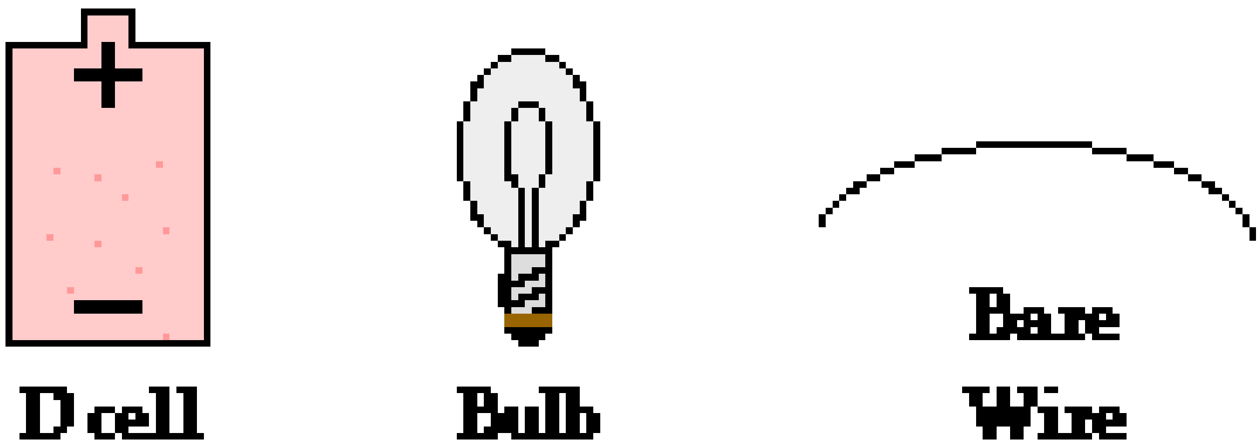
Unit 4 - Electric Circuits…

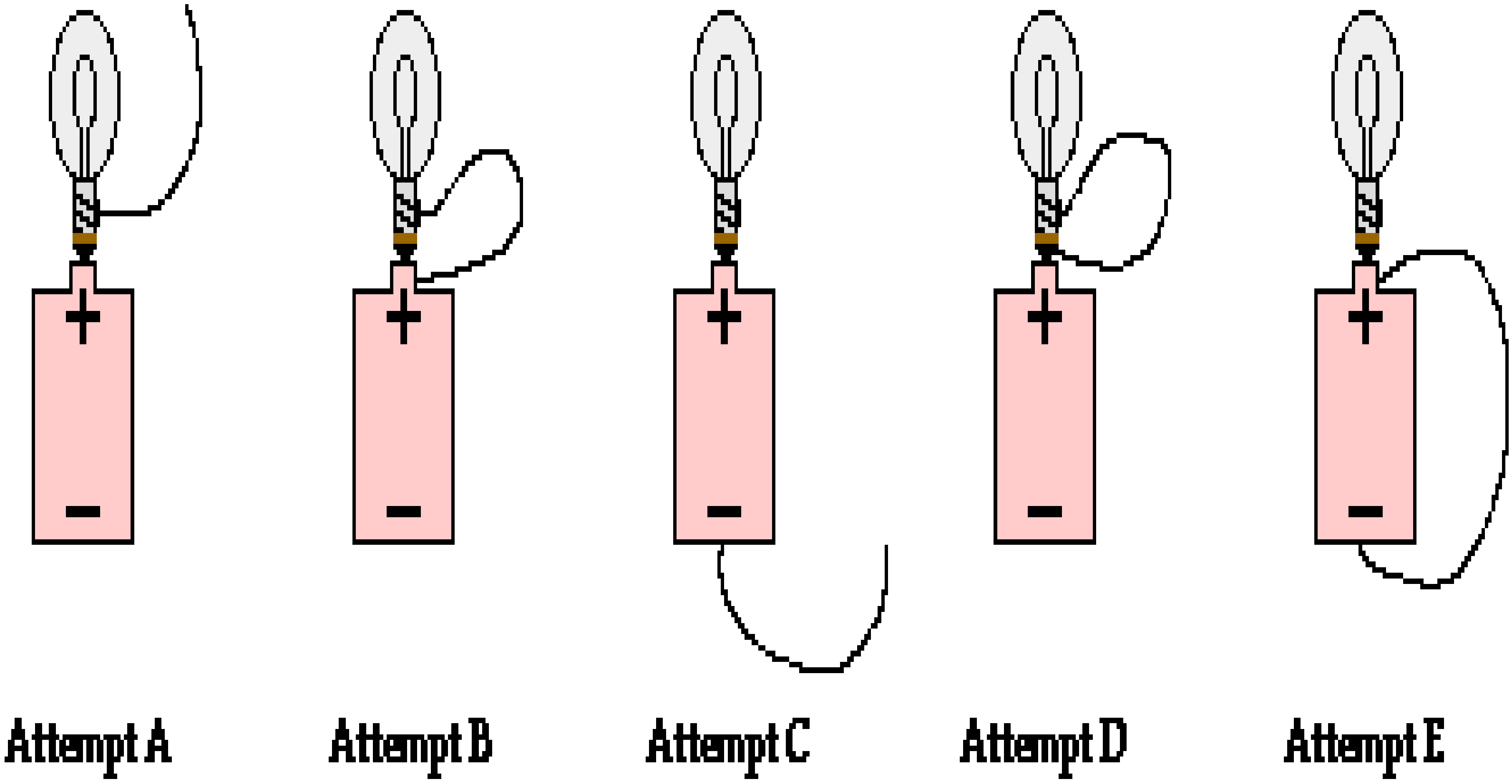
…the movement of charge between varying locations and the corresponding loss and gain of energy which accompanies this movement.

How would you light this bulb?

