
STATIC ELECTRICITY
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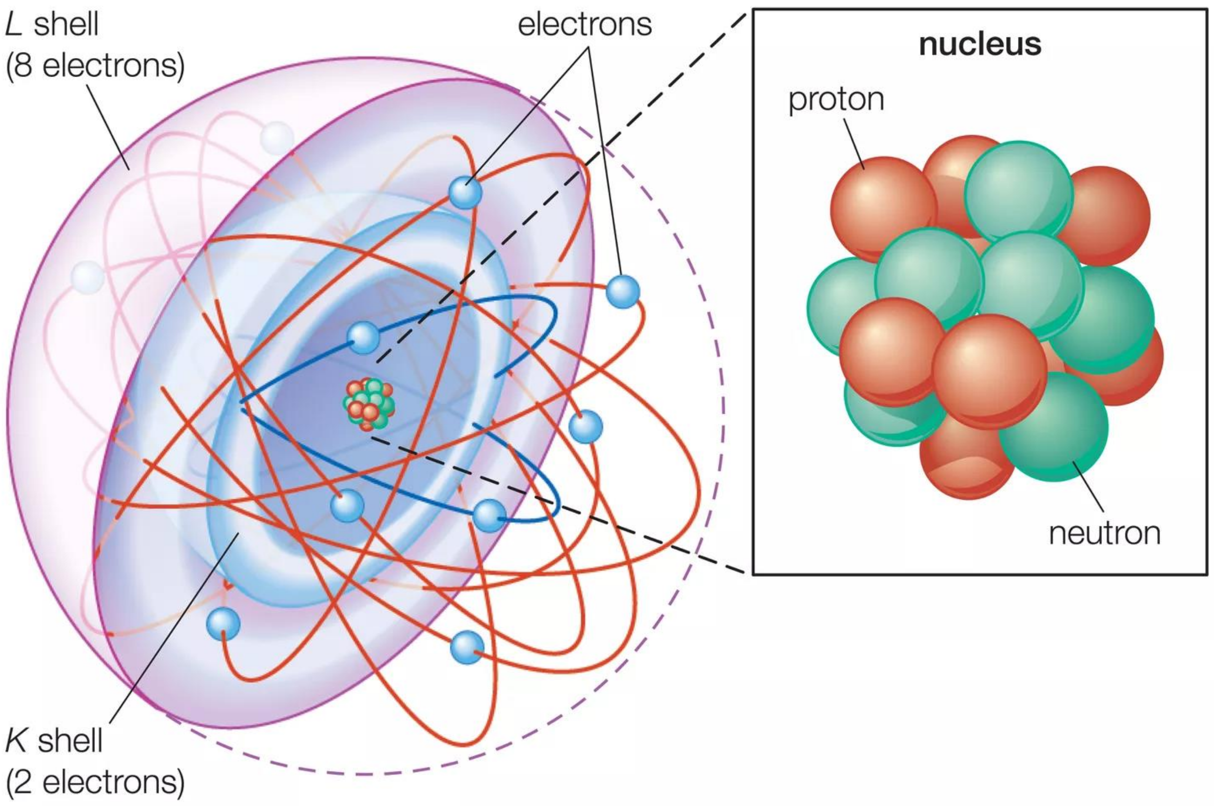
ELECTRIC CHARGE

Electric Charge

- An atom
  - Nucleus
    - Protons – positive charge
    - Neutrons – no charge, but same mass as proton
  - Electron cloud
    - Electron – negative charge, little mass
    - $q_e = -1.60 \times 10^{-19}\ C$
      - Unit of charge: Coulomb (C)
      - q_e is the smallest charge discovered
      - Electricity is quantized → comes in discreet numbers
      - $|q_e|$ is the elementary charge
        - $e = 1.60 \times 10^{-19}\ C$
  - In nature atoms have no net charge
    - # protons = # electrons



ELECTRIC CHARGE

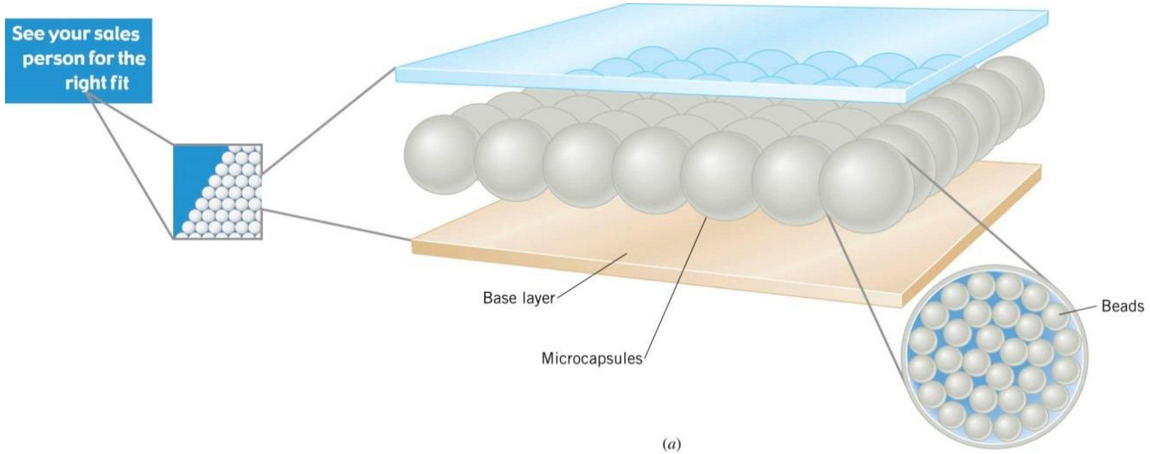
- How many electrons does it take to make a charge of $-4 \times 10^{-6}\ C$? What is their mass ($m_e = 9.11 \times 10^{-31}\ kg$)?

