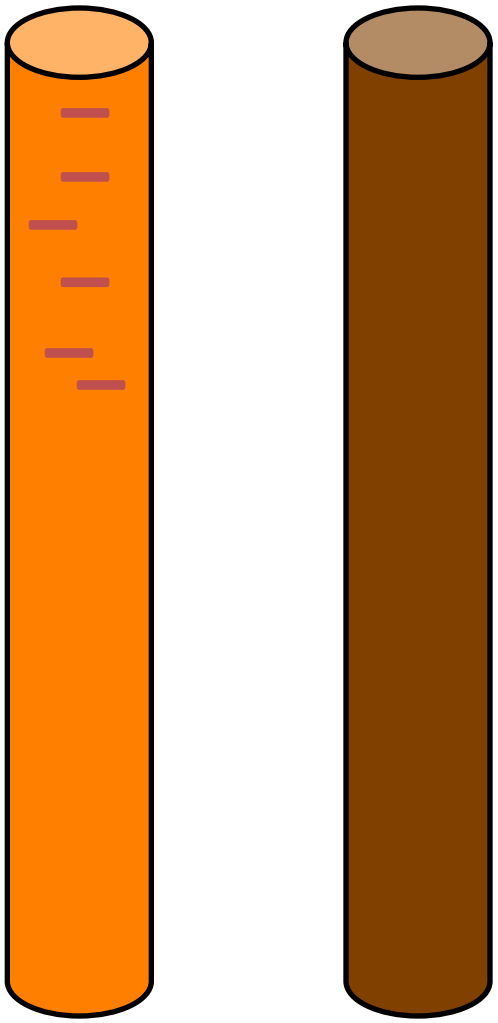
Electric Field

- When a charged body experiences an electric force, we consider there to be an “electric field”.
- In particular, since the force is proportional to the charge on the body, what characterizes the field is the force per unit charge.
- In other words, the electric field is just the force at any given point in space that a unit charge (1 Coulomb) would experience if placed at that point.
- It is a vector.





Clicker #1

A charged plastic rod is brought next to an insulating wood rod. The rods will

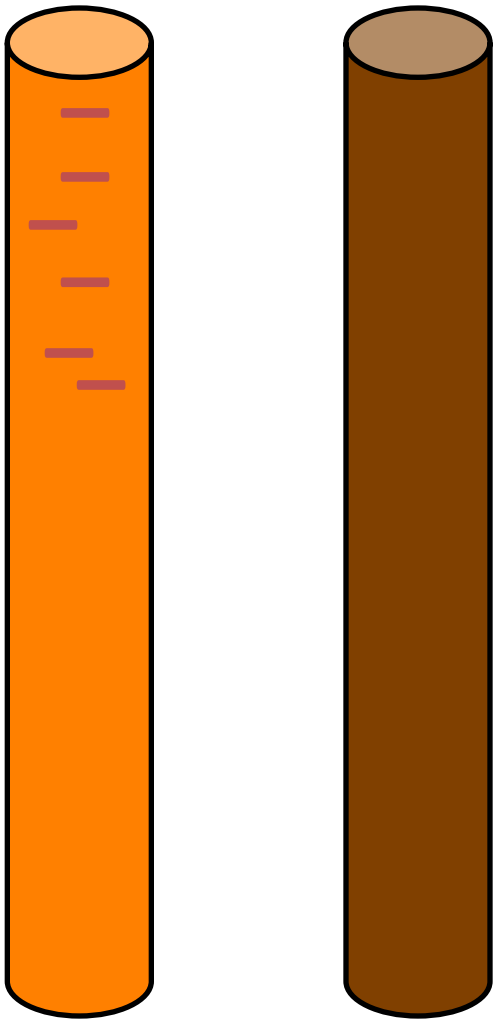
A) Attract

B) Repel

C) Neither attract nor repel

D) Explode

E) Disappear



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Which of the two forces is stronger?

A) F_L is stronger

B) F_R is stronger

C) F_L and F_R are equal and opposite

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Clicker Question

A. Electrostatic forces can be repulsive or attractive, just like gravitational forces.
B. Electrostatic forces can be repulsive or attractive, whereas gravitational forces are always repulsive.
C. Positive charges attract negative charges, and positive masses repel negative masses.
D. Positive charges attract positive charges, and positive masses attract positive masses.
E. Positive charges repel positive charges, and positive masses attract positive masses.

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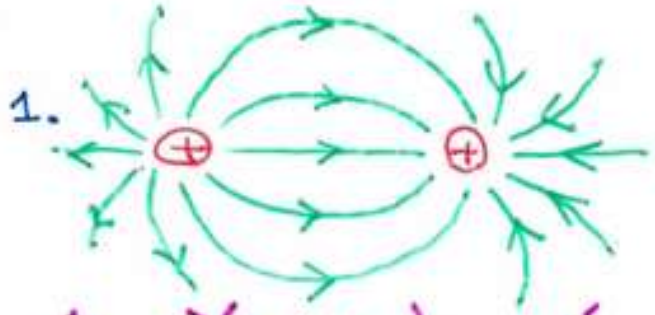
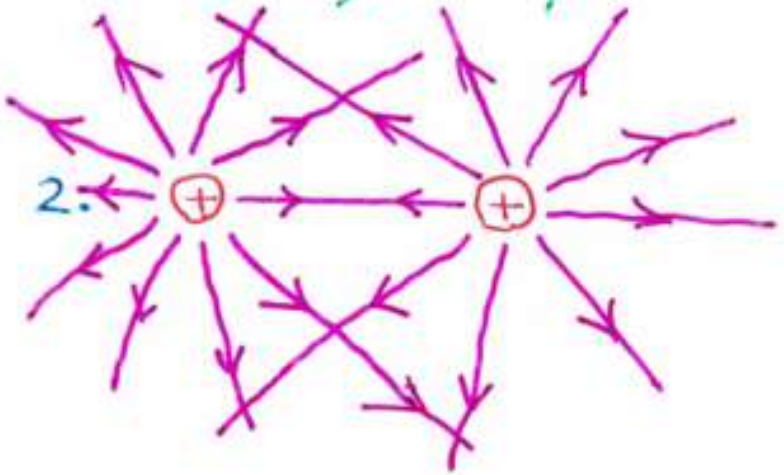
WHICH OF THE FOLLOWING SKETCHES BEST REPRESENTS THE ELECTRIC FIELD LINES ABOUT TWO POSITIVELY CHARGED PARTICLES?