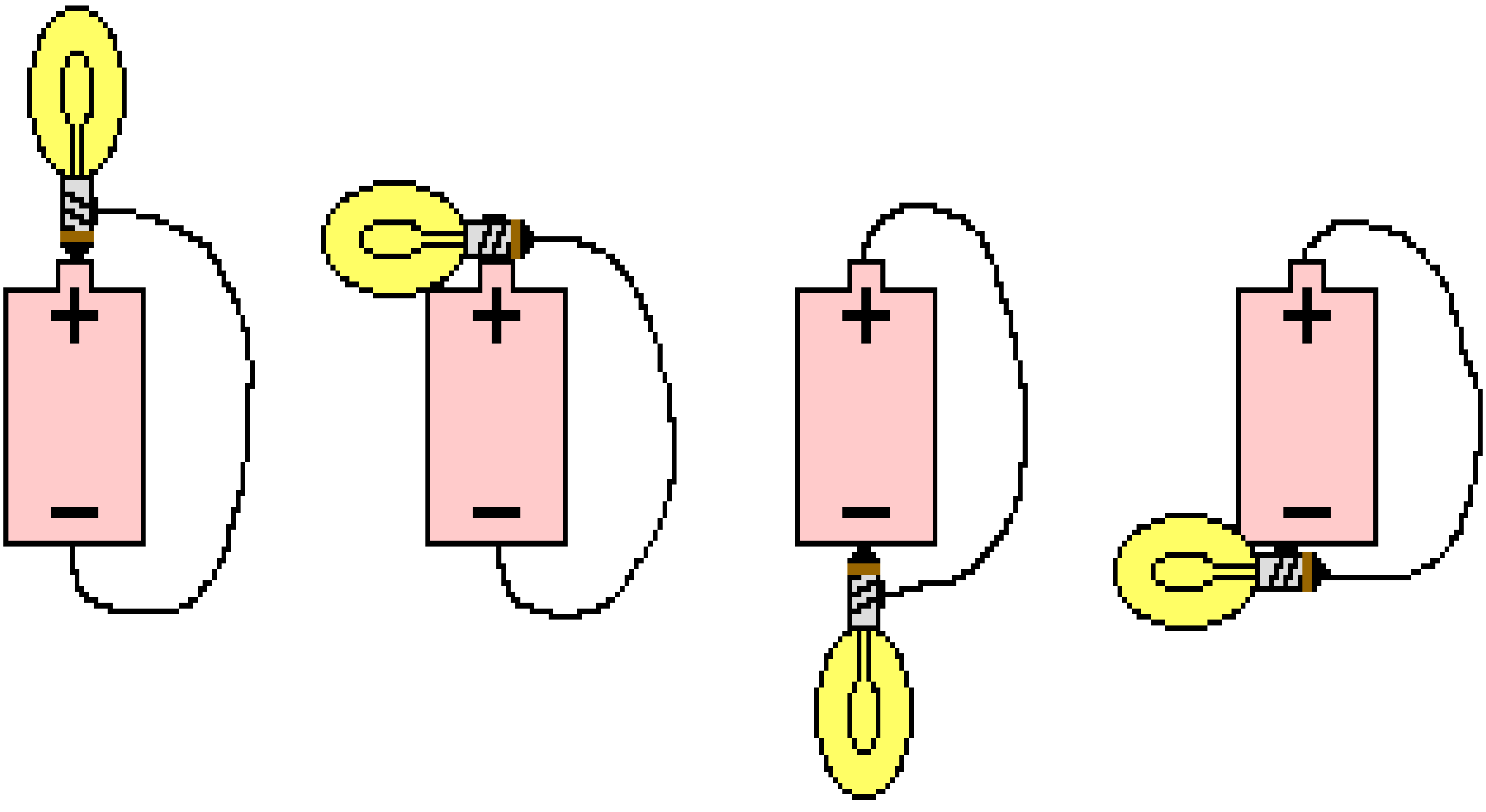
- Suppose that you were given a small light bulb, a battery and a bare copper wire and were asked to find the four different arrangements of the three items that would result in the formation of an electric circuit that would light the bulb. What are the four ways?