- N = 2.5×10^{13} electrons (a lot)
- m = 2.28×10^{-17} kg (very small)

Electric Charge

- Law of Conservation of Charge
  - During any process, the net electrical charge of a closed system remains constant
- Like charges repel
- Unlike charges attract
  - The attraction and repulsion are forces and can be used with Newton's Laws and other dynamics problems

ELECTRIC CHARGE



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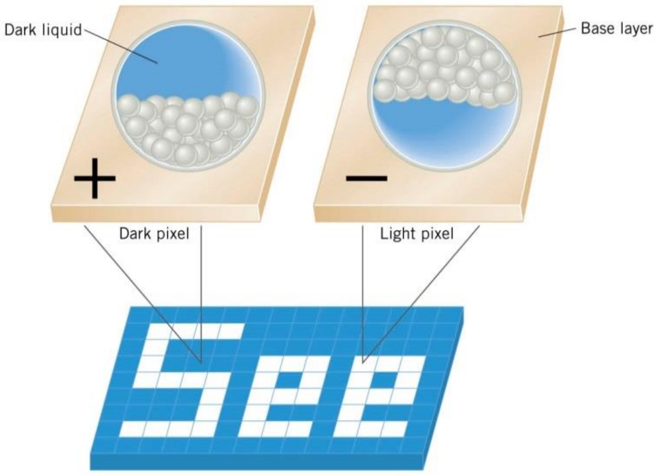


(b)