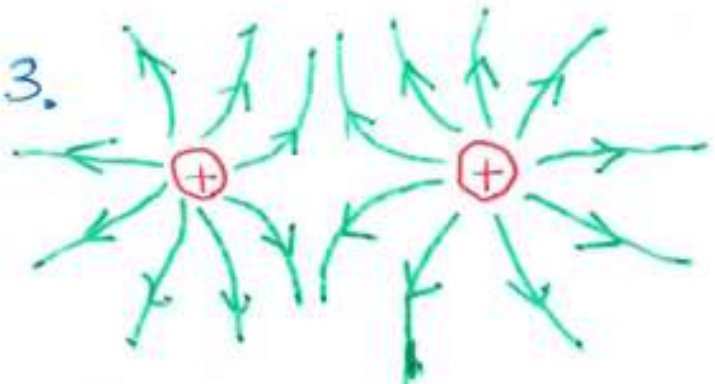
A



B



C



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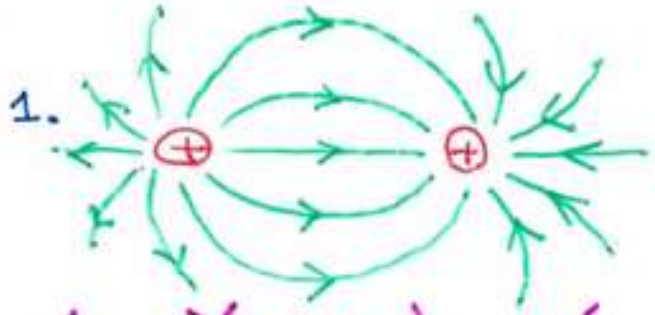

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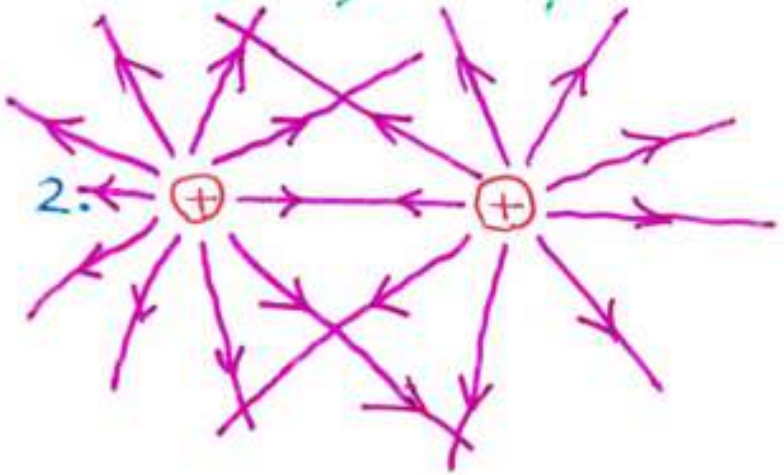

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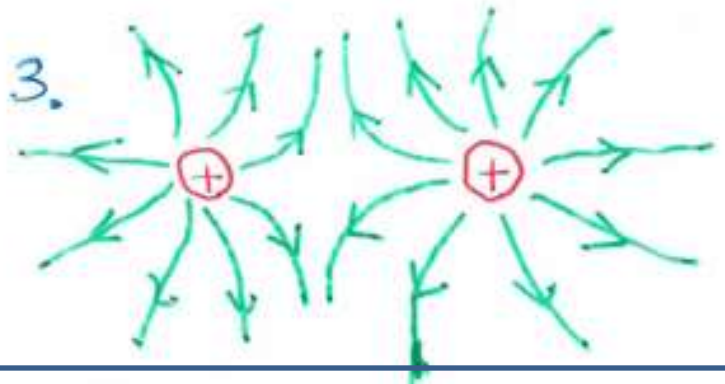
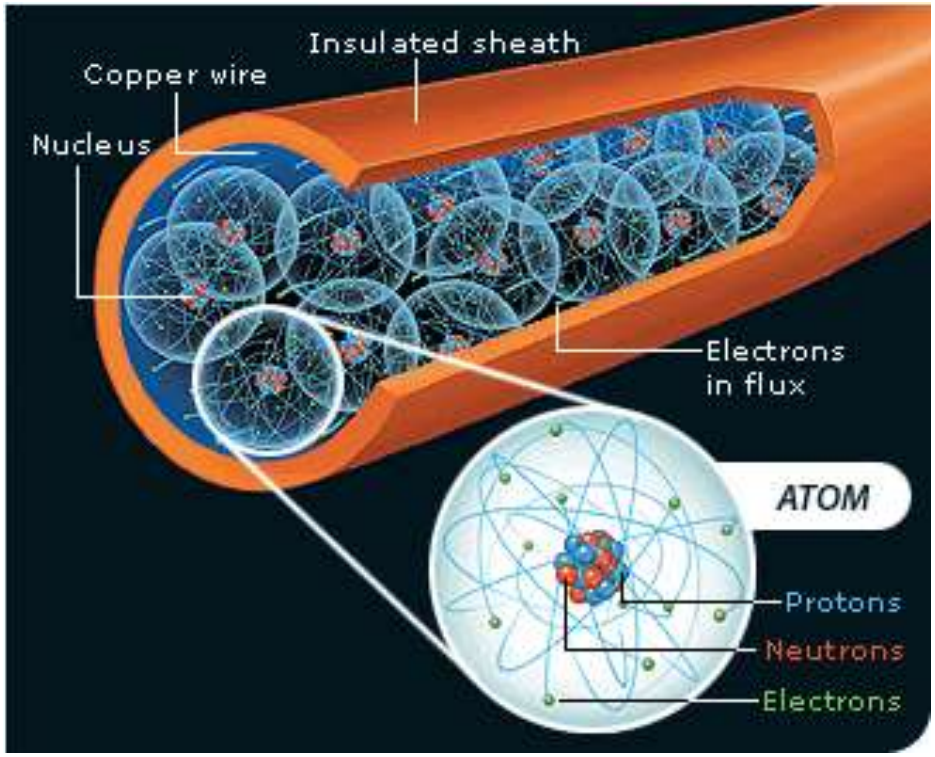
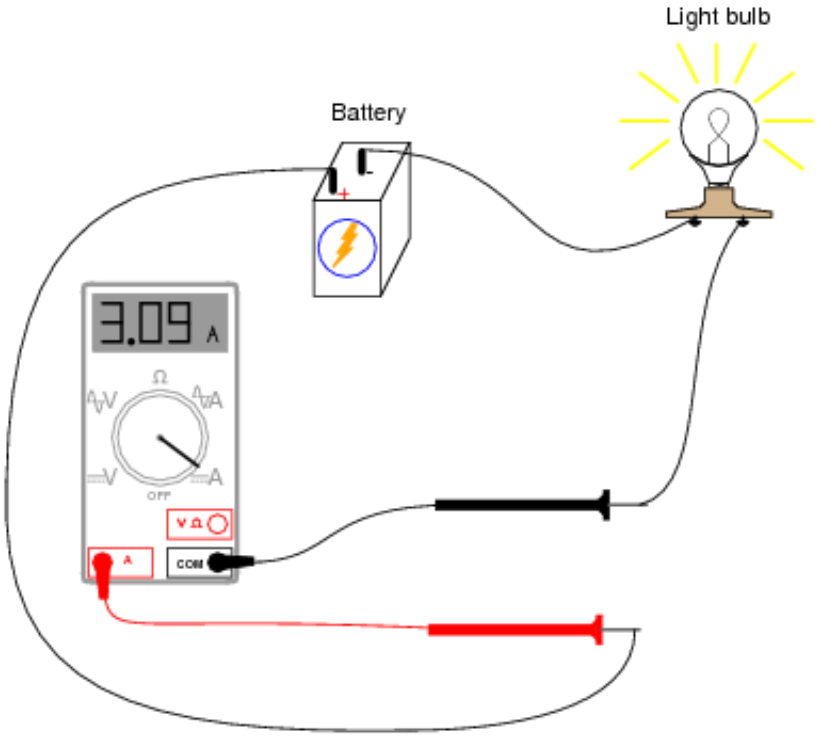