Unsuccessful Attempts

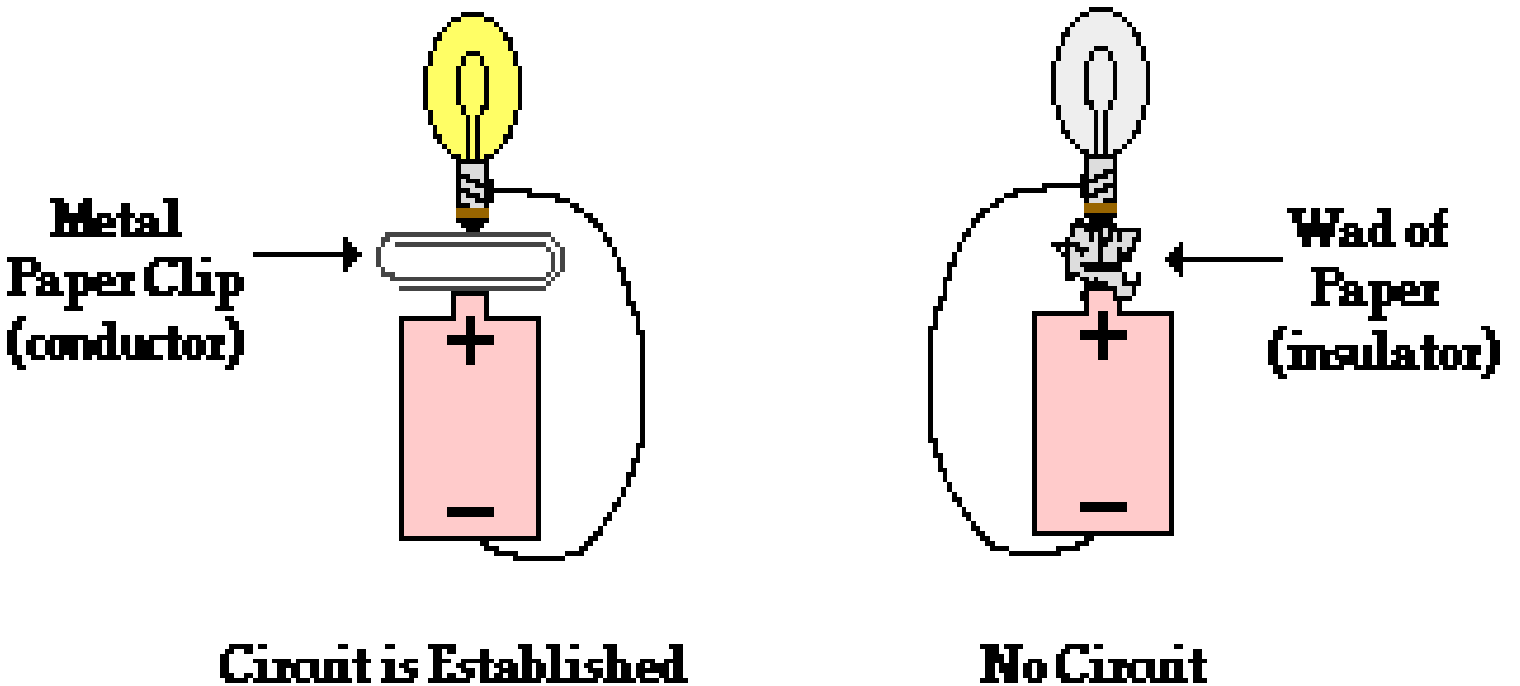


Successful Attempts



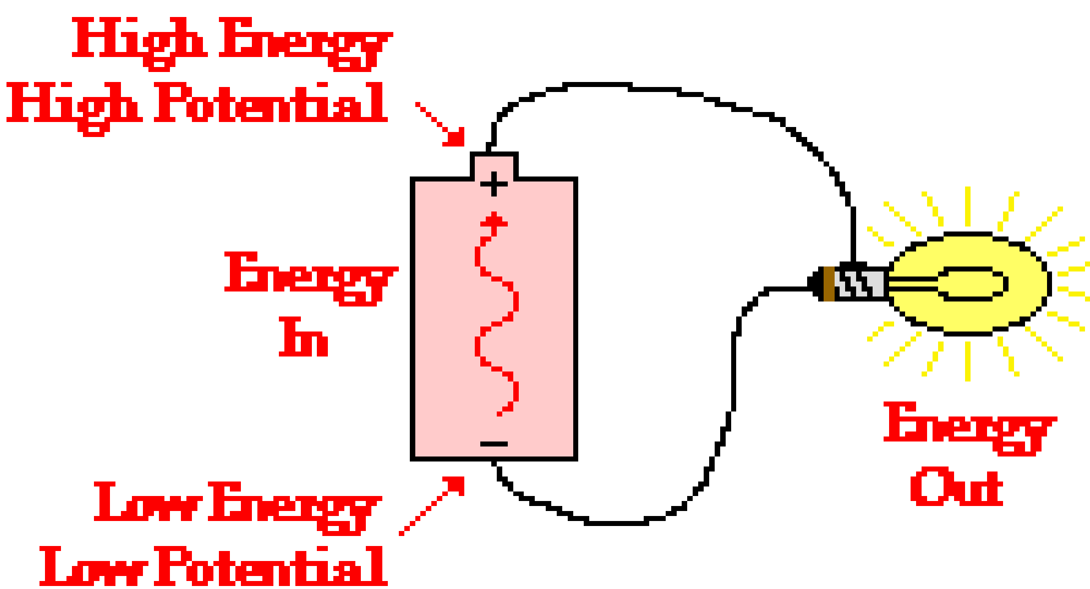
Requirements for an Electric Circuit

- There must be a closed conducting path which extends from the positive terminal to the negative terminal
- In an electric circuit, all connections must be made and made by conducting materials capable of *carrying* charge.



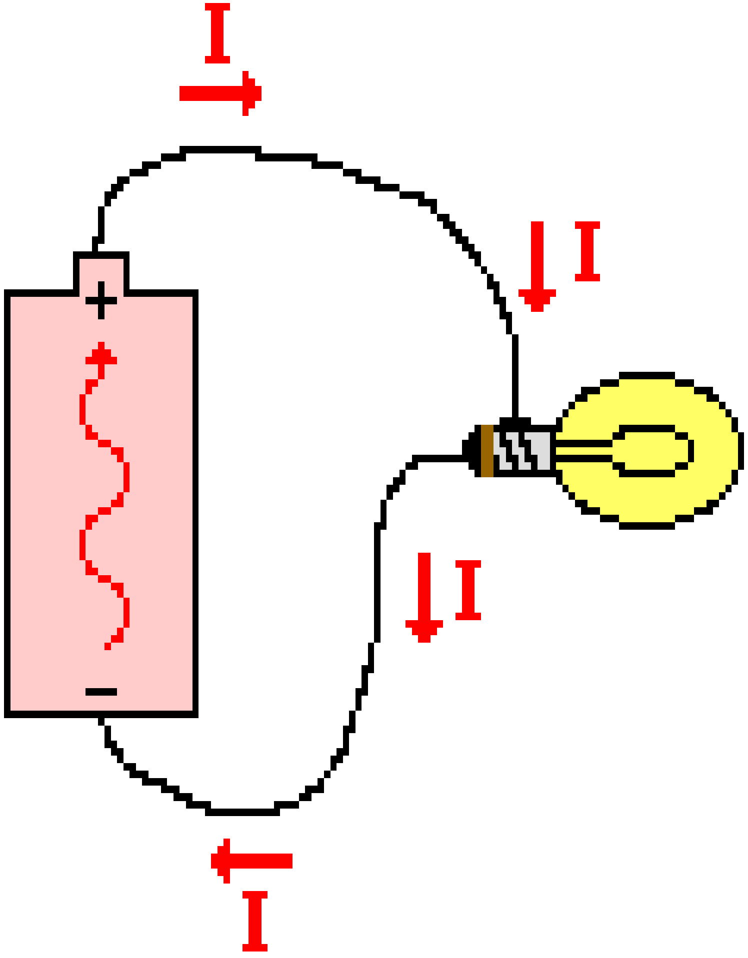
Requirements for an Electric Circuit

- There must be an energy supply capable of doing work on a charge to move it from a low energy location (negative terminal) to a high energy location (positive terminal) and thus establish an electric potential difference across the two ends of the external circuit.