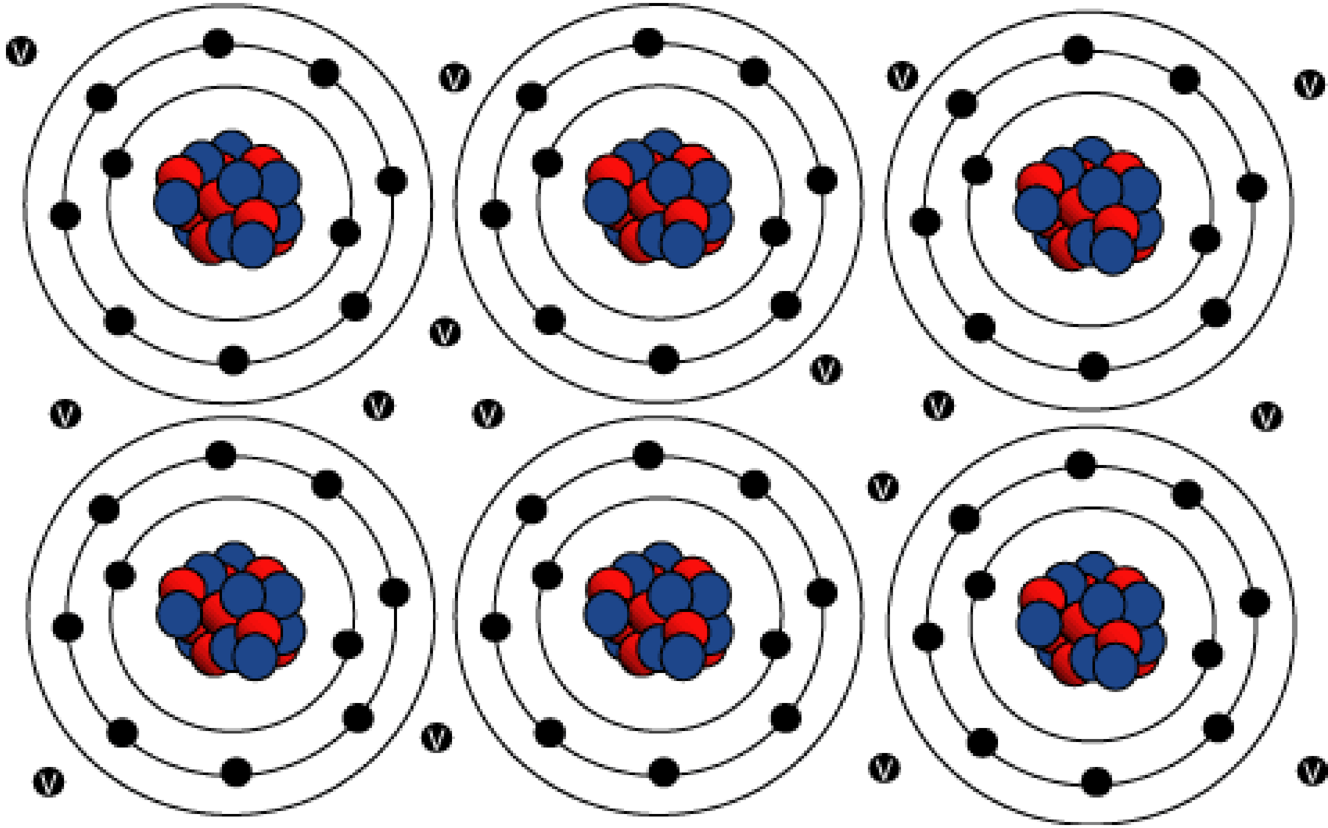
- Electric Ink

ELECTRIC CHARGE

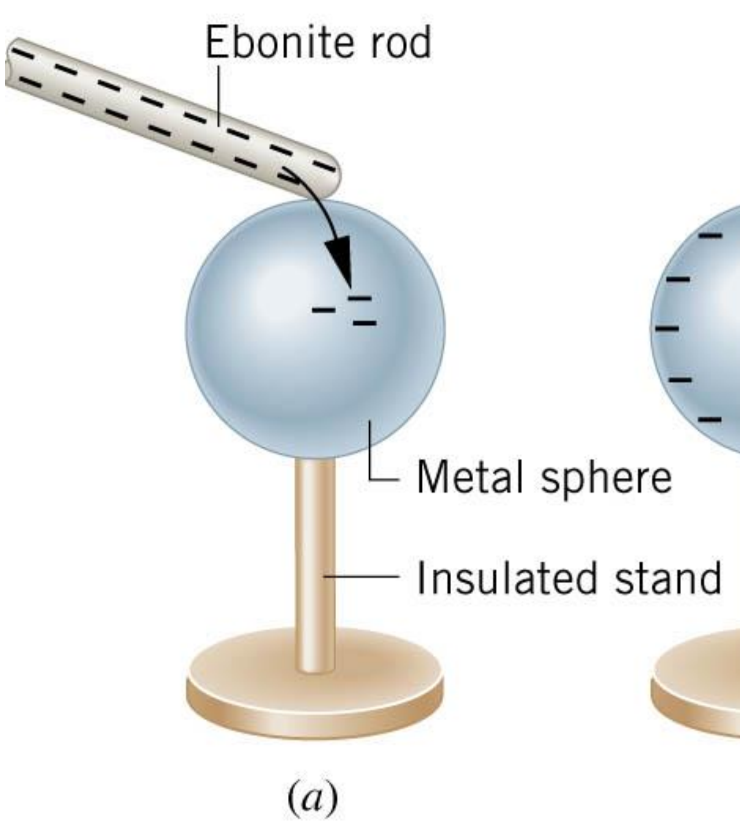
- Electricity can flow through objects

- Conductors let electrons flow easily
  - Most heat conductors are also electrical conductors
  - Metals

- Insulators are very poor conductors
  - Rubber
  - Plastic
  - Wood



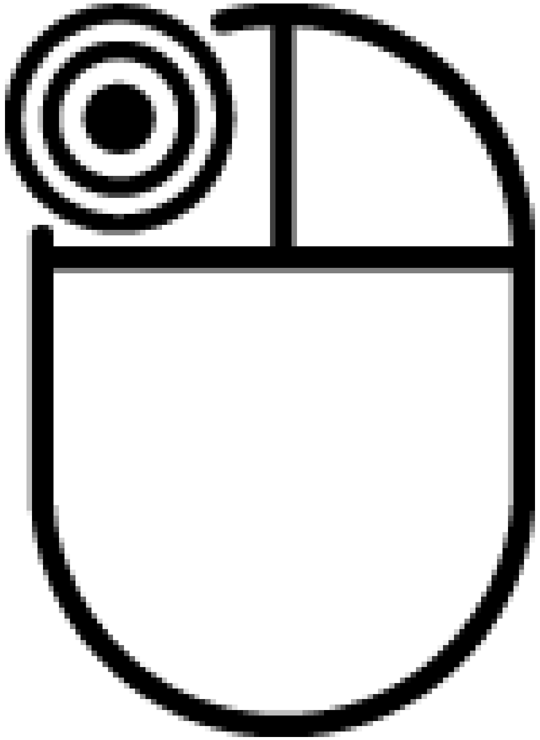
Electric Charge



- Charging by contact
- Negative charged rod gives some electrons to sphere
- Sphere becomes negatively charged until charges are equal