Moving charges: electric current



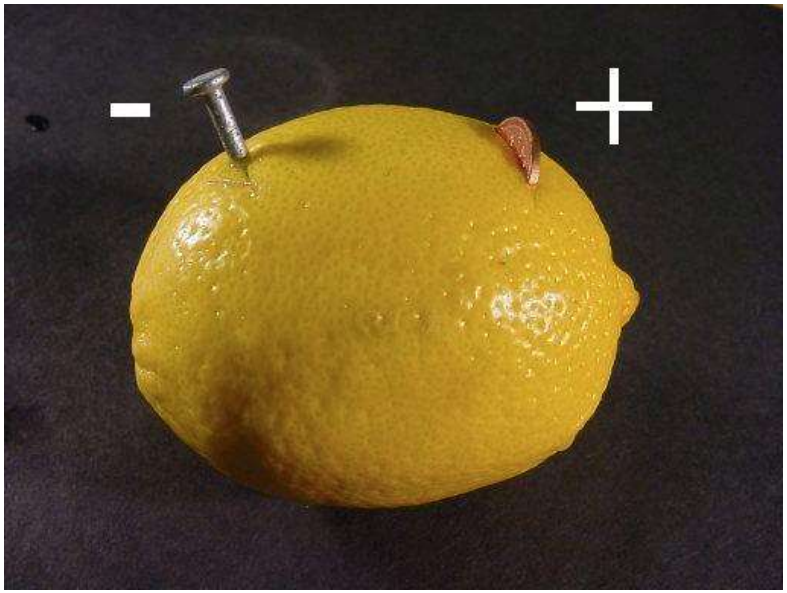
- Some atoms/molecules/materials hold on to their electrons tightly.
  - Insulators: plastic, rubber, glass
- Some let their charges roam about freely
  - Conductors: metals
- Units of electric current: Coulombs/sec = **Ampere**
- -1 **Coulomb** is the charge of approx. 6.24×10^{18} electrons

Toll plaza counts
Cars per second



Amp-meter counts
Coulombs per second = Amperes

Batteries



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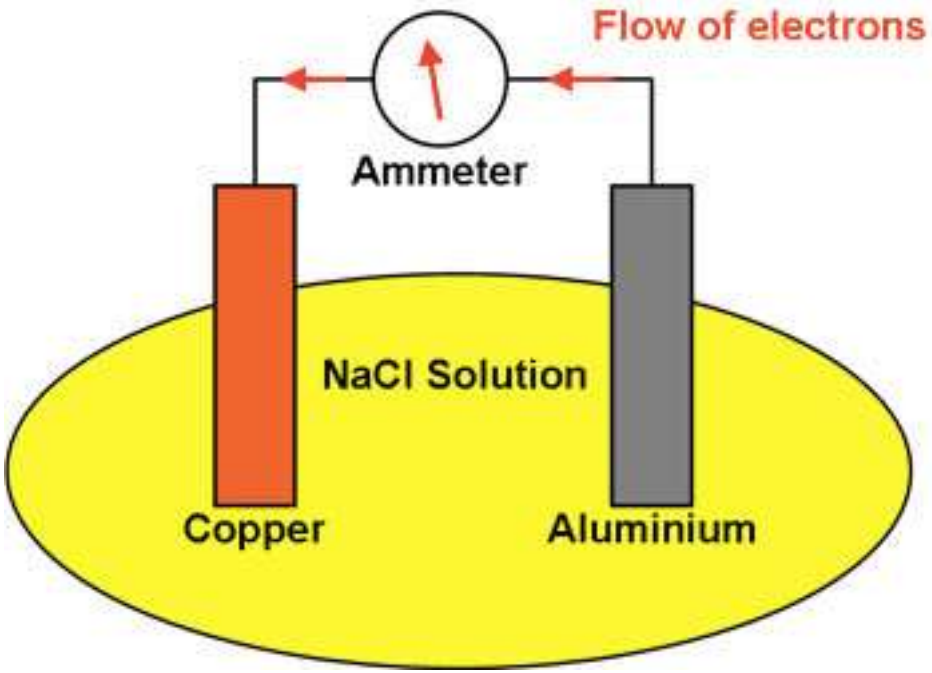


Constant flow of current!

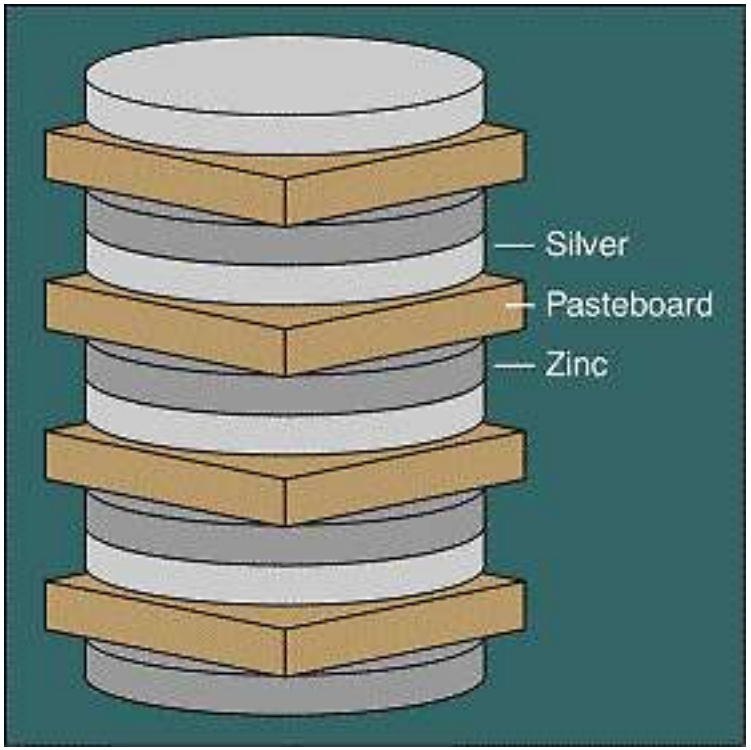
Voltage

- When charges move in an electric field, the electrostatic force does WORK on the charge.
- Moving from point A to point B, the work done per unit charge would be measured in Joules/Coulomb.
- This is called the **potential difference** between the points A and B. It is measured in Joules/Coulomb, also called **Volts**.
- Therefore, a potential difference is also called a **voltage.**

