Electric Potential Difference

Read from **Lesson 1** of the **Current Electricity** chapter at **The Physics Classroom**:

   http://www.physicsclassroom.com/Class/circuits/u9l1a.html
   http://www.physicsclassroom.com/Class/circuits/u9l1b.html
   http://www.physicsclassroom.com/Class/circuits/u9l1c.html

MOP Connection: Electric Circuits: sublevels 2 and parts of 3

Review:
1. **Electric field** is defined as the aura about the space surrounding a charged object which exerts an electrical influence upon other charged objects in that space. The **direction of the electric field vector** is defined as the direction which a positive test charge would be accelerated. **Potential energy** is the energy stored in an object due to the position of that object.

A Gravitational Analogy:
2.   Two diagrams are shown at the right.

   In diagram A, a mass is held at an elevated position. When let go of, the mass falls from point A to point B.

   In diagram B, the mass is originally at point A and a person moves it back up to point B.

   For each diagram, indicate if work is done by a non-conservative force in moving the object from its initial position (point A) to its position at point B. Finally, indicate the position of greatest gravitational potential energy.
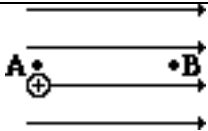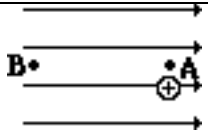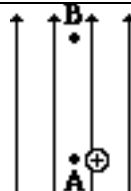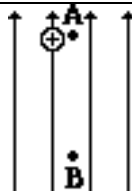
   Circle the answers in the space below the diagrams.
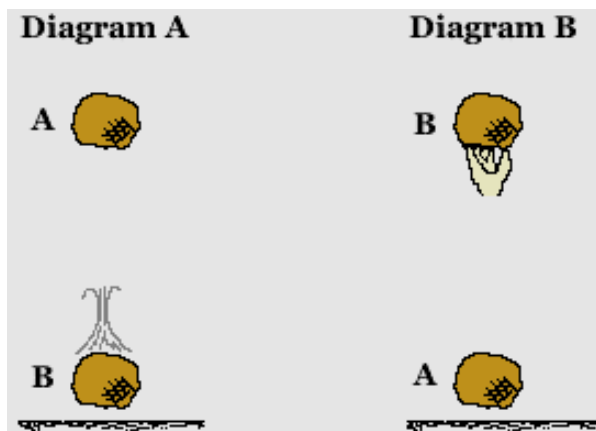
W_{nc} done on mass: W_{nc} done on mass:
   Yes or No   Yes or No
Highest PE: A or B   Highest PE: A or B

3.   The following diagrams show an electric field and two points - labeled A and B - located within the electric field. A positive test charge is shown at point A. For each diagram, indicate whether work must be done upon the charge to move it from point A to point B. Finally, indicate the point (A or B) with the greatest electric potential energy and the greatest electric potential (PE/charge).

|	
Work done on test charge? Yes or No	Work done on test charge? Yes or No
Potential energy is greatest at: A B	Potential energy is greatest at: A B
Electric potential is greatest at: A B	Electric potential is greatest at: A B
Work done on test charge? Yes or No	Work done on test charge? Yes or No
Potential energy is greatest at: A B	Potential energy is greatest at: A B
Electric potential is greatest at: A B	Electric potential is greatest at: A B

3. When work is done on a positive test charge to move it from one location to another, potential energy _____ (increases, decreases) and electric potential _____ (increases, decreases).

    When a positive test charge naturally moves from one location to another (without the exertion of a non-conservative force), potential energy _____ (increases, decreases) and electric potential _____ (increases, decreases).

    This is the BIG Idea

4. The diagram at the right shows a light bulb connected to a 12-V car battery. The + and - terminals are shown.
    a. As a + charge moves <u>through the battery</u> from D to A, it _____ (gains, loses) potential energy and _____ (gains, loses) electric potential. The point of highest energy within a battery is the _____ (+, -) terminal.

    b. As a + charge moves <u>through the *external circuit*</u> from A to D, it _____ (gains, loses) potential energy and _____ (gains, loses) electric potential. The point of highest energy within the external circuit is closest to the _____ (+, -) terminal.

    c. Use >, <, and = signs to compare the electric potential (**V**) at the four points of the circuit.
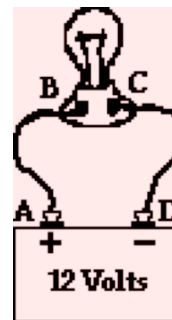
    V_A _____ V_B _____ V_C _____ V_D

5. The **role of a battery** in an electrical circuits can be described in three different ways. First, it is the energy supply. Second, the energy supplied by the battery is required to do work upon the charge to move it against the electric field from the negative terminal to the positive terminal. And third, by moving the charge against the field from negative to positive terminal, the battery establishes an electric potential difference across the two ends of the external circuit.

    Without a potential difference between two locations, charge will not move. When there is an electric potential between two locations, charge will move from the location of high potential to the location of low potential. The amount of potential difference (**ΔV**) between two locations is related to the work done in moving an amount of charge (**Q**) from the low potential to the high potential location.