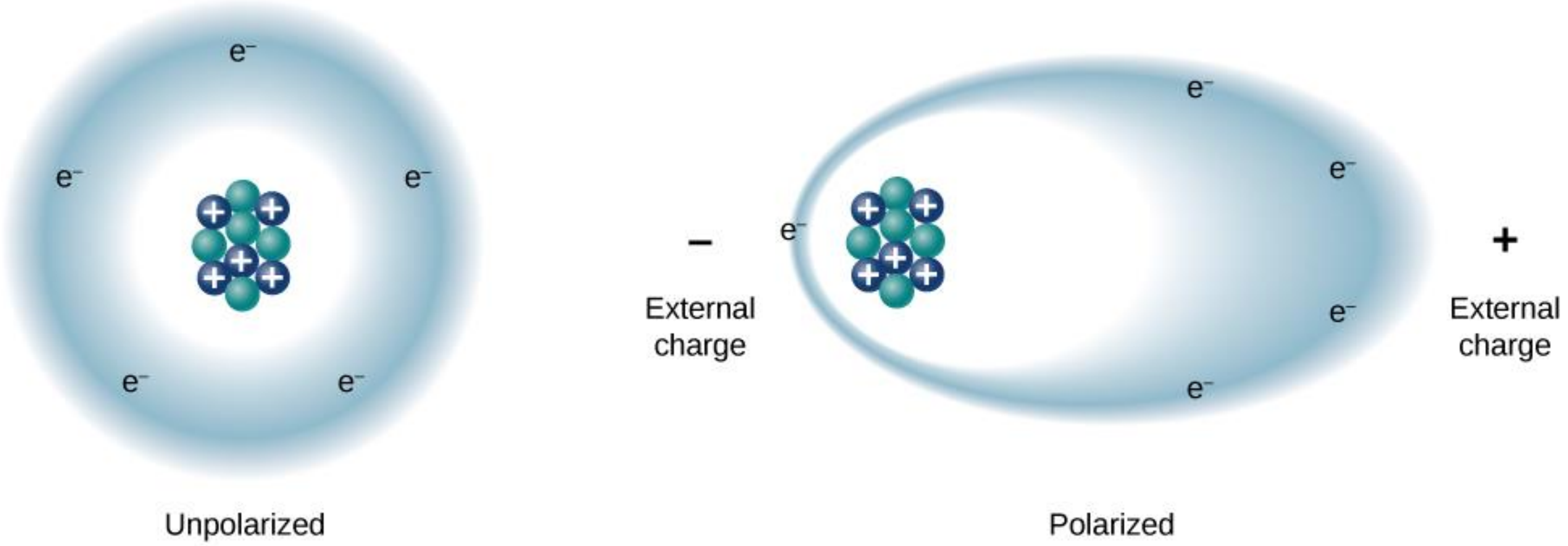
Electric Charge

- Static Electricity Charging
  - When two insulators are rubbed together
    - One steals the electrons from the other
    - It becomes negatively charged
    - The other becomes positively charged



Electric Charge

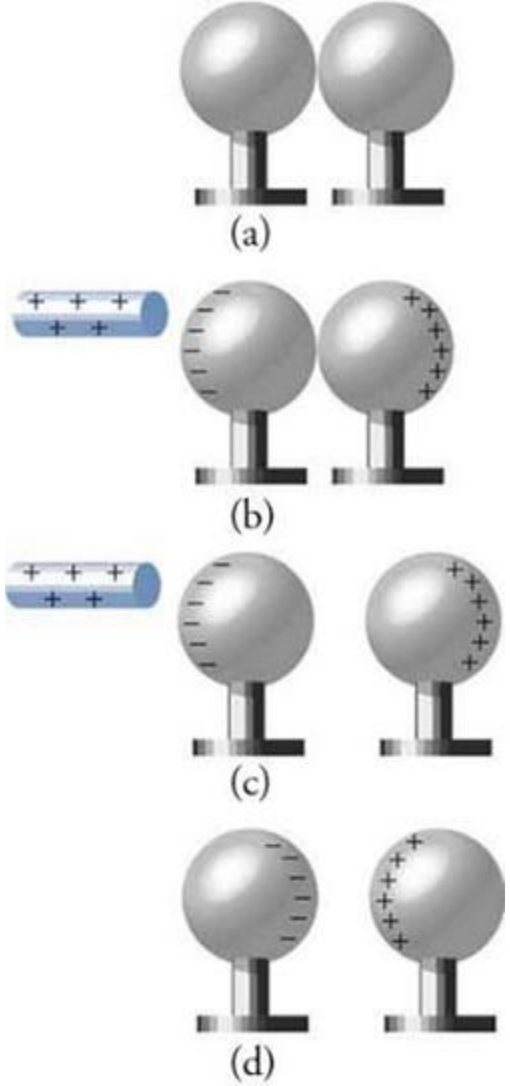
- Polarization
  - Insulators
    - Electrons are not free to move away from the atoms or molecule
    - When a charge is brought near, the electrons move to one side of the atom/molecule so that more electrons are on that side
    - One side is negative, and the other side is more positive



Electric Charge

Charge by Induction

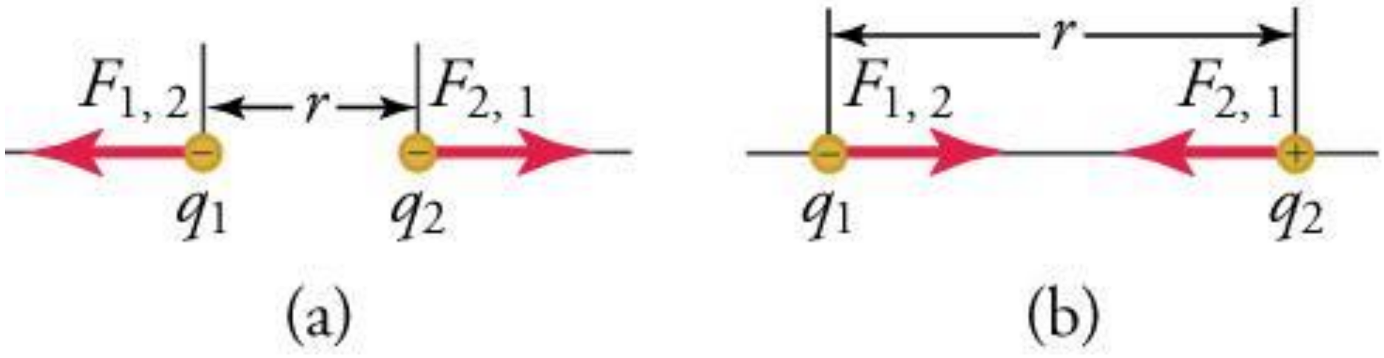
- Charge without touching
- Charged rod comes near neutral sphere
- The like charges are repelled to other sphere
- The spheres are separated
- The rod is removed
- Spheres are charged