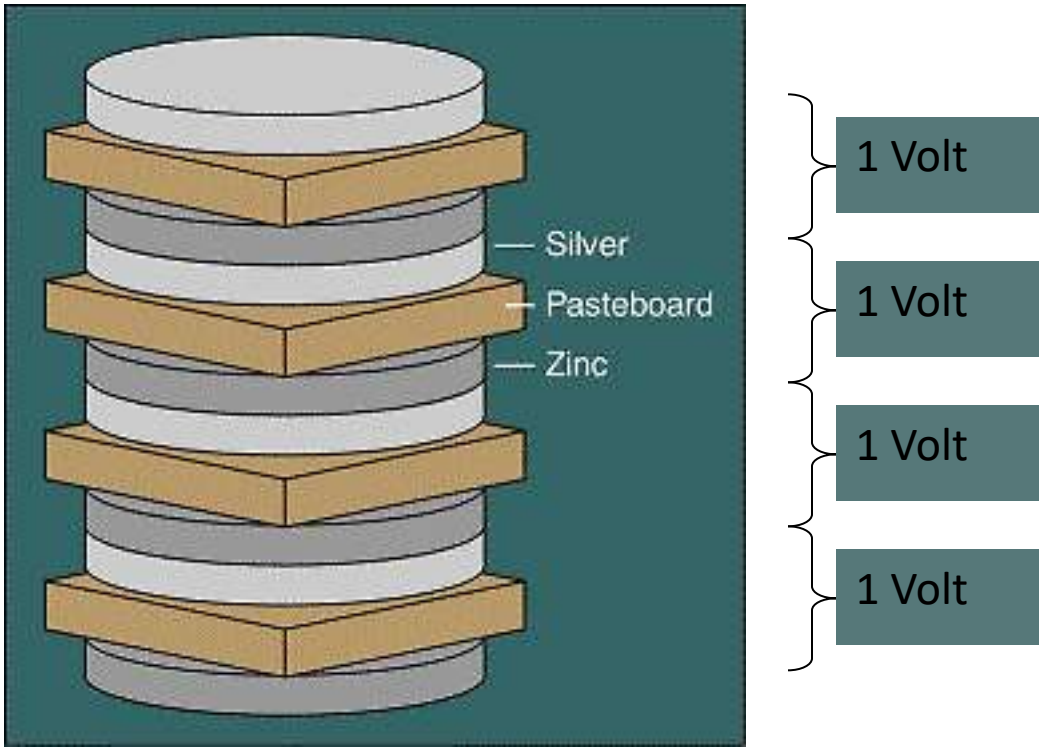
Units of **Volts = Joules/Coulomb**

Alessandro Volta (1745-1827)
(Padua, Italy)

Volta invented a practical way of producing electricity: Electrochemistry



- 4-Volt “Voltaic pile” = 4-Volt “battery”
- A single one of the sandwich structures is called an “electrochemical cell”, or just “cell”.
- A battery is a stack of cells.



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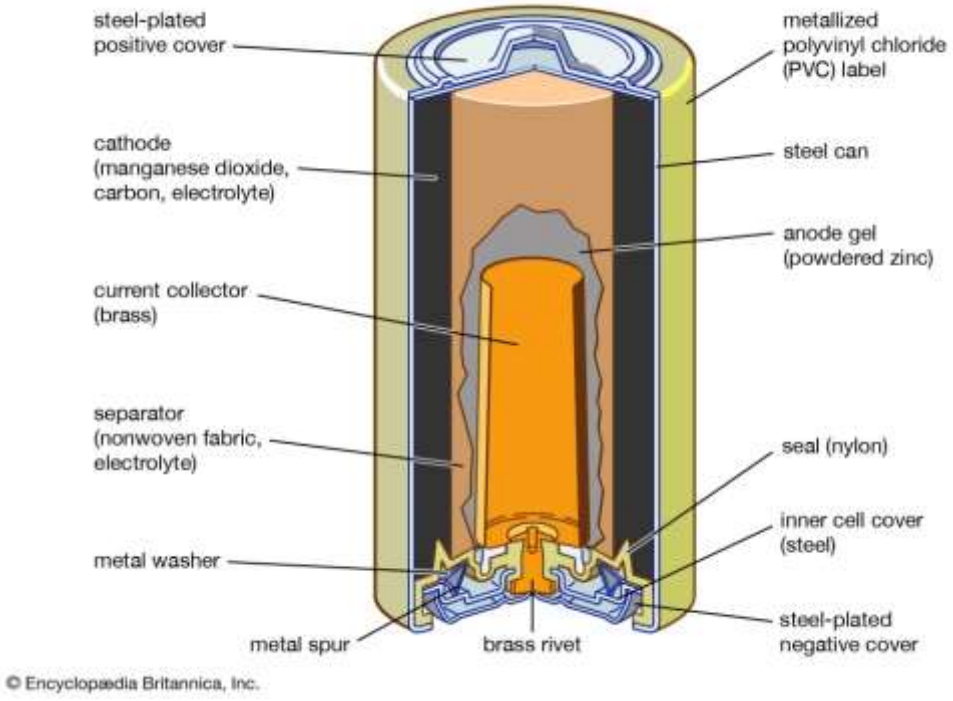
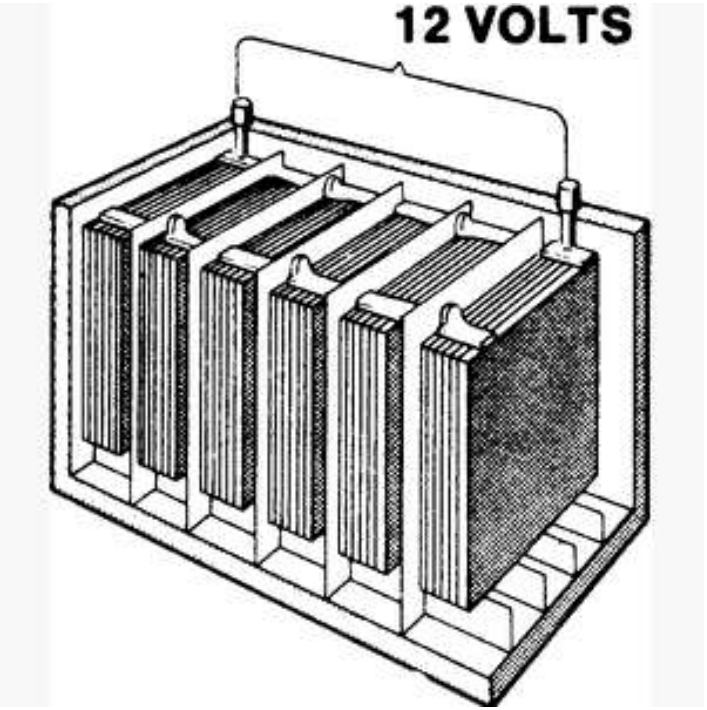
- A battery is a stack of cells.
- The voltages of the stacked cells add up.

