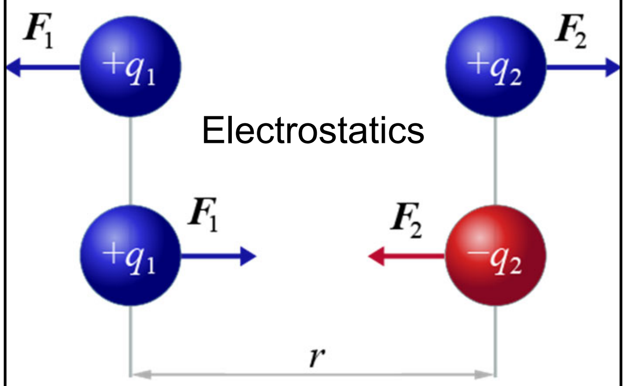
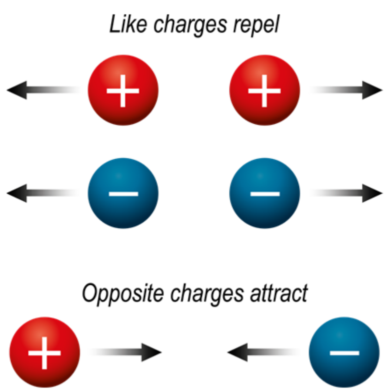
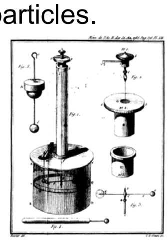
Electrostatics



- Charges exert forces on each other.



- Charles-Augustin de Coulomb (French)
- 1785
  - Mathematically described the force between charged particles.



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

Where:

q_1 and q_2 are the charges

r is the distance between the charges

$k = 9 \times 109$ Nm²/C²

- Coulomb's law applies to objects whose size is much smaller than the distance between them.

Example

- A hydrogen atom has a proton at its center and an electron "orbiting" at a distance of 0.53x10^{-10} m. Determine the magnitude of the force on the electron.

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

$$F_E = (9 \times 10^9)\frac{(1.6 \times 10^{-19})(1.6 \times 10^{-19})}{(0.53 \times 10^{-10})^2}$$

$$F_E = 8.2 \times 10^{-8}\ \mathrm{N}$$

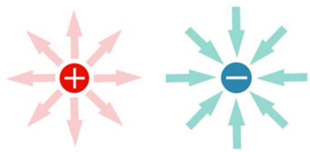
- Michael Faraday (English)
  - 1845
  - Used and defined "line of electric force" in his writings to describe the idea that the electric action was transmitted through space and was not an instantaneous "action at a distance."

  - This idea eventually became an "electric field."

- An electric field is generated by electric charge and tells us the force per unit charge at all locations in space around a charge.
- We define the electric field as the force per unit charge experienced by a small **positive** test charge q.

$$E = \frac{F_E}{q}$$

Units: N/C

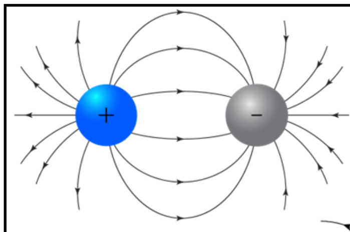


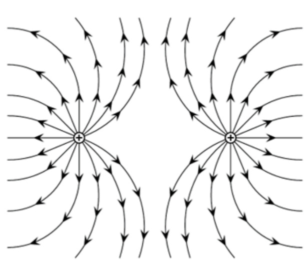
- If the electric field is constant (uniform field), then the force is constant.
- If the electric field is from a point charge, then the force is given by Coulomb's law.

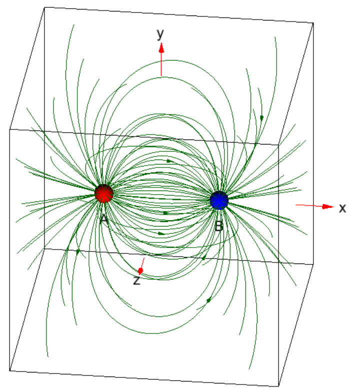
$$E = \frac{F_E}{q}$$

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

$$E = k\frac{q}{r^2}$$



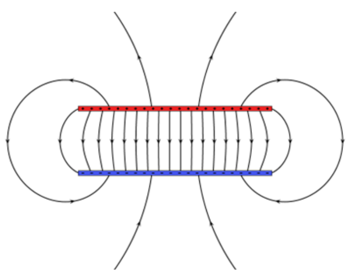




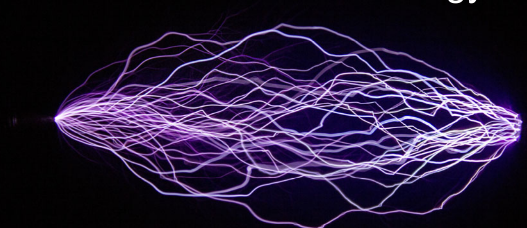
http://labman.phys.utk.edu/3D%20Physics/fieldlines/Fieldlines.html