COULOMB'S LAW

Coulomb's Law

- Point charges exert force on each other
  - Related to the size of the charges and the distance between them
  - If the signs are same force repels
  - If the signs are opposite force attracts
  - Force of the first to the second is equal and opposite of the second to the first
    - Newton's Third Law



Coulomb's Law

- Coulomb's Law

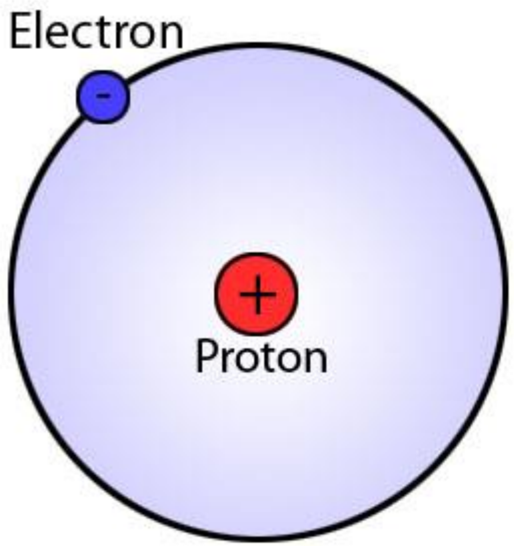
$$F = k\frac{|q_1 q_2|}{r^2}$$

- Where
  - F = electrostatic force
  - k = constant (8.99×10^9 $\mathrm{Nm^2/C^2}$)
  - q = charge
  - r = distance between the charges

COULOMB'S LAW

- In a hydrogen atom, the electron ($q = -1.60 \times 10^{-19}$ C) is 5.29×10^{-11} m away from the proton of equal charge magnitude. Find the electrical force of attraction.

- $F = 8.22 \times 10^{-8}$ N



COULOMB'S LAW

- Coulomb's Law – other notes
  - Notice the similarity to Newton's Law of Universal Gravitation

  - Notice that $F \propto 1/r^2$
    - Distance increases by 4, force decreases by 16

COULOMB'S LAW

- Force on 1 charge by 2 others

  - Work in two parts
    - Find force of attraction by one of the points
    - Find force of attraction by the other point
    - Add the force vectors
      - REMEMBER!!!!! → you have to add the x and y components!!!!!

Coulomb's Law

- There are three charges in a straight line
- $q_1 = +2\mu C$ at $x = -0.1$ m
- $q_2 = -3\ \mu C$ at $x = 0$ m
- $q_3 = +5\ \mu C$ at $x = 0.3$ m
- What is the force on q_2?

- $F = -3.89$ N


ELECTRIC FIELD

Electric Field

- We can use a ***test charge*** to determine how the surrounding charges generate a force

- Pick a small test charge so it doesn't change the surrounding charge orientation

ELECTRIC FIELD

- A test charge ($q_0 = 1.0 \times 10^{-10}\ C$) experiences a force of $2 \times 10^{-9}\ N$ when placed near a charged sphere. Determine the Force per Coulomb that the charge experiences and predict the force on a $2\ C$ charge.

- $\frac{F}{q_0} = 20\ N/C$
- $F = 40\ N$

Electric Field

- Electric Field Definition

$$E = \frac{F}{q_0} = \frac{kq_1}{r^2}$$

  - Force per charge
  - Vector
    - Same direction as the force on a positive test charge
    - Remember to add them as vectors!!!!
  - Unit: N/C