Batteries

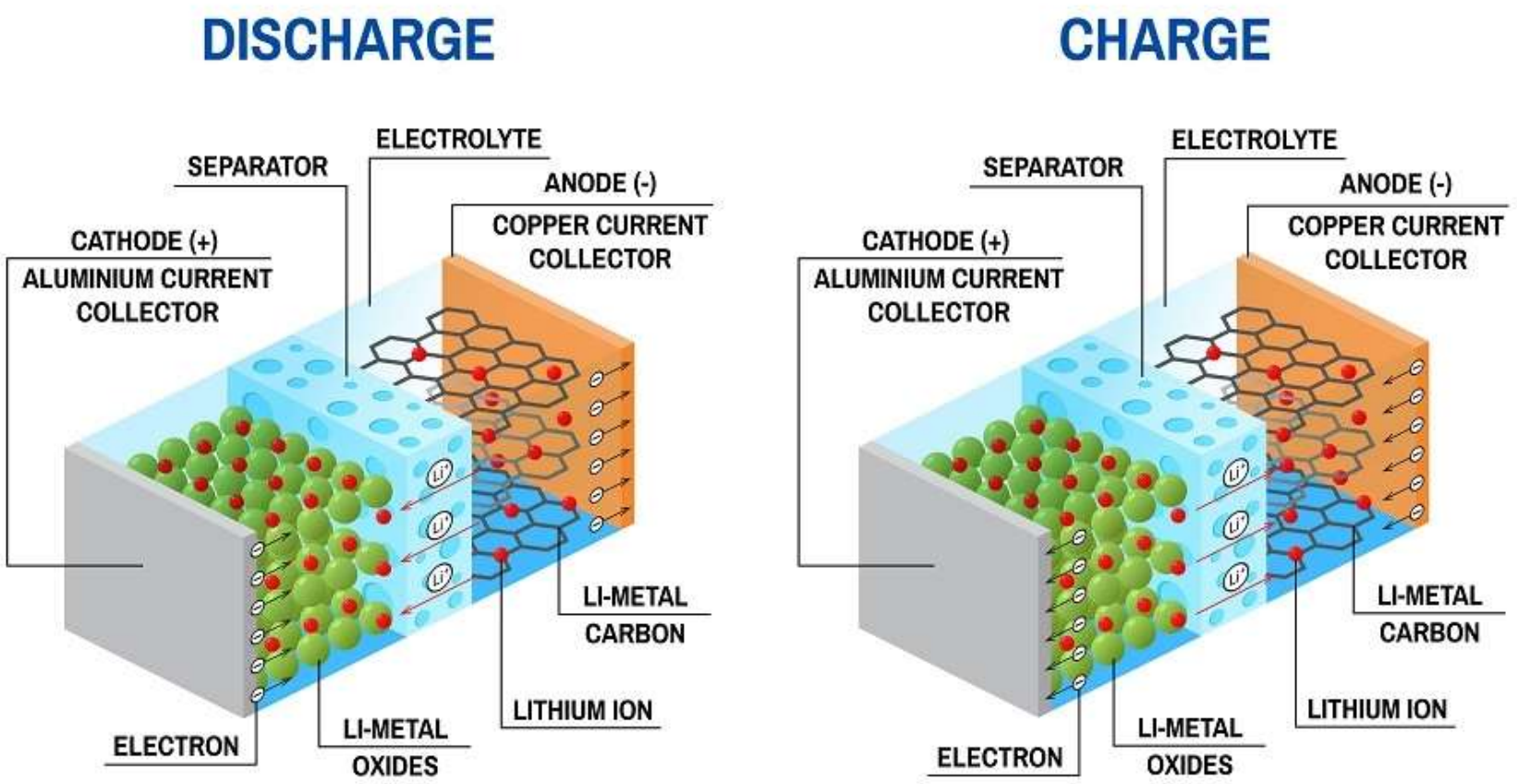


- Single-cell flashlight battery 1.5 V
- Alkaline battery



- Auto battery: 6 cells x 2 V = 12 V
- Lead acid battery
- Rechargeable!

Lithium Ion Battery



Electric Power

- Voltage = Energy / charge
- Energy = Voltage * charge
- Power = Energy/unit time

  = Voltage * charge/unit time

  = Voltage * current

Units: **Watts** = Volts * Amperes

A 1-Watt light bulb is connected to 10-volt battery. How much current (Amps) is flowing through the wires?

A) 10 Amps

B) 1 Amp

C) 1/10 Amps

D) 100 Amps

E) Depends on the color of the light bulb.

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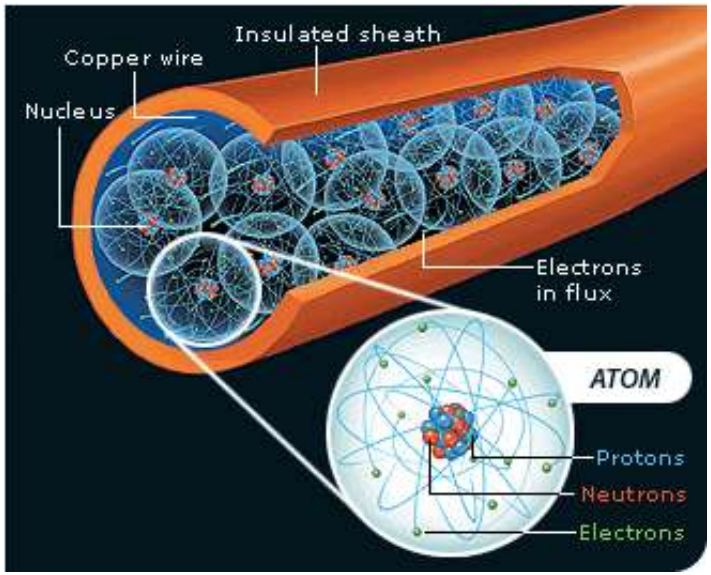
Ohm's law of conductivity



$$I = \frac{V}{R}$$

I = current, in amperes

V = applied voltage

R = resistance, in ohms

A 1 k-Ohm resistor is connected to a 2 V battery. How much current (in milli-Amperes) is flowing through the resistor?