Current

- If the requirements of an electric circuit are met, then charge will flow through the circuit.
- Current is a flow of charge
- Symbol: **I**
- Units: Ampere, shortened to *Amp*, **A**
- The direction of an electric current is, by convention, the direction in which a positive charge would move

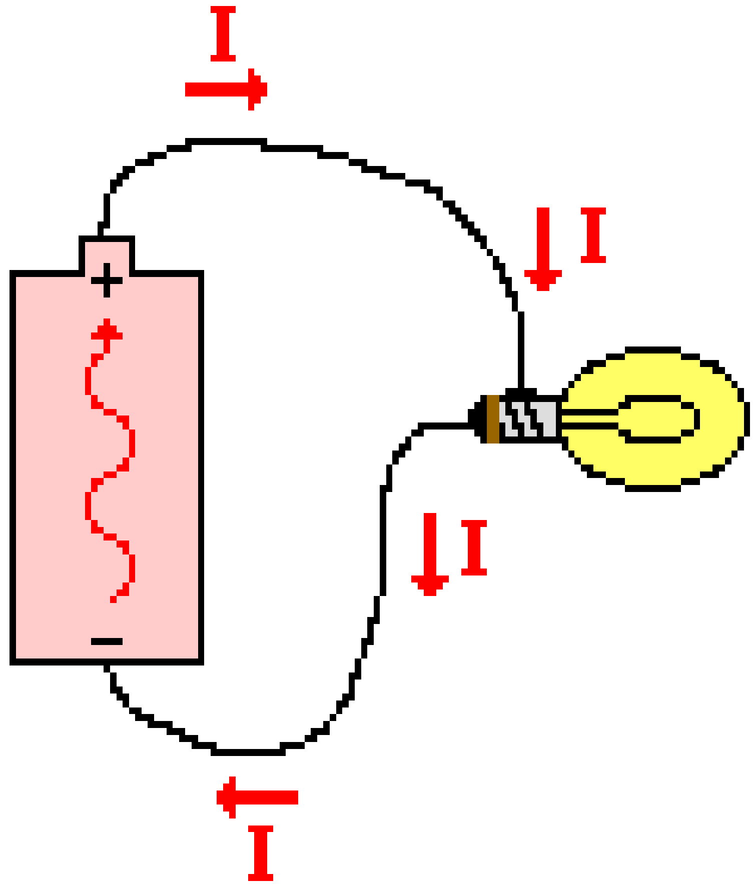


Voltage

- Also defined as electric potential, is the potential energy per unit of charge.