ELECTRIC FIELD

- Point Charges

$$E = \frac{F}{q_0}$$

$$F = \frac{kqq_0}{r^2}$$

$$E = \frac{\frac{kqq_0}{r^2}}{q_0}$$

$$E = \frac{kq}{r^2}$$

- Notice the q_0 does not affect the E-field

ELECTRIC FIELD

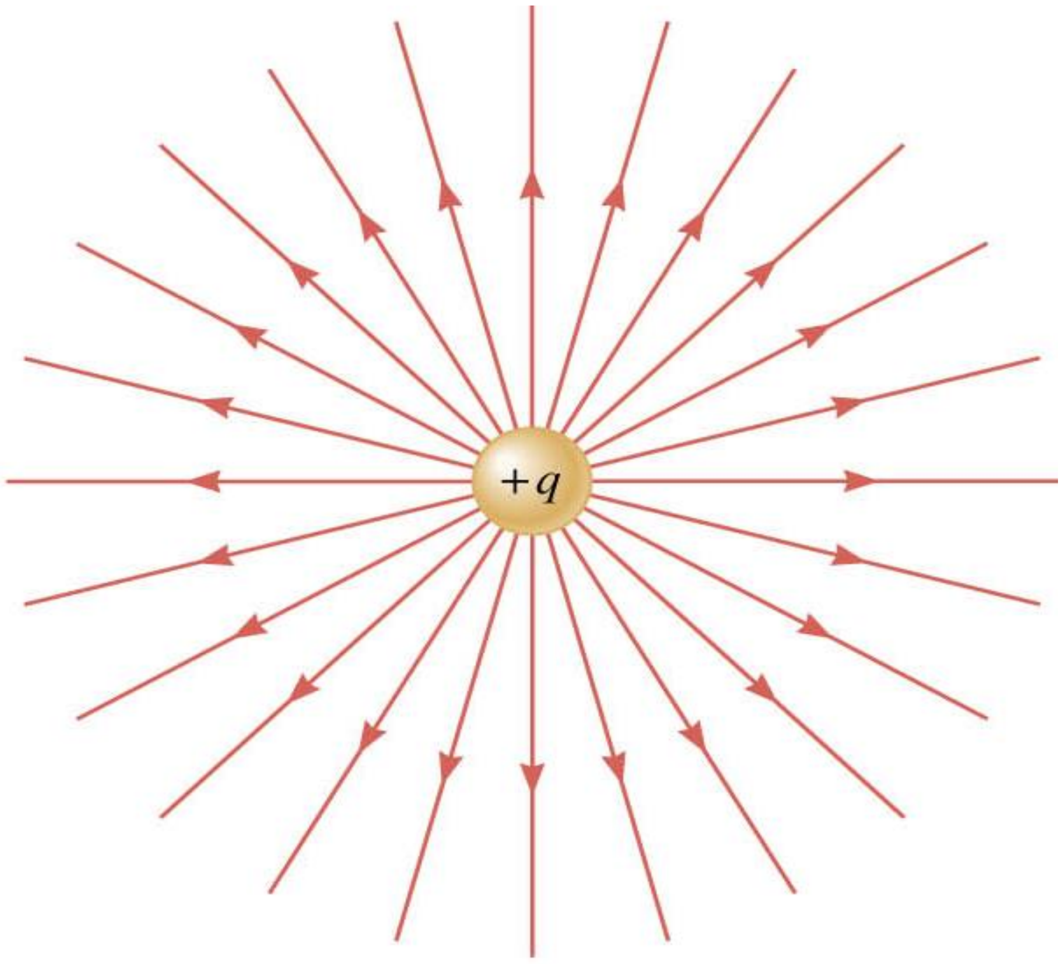
- There are two point charges of q_1 = 4 C and q_2 = 8 C and they are 10 m apart. Find point where E = 0 between them.