Uniform Field

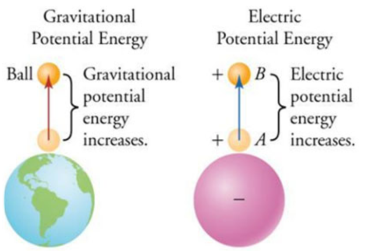
- A uniform field has constant magnitude and direction.



Electric Potential Energy



- Electric potential energy is similar to gravitational potential energy.
  - They both are energies of position.
    - One is in a gravitational field, the other is in an electric field.



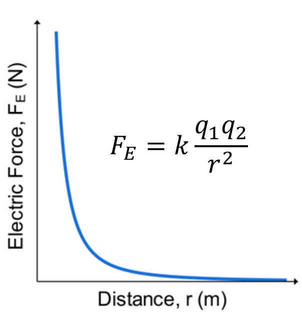
- The change in electric potential energy is the work done by the electric field to move a charge q from an initial position x_i to a final position x_f.

$$\Delta U_e = W = Fd$$

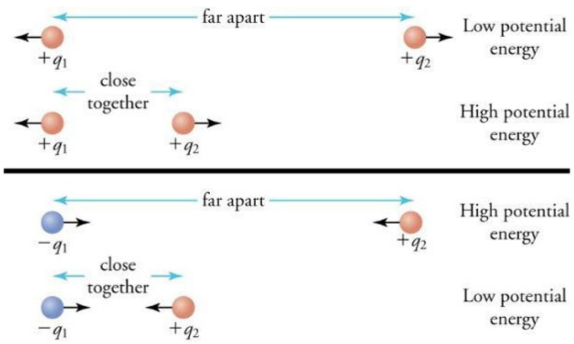
- The force is due to a constant electric field is $F = qE$.

$$\boxed{\Delta U_e = qE\Delta d}$$

- If the electric force is not constant, the potential energy is the area under a force vs distance graph.



$$\boxed{U_E = \frac{kq_1 q_2}{r}}$$



Electric Potential

- Electric potential is defined as the electric potential energy per unit charge.

$$V = \frac{U_E}{q}$$

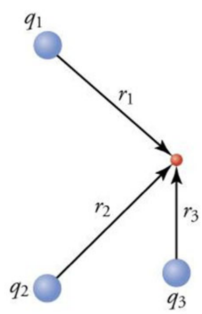
  - Electric potential is measured in volts (V).
  - Electric potential is often called potential or voltage.
    - Practically, we measure the potential difference between two points.

$$V = \frac{U_E}{q} \qquad U_E = k\frac{q_1 q_2}{r}$$

$$\boxed{V = k\frac{q}{r}}$$

This is the amount of energy required to bring a positive test charge from infinity, where the potential is zero, to a distance r near a charge q.

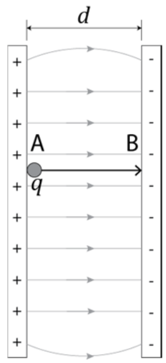
- The electric potential at a point due to multiple charges is the sum of the individual electric potentials.



$$V = \frac{kq_1}{r_1} + \frac{kq_2}{r_2} + \frac{kq_3}{r_3}$$

- When we measure electric potential, we measure it relative to some other point (often ground or zero potential).
  - We are measuring the potential difference between two points.
  - For example, the potential difference between two points in an electric circuit.
- It is often more practical to use the potential difference to calculate the electric field.

- A positive test charge q moves from point A to point B in a uniform electric field.



- Work is done by the electric field to move the charge from a point of high potential (A) to a point of low potential (B).

$$W = Fd$$

- The force is the electric force, and d is the distance from point A to point B.

$$F_E = qE$$

$$W = qEd$$

- The charge is moving from a point of high potential (A) to a point of low potential (B). Therefore, the work done by the electric field causes the charge to lose potential energy.

$$W = -\Delta U_E$$

$$U_E = qV$$

The potential energy is changing because the electric potential is changing.

$$\Delta U_E = q\Delta V$$

$$W = -q\Delta V$$

$$W = qEd \qquad W = -q\Delta V$$

$$qEd = -q\Delta V$$

$$E = -\frac{\Delta V}{d}$$

The negative sign indicates that the electric field points in the direction of decreasing electric potential. In other words, the electric field points from positive to negative.