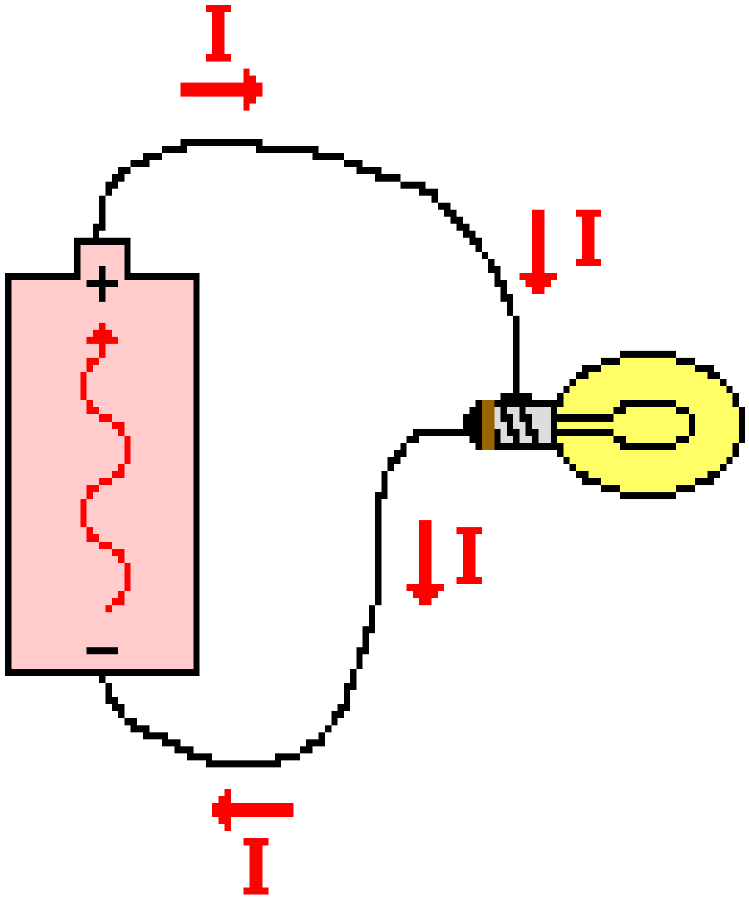
- Symbol: **V**

- Units: Volts, **V**

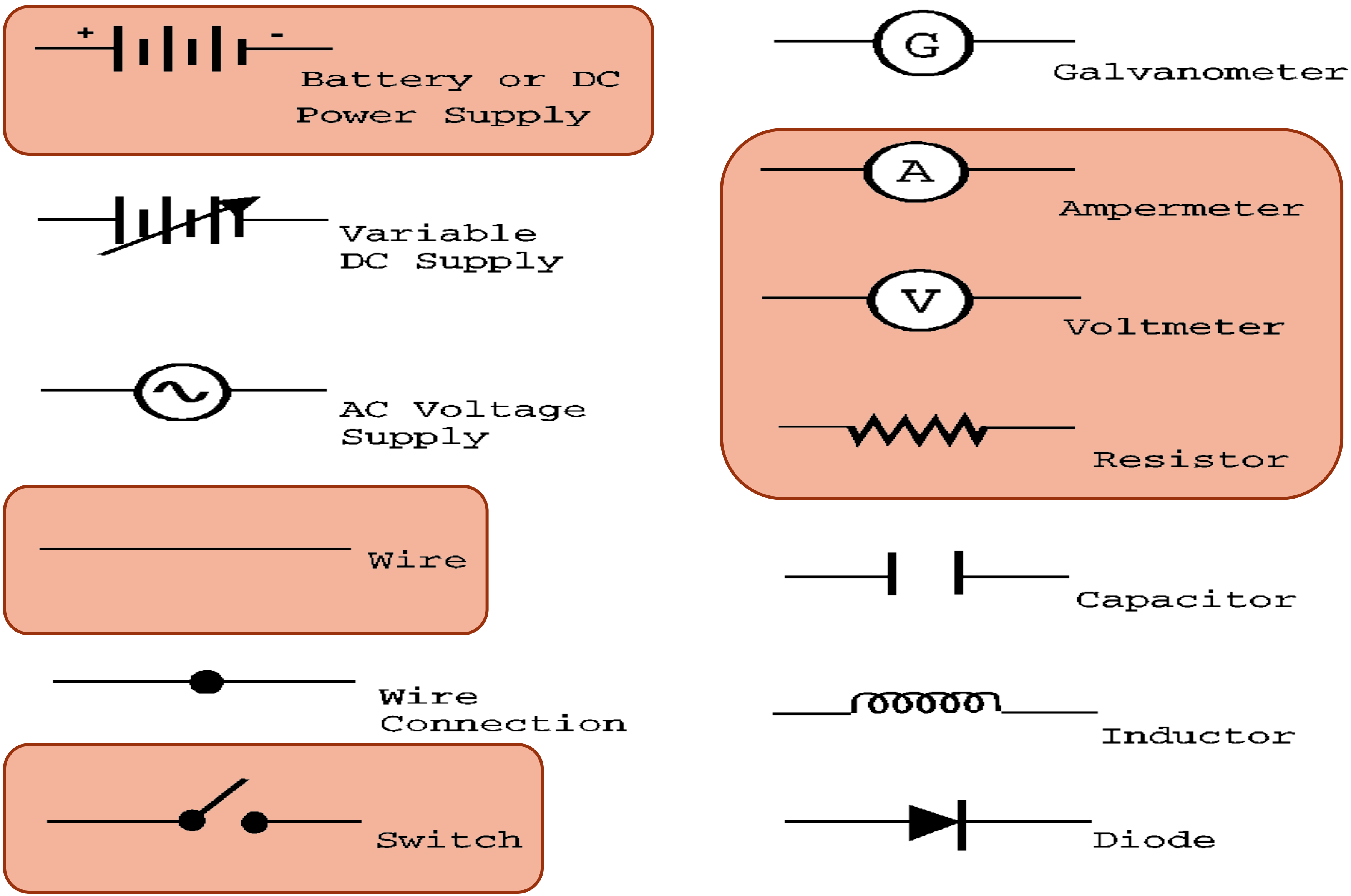


Resistance

- A hindrance to the flow of charge.
- Symbol: **R**
- Units: Ohms, Ω



Circuit Symbols



Ohm's Law

- Voltage = Current • Resistance
- $V = I \cdot R$
- V – units: Volts, V
- I – units: Amps, A
- R – units: Ohms, Ω

Ohm's Law Practice 1

- An automobile headlight with a resistance of 30 ohms is placed across a 12-volt battery. What is the current through the circuit?

Ohm's Law Practice 2

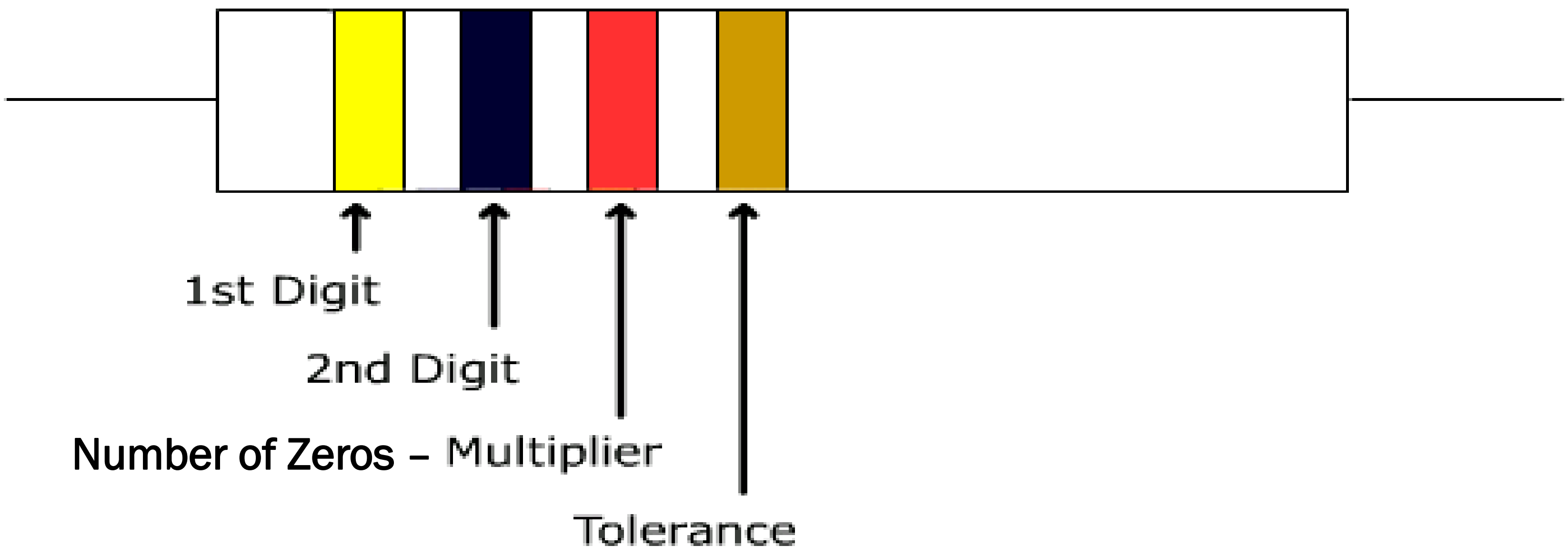
- A lamp draws a current of 0.50 amps when it is connected to a 120-V source. What is the resistance of the lamp?