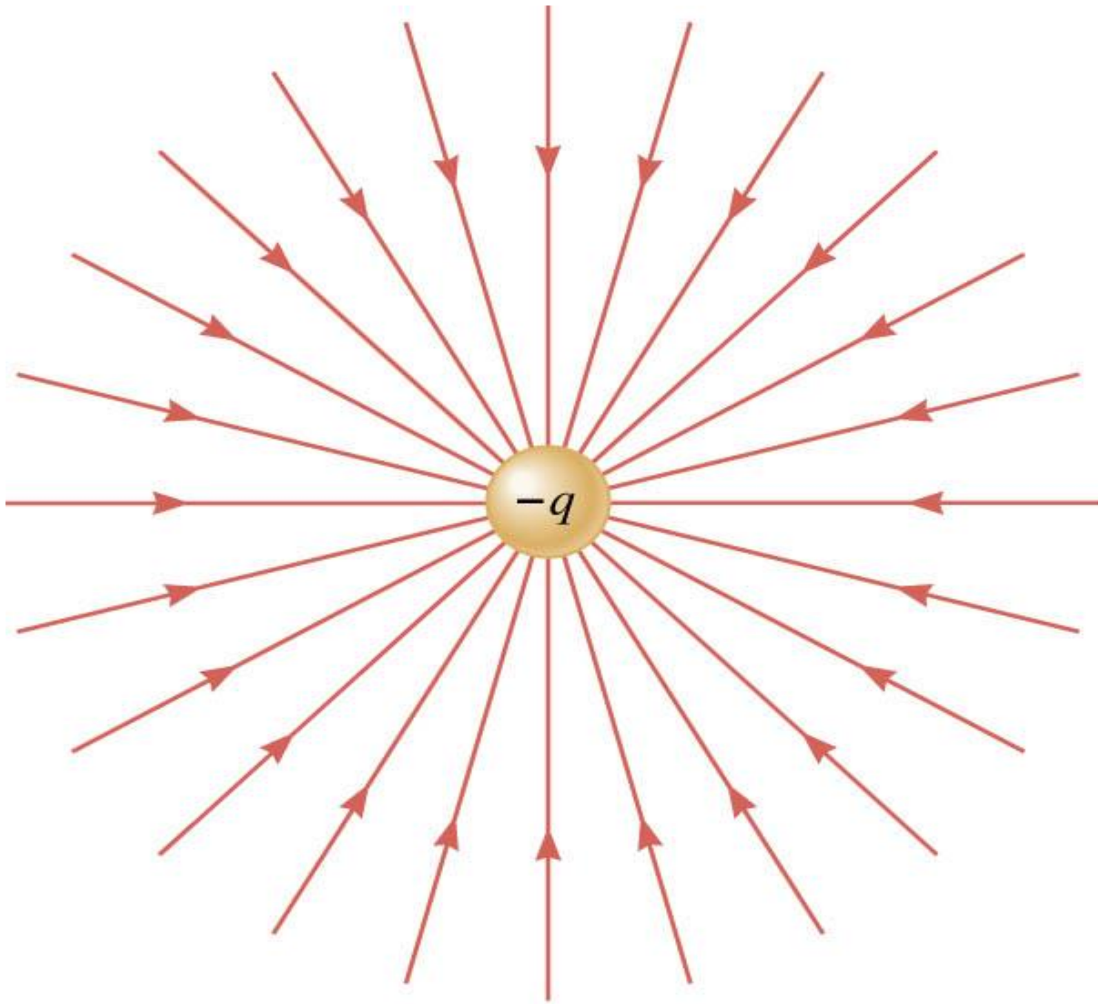
- d = 5.85 m from q_2 towards q_1

Electric Field

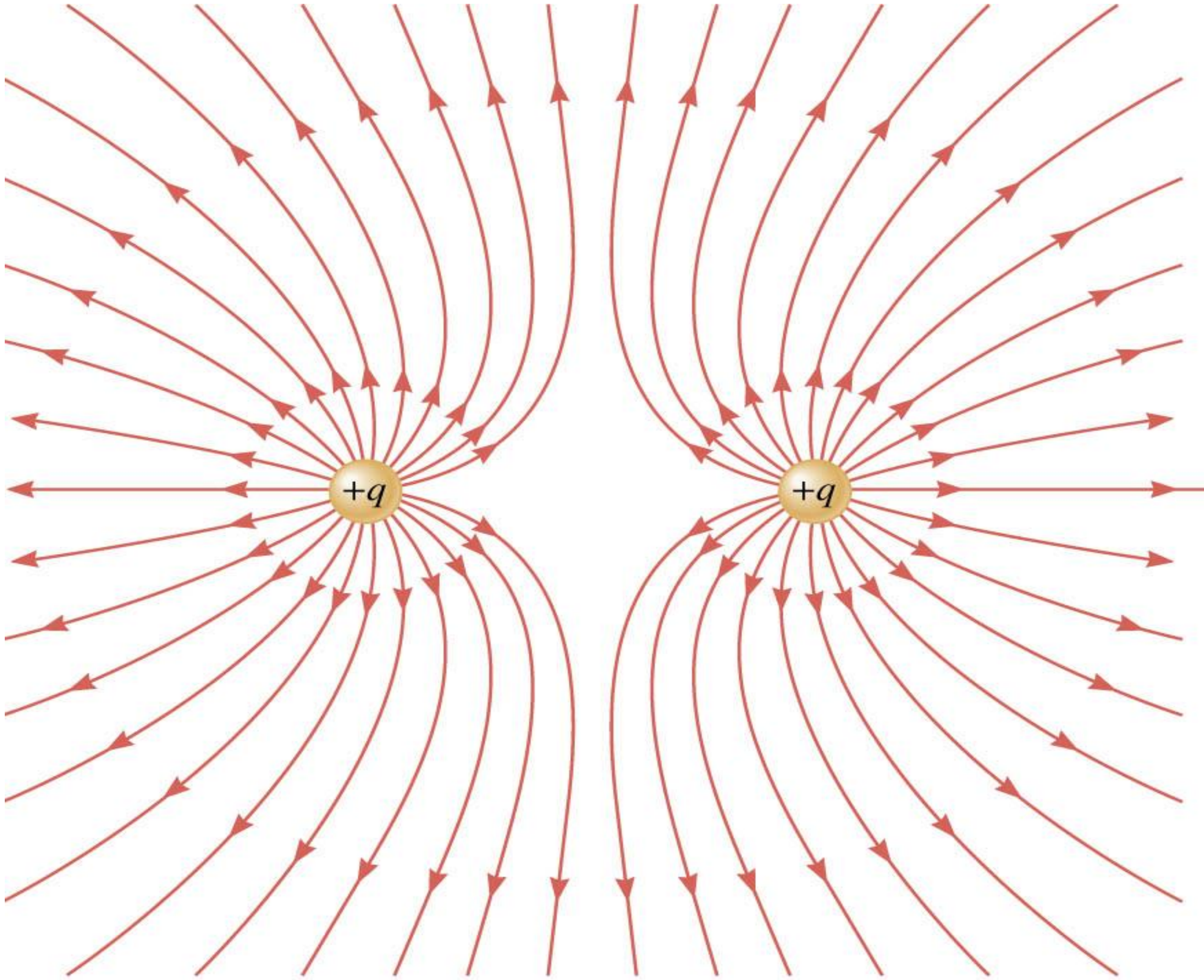
- It would be nice to have some kind of map to show the E-field in space
- Rules
  - Lines begin at positive charges only
  - Lines end at negative charges only
  - The number of lines entering or leaving a charge is proportional to the size of charge
  - Lines don't cross each other
  - Lines leave surfaces at 90 degrees

ELECTRIC FIELD





Electric Field




ELECTRIC POTENTIAL

Electric Potential

- Change in PE due to Gravity
  - Force of gravity is conservative
  - $W = mgh_0 - mgh_f = PE_0 - PE_f$
- Change in PE due to Electrical Force
  - Electrical Force is conservative
  - $W = PE_0 - PE_f$

