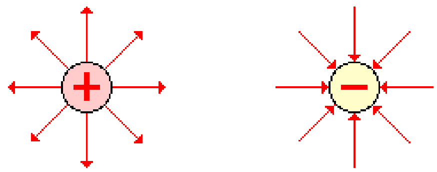
Electric Fields

- Electric Field: an alteration of the space created by a charged object in the region that surrounds it.
  - Affects other charges in that enter that space
  - As another charged object enters the space and moves closer to the source of the field (the charged object), the affect of the field is more noticeable.
  - A vector quantity whose direction is defined as the direction which a positive test charge would be pushed when placed in the

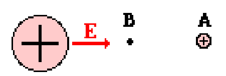
Direction of an Electric Field



The electric field direction is always directed away from positive source charges and towards negative source charges.

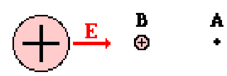
  - field.
- Electric Fields, Work, and Potential Energy
  - Recall: the natural direction of motion of an object is from high energy to low energy
    - work (W = force x distance) is not required to move an object from a high potential energy location to a low potential energy.
    - work must be done to 1move the object against nature (low PE to high PE).
    - Source Charge: the charged object creating the electric field
    - Test charge: the charged object entering an electric field

Diagram A



Moving the + test charge from location A to location B will require work and increase the potential energy of the charge.

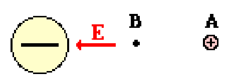
Diagram B



The + test charge will naturally move in the direction of the E field; work is not required. The potential energy of the charge will decrease.

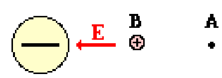
    -
      - the high energy location for a + test charge is a location nearest the + source charge; and the low energy location is furthest away.

Diagram C



The + test charge will naturally move in the direction of the E field; work is not required. The potential energy of the charge will decrease.

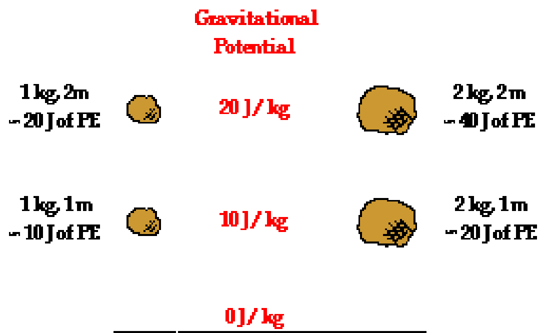
Diagram D



Moving the + test charge from location B to location A will require work and increase the potential energy of the charge.

    -
      - the low energy location for a + test charge is a location nearest a - source charge and the high energy location is furthest away from a - source charge.
    - Unit of Energy: the Joule (J)
      - Energy: the ability to do work
      - Work = Force x Distance
      - Work = Force (Newtons) x Distance (meters)
      - Joule = N · m
      - J = [kg · (m/s^2)] · m
      - J = (kg · m^2) / s^2

Gravitational Potential Energy Revisited



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Electric Potential Energy: PE due to charge interactions

- Dependent upon
  1. Amount of charge on the object experiencing the field and
  2. Distance from the source location within the field.
-

Electric Potential: the potential energy per charge

- Dependent upon
  - Distance from the source location within the field.

Electric Potential Energy vs. Electric Potential

- Electric potential energy depends upon the charge of the object experiencing the electric field
- Electric potential is purely location dependent.
  - A test charge with twice the quantity of charge would possess twice the potential energy at a given location; yet its electric potential at that location would be the same as any other test charge.

Electric Potential Difference: the difference in electric potential (V) between the final and the initial location when work is done upon a charge to change its potential energy.

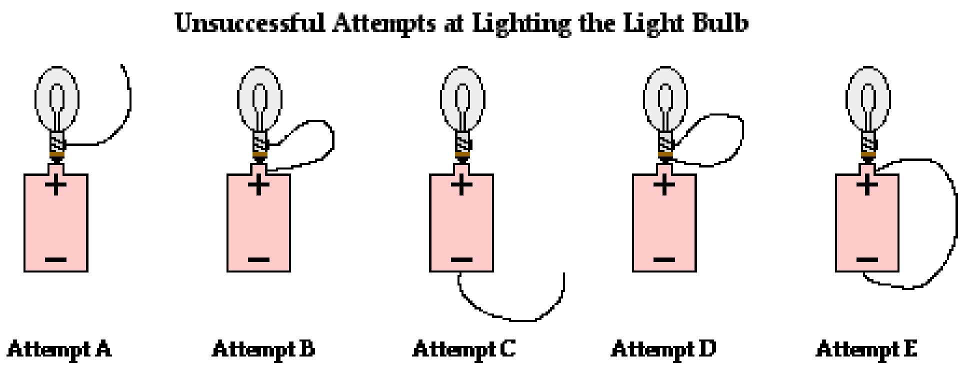
- Units of Electric Potential Difference: Volts (V); difference in voltage = ΔV
  - One Volt is equivalent to one Joule per Coulomb.
  - $V = J / C$

What is an Electric Circuit?