Ohm's Law Practice 3

- A lamp with a resistance of 30 Ω is connected to a voltage source. The current in the circuit is 3.0 A. What is the voltage of the source?

Resistor Color Code

The color stripes on a resistor is the method the manufacturer uses to label the resistor with its ohmic value and tolerance.



Resistor Color Code

Each color represents a different number.
The first three bands use these colors:

0	1	2	3	4	5	6	7	8	9
Black	Brown	Red	Orange	Yellow	Green	Blue	Violet	Gray	White

The last band can contain one of four colors:

1%	5%	10%	20%
Brown	Gold	Silver	No Band

Series Circuits

- There is only **1 path** for the current to flow.
- Current is the **same** throughout the circuit

$$I_T = I_1 = I_2 = I_3 = \ldots$$

- Resistance **adds**

$$R_T = R_1 + R_2 + R_3 + \ldots$$

- Voltage **adds**

$$V_T = V_1 + V_2 + V_3 + \ldots$$

Series Example 1

- Three 20-Ω resistors are connected in series across a 120-V generator.
    a) Draw the circuit
    b) What is the equivalent (total) resistance?
    c) What is the current in the circuit?
    d) What is the potential drop (voltage) across each resistor?

Series Example 2

- A 3 Ω, 4 Ω and 7 Ω resistor are connected in series across a 12-V battery.
  a) Draw the circuit
  b) What is the equivalent (total) resistance?
  c) What is the current in the circuit?
  d) What is the potential drop (voltage) across each resistor?

Series Example 3

- Four resistors, 45-Ω, 5-Ω, 30-Ω, and 40-Ω are connected in series across a 240-V generator.
  a) What is the equivalent (total) resistance?
  b) What is the current through the entire circuit?
  c) What is the potential drop across each resistor?

Series Example 4

- Two resistors, 10-Ω and 30-Ω are connected in series across a 20-V battery.
  a) What is the equivalent (total) resistance?
  b) What is the current through the entire circuit?
  c) What is the potential drop across each resistor?
  d) What is the power drawn by each resistor?

Parallel Circuits

- There are **multiple paths** for the current to flow.
- Current **adds**

$$I_T = I_1 + I_2 + I_3 + \ldots$$

- Equivalent (total) Resistance is always smaller than the smallest resistor

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

- Voltage is the **same** throughout the circuit

$$V_T = V_1 = V_2 = V_3 = \ldots$$

Parallel Example 1

- A 120-Ω resistor, a 60-Ω resistor and a 40-Ω resistor are connected in parallel across a 12-V generator.
  a) Draw the circuit
  b) What is the equivalent (total) resistance?
  c) What is the current through the entire circuit?
  d) What is the current through each branch of the circuit?

Parallel Example 2

- Two resistors, 45-Ω and 5-Ω, are connected in parallel across a 90-V generator.
  a) Draw the circuit
  b) What is the equivalent (total) resistance?
  c) What is the current through the entire circuit?
  d) What is the current through each branch of the circuit?

Parallel Example 3

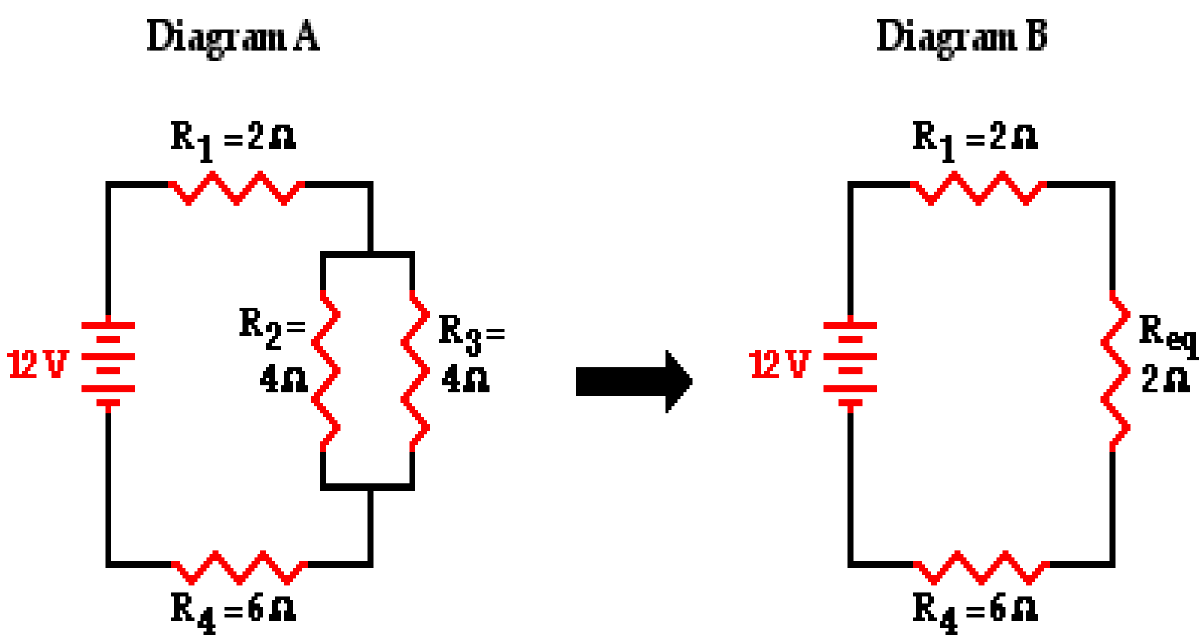
- Three resistors, 3-Ω, 12-Ω and 6-Ω, are connected in parallel across a 30-V generator.
    a) What is the equivalent (total) resistance?
    b) What is the current through the entire circuit?
    c) What is the current through each branch of the circuit?