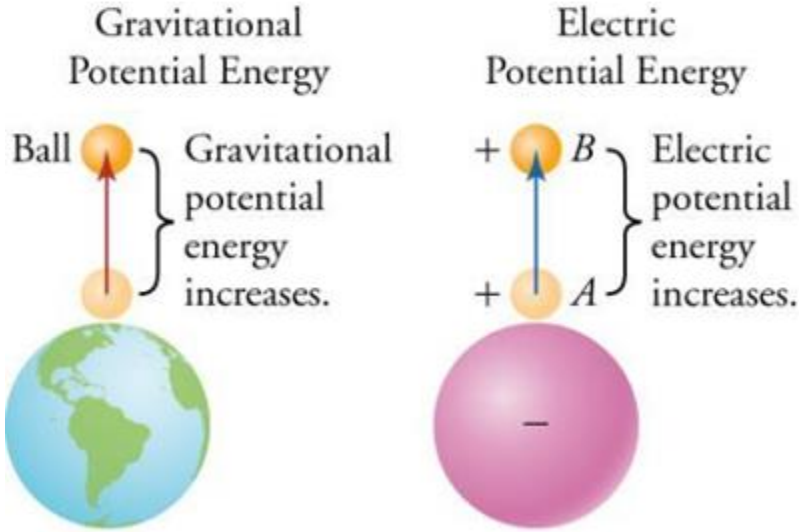
$$F_G = G\frac{m_1 m_2}{r^2}$$

$$F_E = k\frac{q_1 q_2}{r^2}$$

ELECTRIC POTENTIAL

- For gravity (in a constant G-field)
  - $W = -\Delta PE$
  - $W = Fd$
  - $-\Delta PE = Fd$
  - $F = mg$
  - $W = -\Delta PE = mg\left(y_f - y_0\right)$

- For static electricity (in a constant E-field)
  - $W = -\Delta PE$
  - $W = Fd$
  - $-\Delta PE = Fd$
  - $F = q_0 E$
  - $W = -\Delta PE = q_0 E(x_f - x_0)$



PE can only be differences because there is no absolute zero position

Electric Potential

- If the field is not constant, then calculus is used.
- For point charges
  - $PE = q_0 E r$
  - $PE = q_0 \left(\frac{kq}{r^2}\right) r$
  - $PE = \frac{kqq_0}{r}$

Electric Potential

- E-field is $E = \frac{F}{q_0}$ and is a vector
- It might be nice to have a similar idea with energy which is not a vector

- Electric Potential (or Potential Difference)
  - $V = \frac{\Delta PE}{q_0}$
- For point charges
  - $V = \frac{kq}{r}$

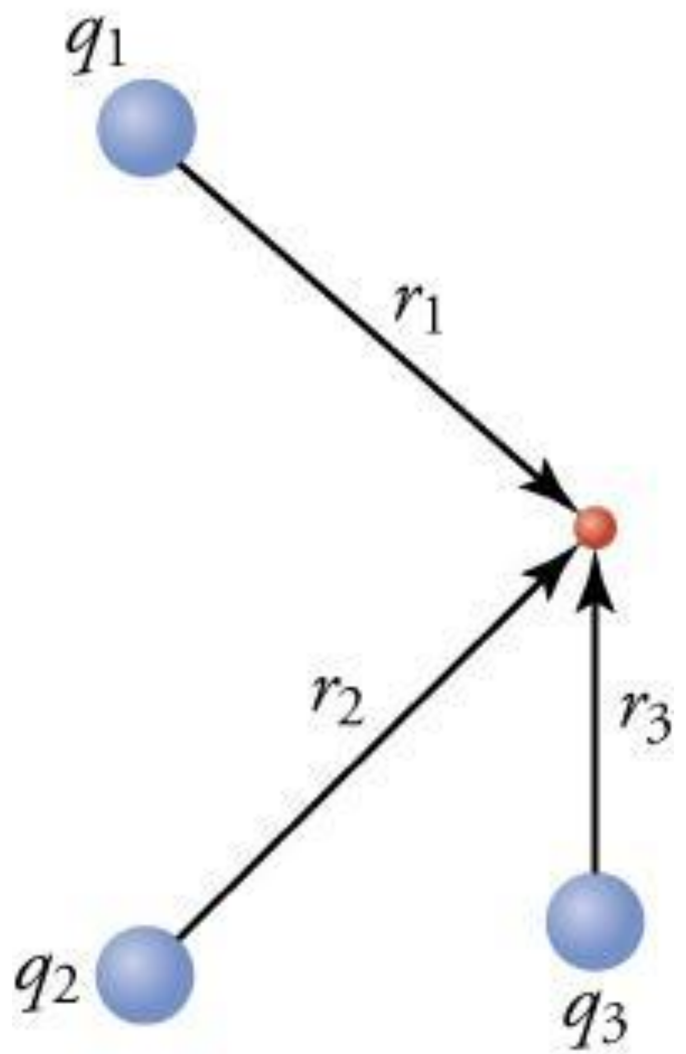
ELECTRIC POTENTIAL

- Potential energy
  - PE
  - $q_0 V$
  - Unit: J

- Electric potential
  - V
  - $\frac{\Delta PE}{q_0}$
  - Unit: J/C = V

Electric Potential

- To add potentials from several point charges, add the potentials at that point



ELECTRIC POTENTIAL

- Two point-charges lie on the x-axis with $q_1 = -2\ \mu C$ at 1 cm and $q_2 = 3\ \mu C$ at 9 cm. Where is the electric potential zero between them?


POTENTIAL AND E-FIELD

POTENTIAL AND E-FIELD

- Electric Potential and E-field
- $\Delta V = \frac{\Delta PE}{q_0} = -E\left(x_f - x_0\right)$
- $W = -\Delta PE = q_0 E(x_f - x_0)$
- $\Delta V = -\frac{\Delta PE}{q_0} = \frac{q_0 E\left(x_f - x_0\right)}{q_0}$
- $\Delta V = E\left(x_f - x_0\right)$
- $E = \frac{\Delta V}{x_f - x_0}$

- E-field units
  - N/C
  - V/m
- It is easy to measure ΔV
  - To find E-field, divide ΔV and the distance between two points

Potential and E-Field

- What is the voltage difference between the positions, $x = 11$ m and $x = 5.0$ m in an electric field of 2.0 N/C?