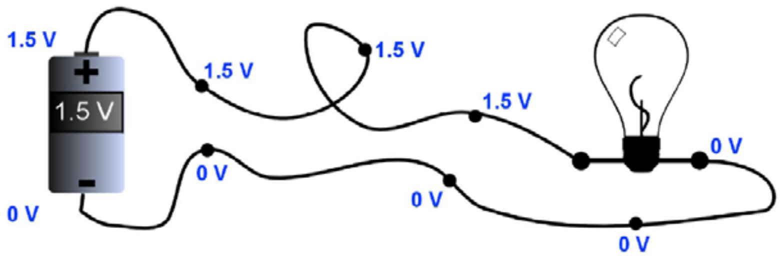
- Electric circuit: a closed loop through which charges can continuously move.
- Current: the flow of charge within the circuit.

Requirements of a Circuit

1. An electric potential difference (an energy supply)
2. A closed conducting loop



- Voltage drop: The loss in electric potential while passing through a circuit.
  - By the time that the positive test charge has returned to the - terminal, it is at 0 volts and is ready to be re-energized and pumped back up to the high voltage, + terminal.



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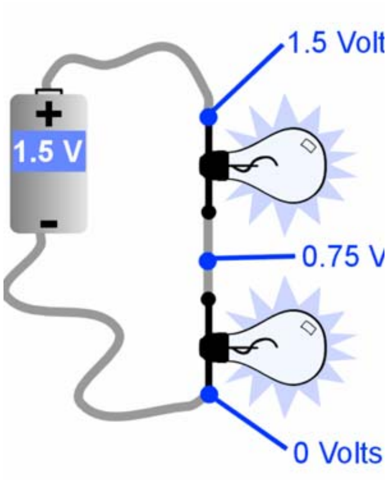
- 

Electric Current

- Current: the rate at which charge flows past a point on a circuit. = Charge / time
  - I = Q / t
- Ampere, A: the standard metric unit for current
  - 1 Amp = 1 Coulomb / second
- Sample problems:
  - A 2 mm long cross section of wire is isolated and 20 C of charge are determined to pass through it in 40 s. How much current is passing through the wire?
    - Ans: I = 20 C / 40 s = 0.5 A
  - A 1 mm long cross section of wire is isolated and 2 C of charge are determined to pass through it in 0.5 s.
    - Ans: I = 2 C / 0.5 s = 4 A
- The Direction of Electric Current
  - by convention (the general agreement) is the direction in which a (+) charge would move.
  - Thus, the current in the external circuit is directed away from the (+) terminal and toward the (-) terminal of the battery.
  - Electrons would actually move through the wires in the opposite direction.

Power: Putting Charges to Work

- Load: the electrical device into which electrical energy supplied to the charge by the battery carries its energy.
- Power: the rate at which electrical energy is supplied to a circuit or consumed by a load.
  - Unit of Power = Watt (W) = J / s
    - P = work done on a charge / time = J / s = 1 watt
    - 60 W light bulb = 60 J of energy used every second
  - Power = Electric Potential Difference • Current
    - $P = \Delta V \cdot I$
- The kilowatt • hour
  - A unit of energy used by electric companies to determine your bill
  - = kW•hr = P • t

<u>General Review of Today's Concepts</u>

Electric Potential Difference: Volts (ΔV)

- 1 Volt = Energy / Charge (ΔE / Q) = Joule / Coulomb (J / C)

Electric Current: Ampere (A)

- 1 A = Charge / time (Q / t) = Coulombs / second (C / s)

Power: Watt (W)

- 1 W = Energy / time (ΔE / t) = Joule / second (J / s)
- P = Electric Potential Difference • Current ($\Delta V \cdot I$) = [(J / C) • (C / s)] = J / s = 1 Watt

kilowatt • hour

- (Energy / time) • (time) = Energy

Electrical Resistance

Resistance: the hindrance to the flow of charge.

- Units: Ohms (Ω)
- Any load (e.g. light bulb, motor, etc.) is usually referred to as a resistor
- Factors that affect resistance
  1. Length of wire
     - Longer → more resistance
     - Shorter → less "
  2. The cross-sectional area of the wires
     - Narrow wire → more resistance
     - Wider " → less "
  3. The material that a wire is made of.
     - depends upon the material's electronic structure
  4. The temperature of the wire
     - Higher temp. → more resistance
     - Cooler " → less "

- Formula
  - $R = \rho \dfrac{L}{A}$
  - R = resistance
  - ρ = resistance of the material (in ohm • meter).
  - L = length of wire (m)
  - A = cross-sectional area of the wire (m^2)

Ohm's Law:

$\Delta V = I \cdot R$

- Potential Difference = Current · Resistance
  - $I = \Delta V / R$
  - $R = \Delta V / I$