Parallel Example 4

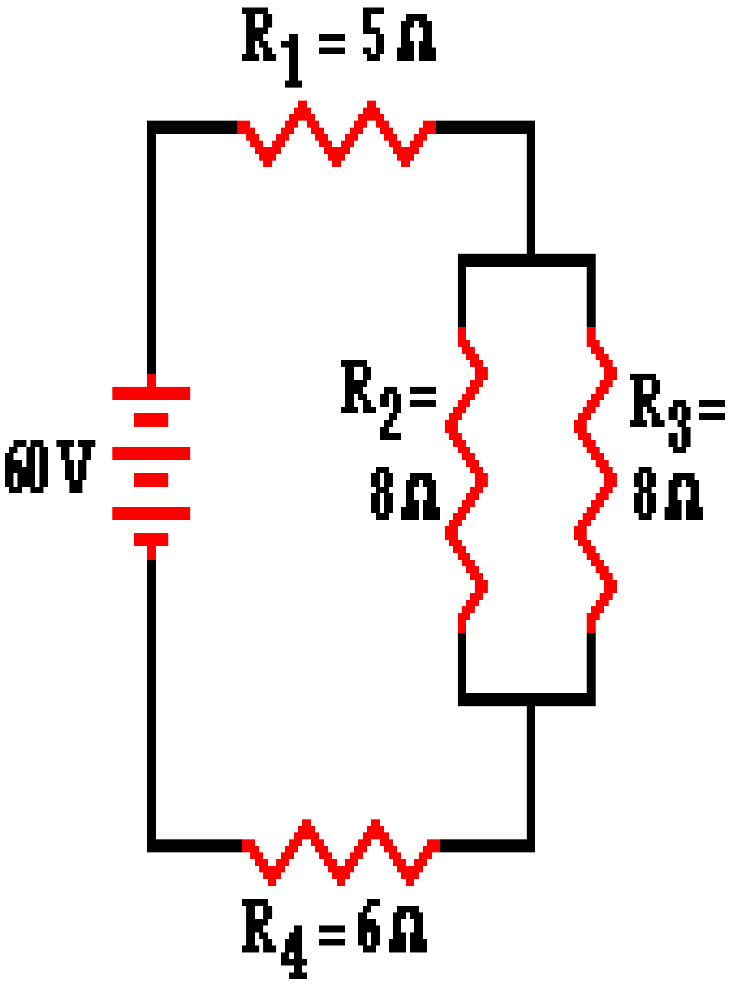
- Two resistors, 24-Ω and 72-Ω, are connected in parallel across a 54-V generator.
  a) What is the equivalent (total) resistance?
  b) What is the current through the entire circuit?
  c) What is the current through each branch of the circuit?

Combination Circuits

- The use of both series and parallel connections within the same circuit.
- Use the meaning of equivalent resistance for parallel branches to transform the combination circuit into a series circuit.