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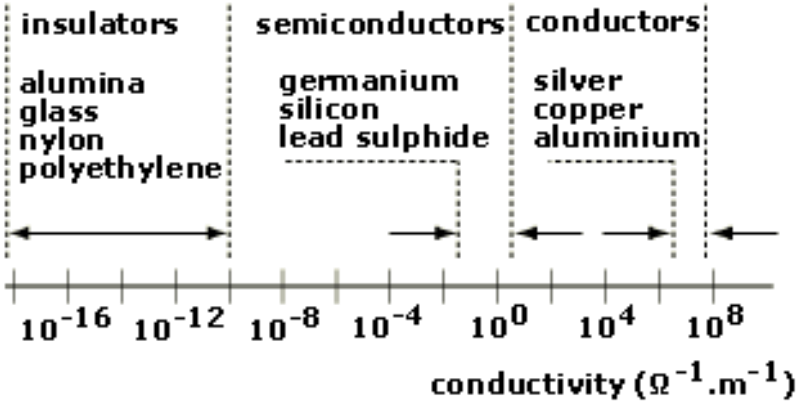
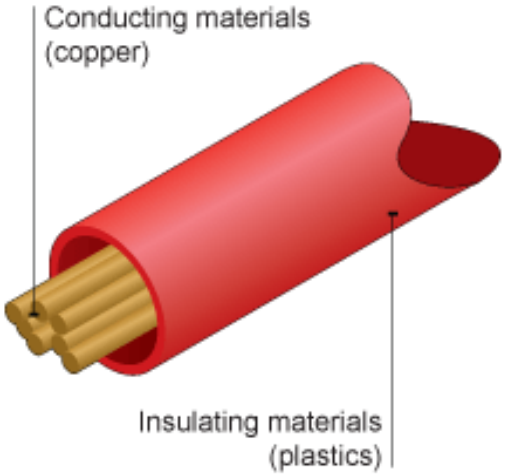
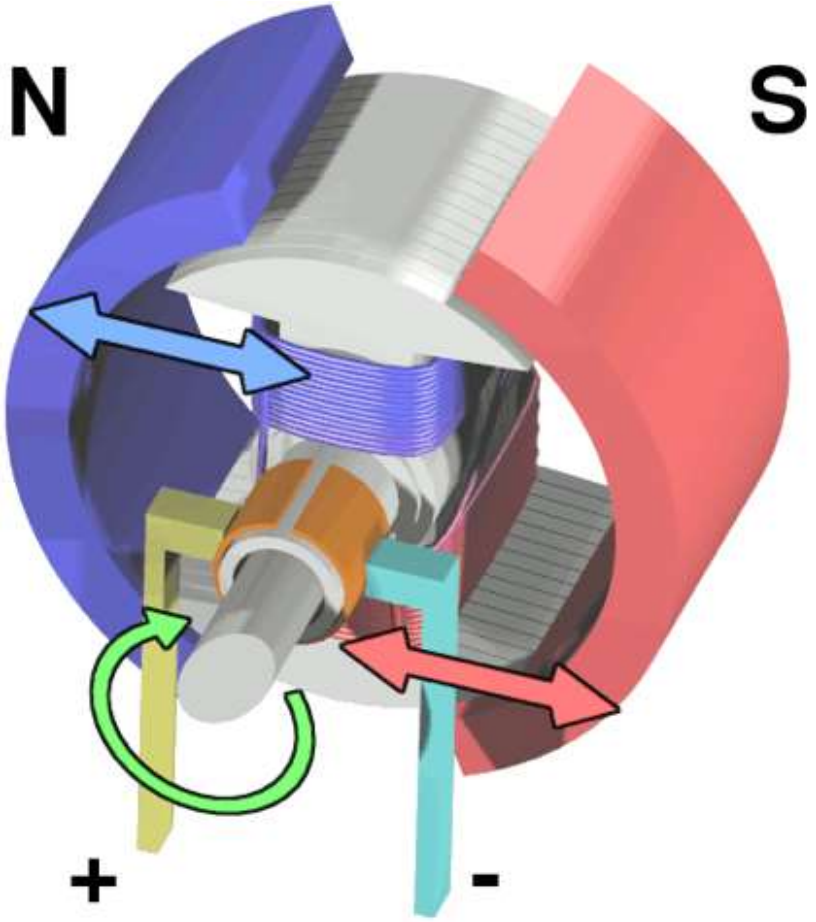
$$I = \frac{V}{R} = \frac{2 \text{ Volts}}{1000 \text{ Ohms}} = 0.002 \text{ Amperes} = 2 \text{ mA}$$





- So is the difference between conductors, semiconductors, and insulators one of degree, or is it qualitative?
- In other words, the dividing line is chosen arbitrarily?
- No: At zero temperature, the resistance of insulators becomes infinite, while the resistance of conductors remains finite.
- Semiconductors (if pure) behave like insulators at zero temp. If impure (doped), they behave like conductors.
- Another class of materials has zero resistance at low temperatures. They are called superconductors.

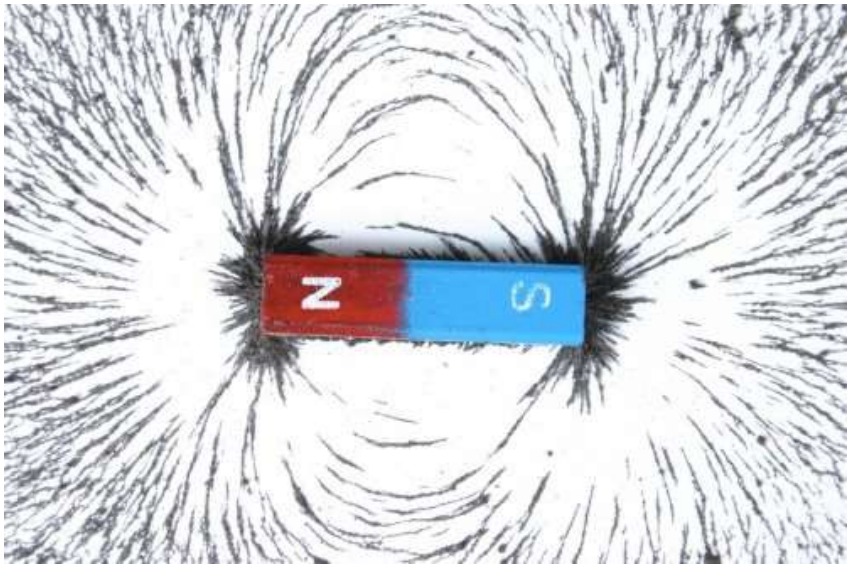
Electromagnetism, Motors, and Generators



Outline

- Last time: Motionless charges: *Electrostatics*
- Now:
  - Motionless magnets: *Magnetostatics*
  - Moving charges: *Electrodynamics*
    - Moving charges feel magnetic force
    - Moving charges generate magnetic field
    - Electric motors
    - Magnetic induction and electric generators

Magnetism



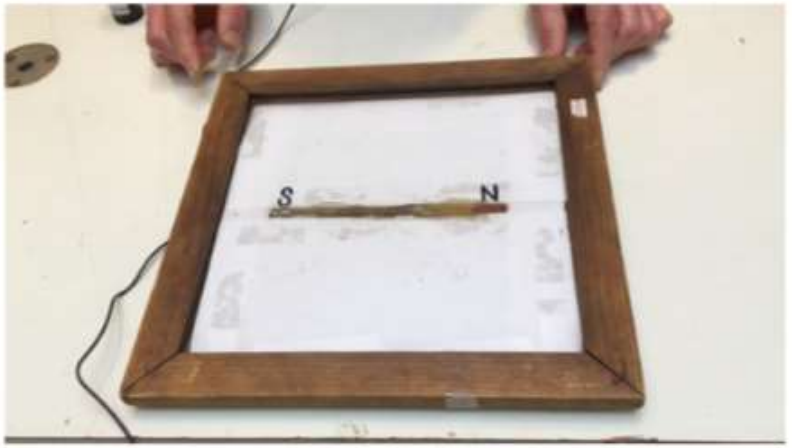
Magnetic minerals known since ancient times (lodestone = magnetite)

Forces between rocks! Attactive/repulsive.

Iron filings also subject to these forces: arrange themselves in curious patterns, similar to electric field lines.

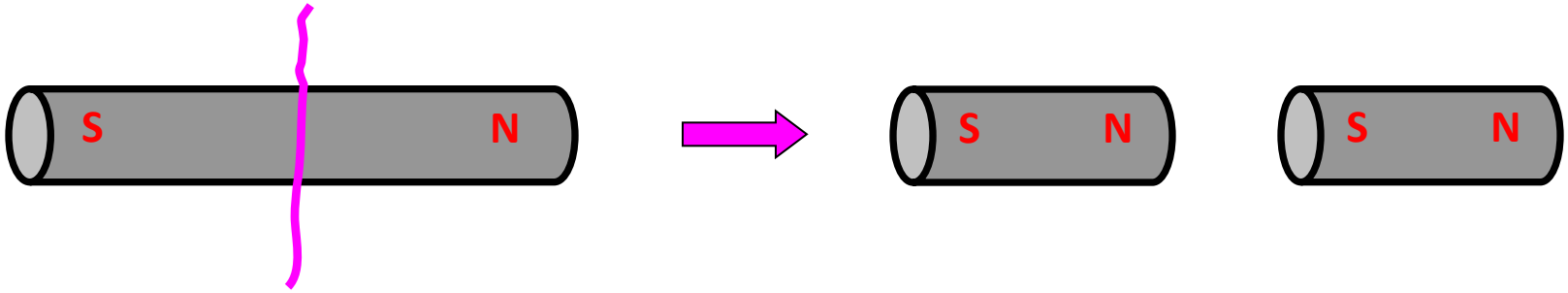
But are these electrostatic forces? No, the objects don't discharge! Cannot separate magnetic "charges" from each other.

Demo: Magnetic Field around Bar Magnet



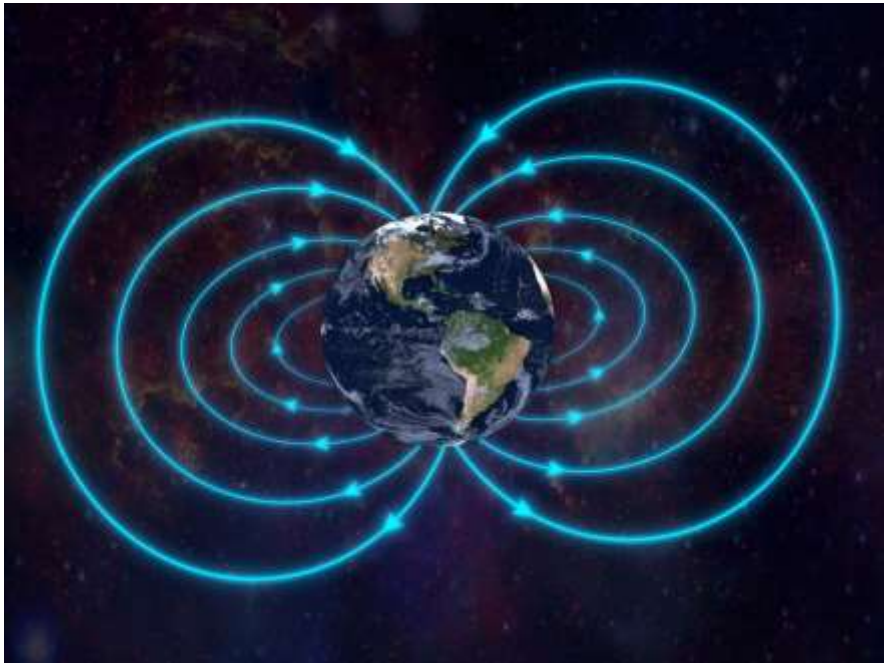
Magnetism

- North poles repel
- South poles repel
- Opposite poles attract
- Poles cannot be isolated
- Cut a dipolar magnet in two: get two dipolar magnets