Combination Example 1



R_{tot} = ________ I_{tot} = ________

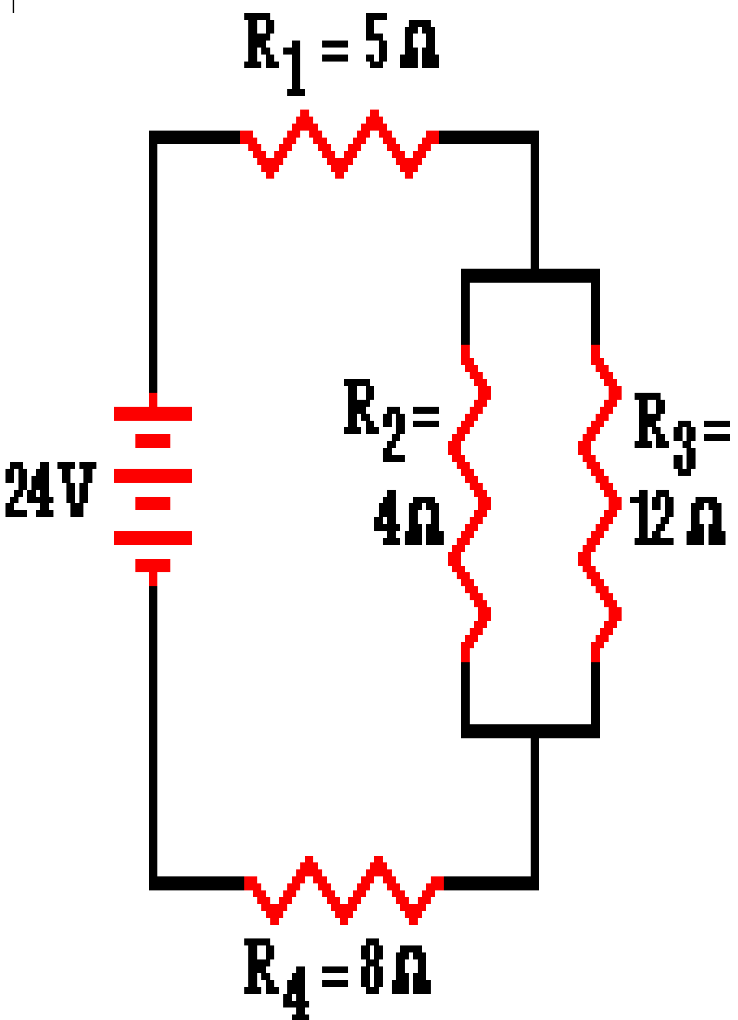
I_1= ________ ΔV_1 = ________

I_2= ________ ΔV_2 = ________

I_3= ________ ΔV_3= ________

I_4= ________ ΔV_4= ________

Combination Example2



R_{tot} = ____________

I_{tot} = ____________

I_1 = ____________

ΔV_1 = ____________

I_2 = ____________

ΔV_2 = ____________

I_3 = ____________

ΔV_3 = ____________

I_4 = ____________

ΔV_4 = ____________

Check Your Understanding

a. The current at location A is ______ (>, =, <) the current at location B.

b. The current at location B is ______ (>, =, <) the current at location E.

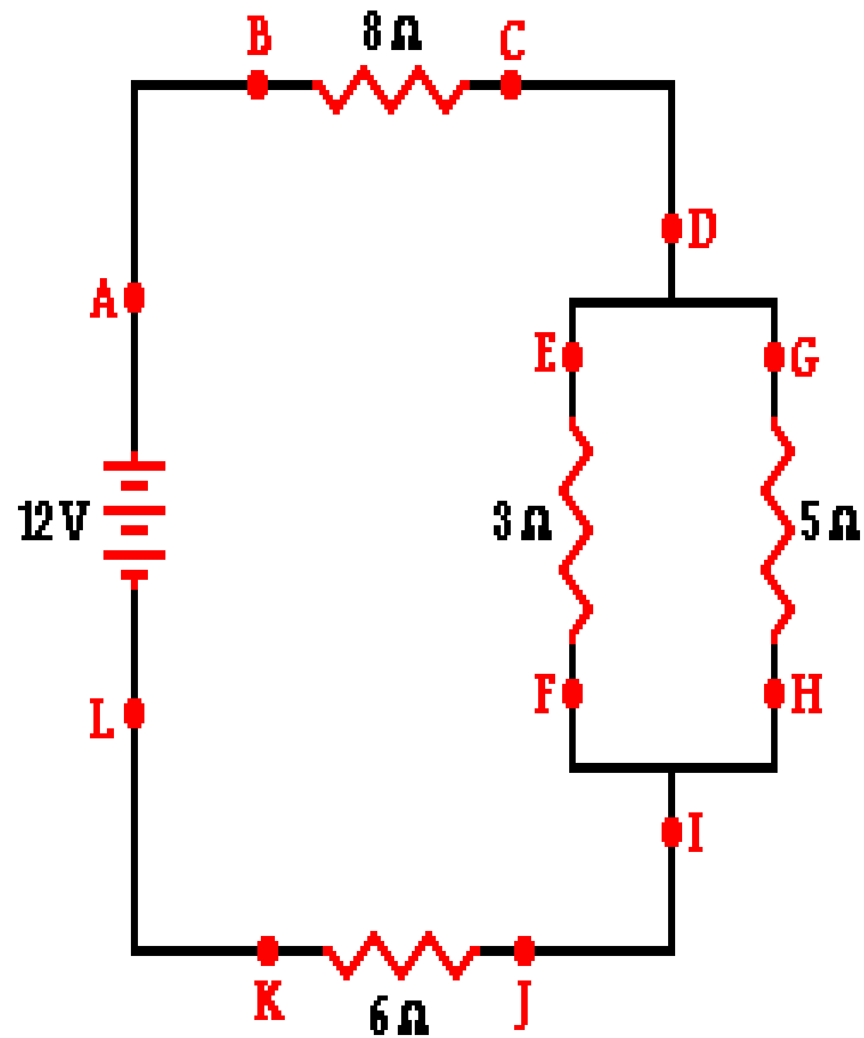
c. The current at location G is ______ (>, =, <) the current at location F.

d. The current at location E is ______ (>, =, <) the current at location G.

e. The current at location B is ______ (>, =, <) the current at location F.

f. The current at location A is ______ (>, =, <) the current at location L.

f. The current at location H is ______ (>, =, <) the current at location I.



Power

variable: P

unit: Watt (W)

- Measure the rate at which energy is transferred or converted from one form of energy to another.
- How fast work is being done.
- $P = IV$
- For a resistor, $V = IR$, therefore power can also be defined as the following:

$$P = I^2R \qquad\qquad P = \frac{V^2}{R}$$

Energy
variable: E
unit: Joule(J)…1 J = W/sec
Or
Kilowatt hour (kWh)…1000 W = 1kW

- The amount of power being used and how long it's being used for (how much work is being done).
- $E = Pt$
- $E = IVt$
- $E = I^2Rt$
- $E = \frac{V^2t}{R}$

Power & Energy Practice

- A 6.0-V battery delivers a 0.50-A current to an electric motor that is connected across its terminals.

  a) What is the power consumed by the motor?

  b) If the motor runs for 5.0 minutes, how much electrical energy is delivered?

Electric Bill

- A 60 W light bulb is on an average of 7 hours a day.
  a) How much energy is used in kilowatt hours (kWh)?
     1000 W = 1 kW

  b) If it costs $0.11 per kWh, how much does running this bulb cost per day? Per month (assume 30 days)?