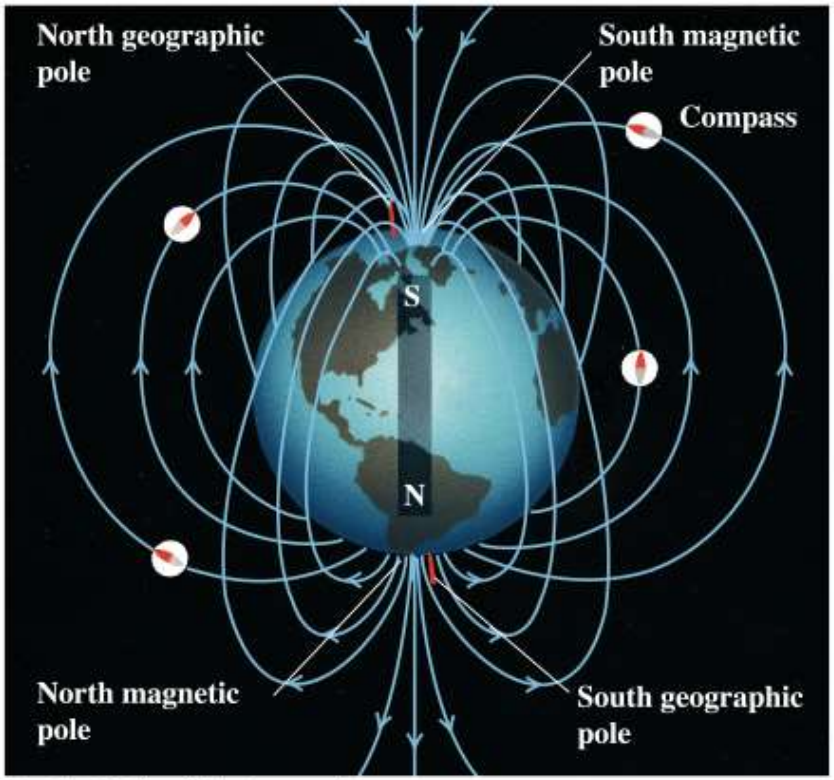


Magnetism

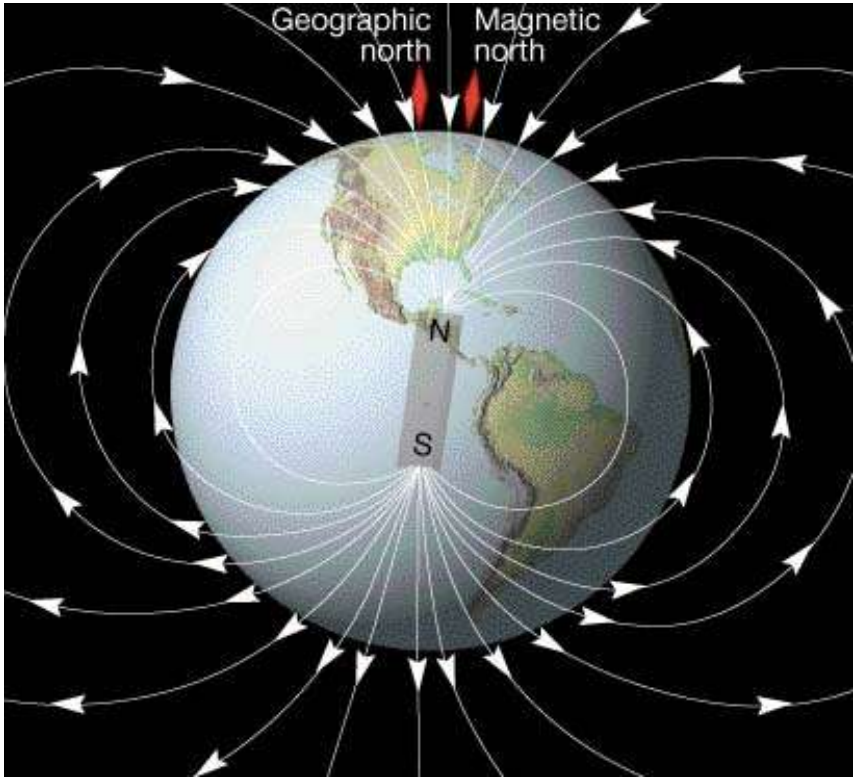
- The Earth is a magnet: A freely spinning magnetic needle will align itself in the north-south direction. The needle end that points north is called the north pole, the other end the south pole of the magnet.



What you can find on the internet



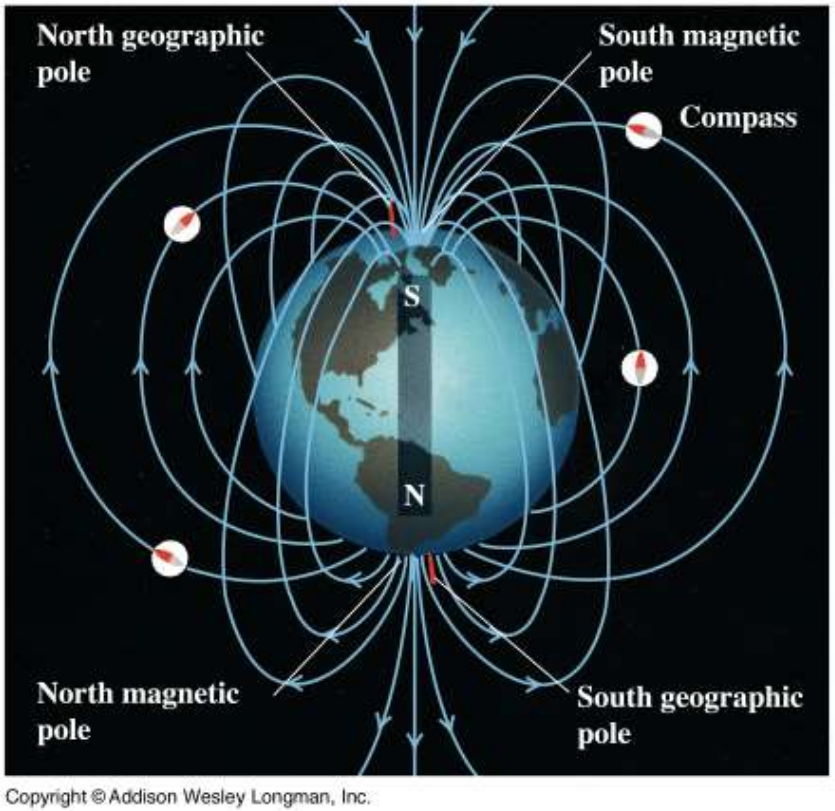
(A)



(B)

Which is correct?

What you can find on the internet



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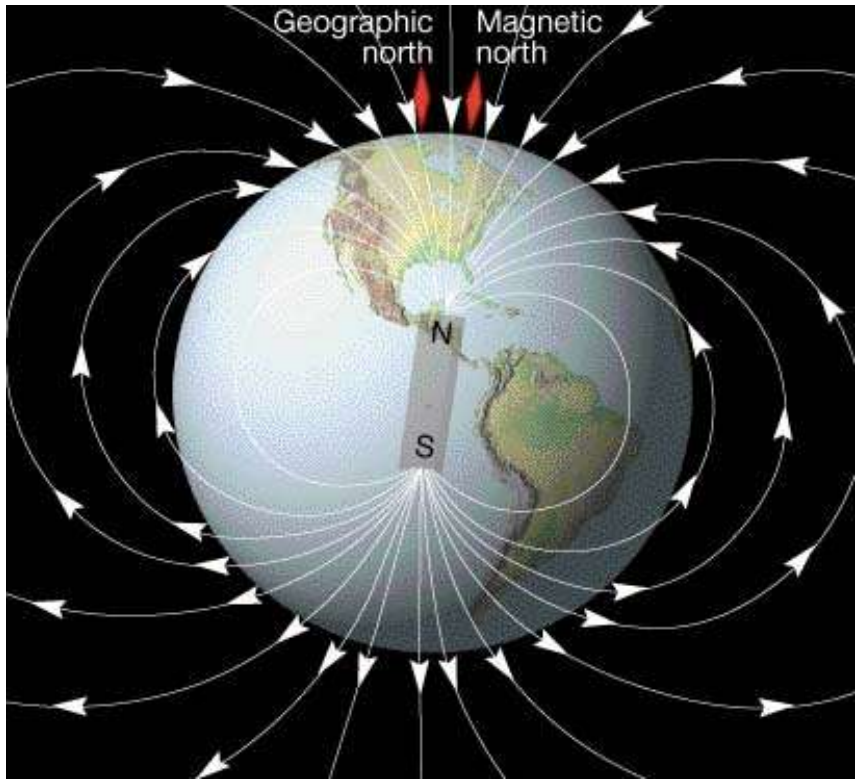

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