    A volt is the unit of electric potential. 1 Volt = 1 Joule/Coulomb
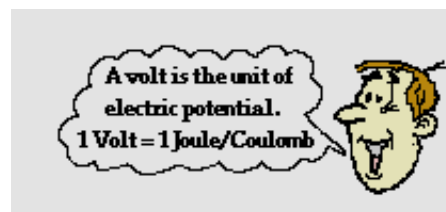
    $$\Delta V = V_{high} - V_{low} = \frac{Work}{Q}$$

    a. It takes _____ J of work to move 1 C of charge from the - to the + terminal of a 1.5-volt battery.
    b. It takes _____ J of work to move 2 C of charge from the - to the + terminal of a 12-volt battery.
    c. It takes 18 J of work to move _____ C of charge from the - to the + terminal of a 12-volt battery.
    d. It takes 12 J of work to move 2 C of charge from the - to the + terminal of a _____-volt battery.
    e. It takes _____ J of work to move _____ C of charge from the - to the + terminal of a 12-volt battery.

6. In the battery, energy is supplied to the charge to move it from low potential (- terminal) to high potential (+ terminal). Once at the + terminal, the charge spontaneously moves through the external circuit, losing energy as it passes through each electrical device. The electric potential which is gained by the charge when it passes through the battery is lost by the charge as it moves through the external circuit. These gains and losses in electric potential are often represented using an electric potential diagram. For the circuit at the right, complete the electric potential diagram, showing the relative potential of locations A, B, C, D, E, and F.
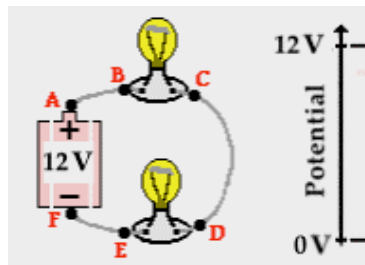
Electric Circuits and Electric Current

Read from **Lesson 2** of the **Current Electricity** chapter at **The Physics Classroom**:

> **http://www.physicsclassroom.com/Class/circuits/u9l2b.html**
> **http://www.physicsclassroom.com/Class/circuits/u9l2c.html**
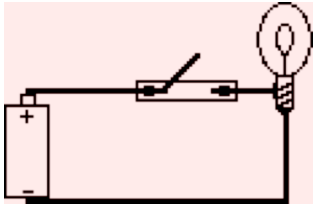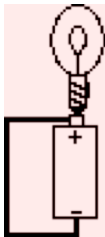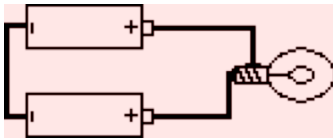> **http://www.physicsclassroom.com/Class/circuits/u9l2e.html**

MOP Connection: Electric Circuits: sublevel 1

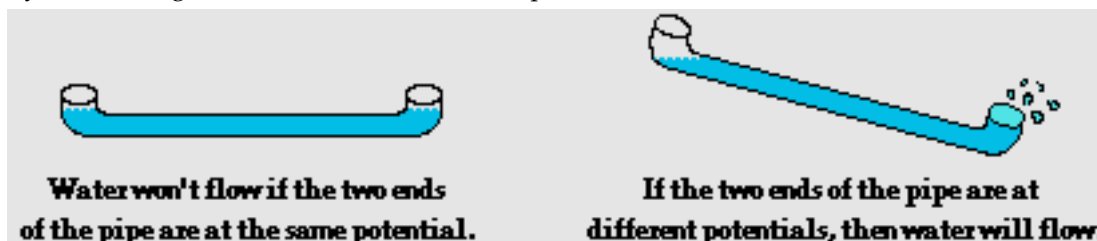1. To maintain a charge flow in an electric circuit, at least two requirements must be met:

    #1: An external energy supply (e.g., battery, wall outlet, generator, etc.) to pump the charge
    through the internal circuit and establish a potential difference across the circuit.
    #2: The external circuit must make up a "closed conducting loop" between the + and - terminal.

    Utilize your understanding of these requirements to state whether charge would flow through the
    following circuits. If there is no charge flow, then explain why not.

Charge Flow: Yes or No? **Explanation:** _____ _____	**Charge Flow: Yes or No?** **Explanation:** _____ _____
Charge Flow: Yes or No? **Explanation:** _____ _____	**Charge Flow: Yes or No?** **Explanation:** _____ _____

Charge flow in a circuit is often compared to water flow. For water to flow between two points, there
must be a difference in water pressure between the points. Water pressure is like electric potential.
Water will only flow through a pipe if there is a difference in potential between the two ends. Charge
will only flow through a wire if there is an electric potential difference across its ends.

**Water won't flow if the two ends
of the pipe are at the same potential.**

**If the two ends of the pipe are at
different potentials, then water will flow.**

2. Consider the two requirements for an electric circuit (described in question #1). When a light bulb is burned out and no longer works, requirement #_____ is not met. When a battery no longer works, requirement #_____ is not met.

3. What do you believe? Respond to the following statements as being **TRUE** or **FALSE**.
    a. When a battery no longer works, it is out of charge and must be re-charged   **T   or   F**
        before it can be used again.

    b. A battery can be a source of charge in a circuit. The charge which flows   **T   or   F**
        through the circuit originates in the battery.

    c. Charge becomes used up as it flows through a circuit. The amount of charge   **T   or   F**
        which exits a light bulb is less than the amount which enters the light bulb.

    d. Charge flows through circuits at very high speeds. This explains why the   **T   or   F**
        light bulb turns on immediately after the wall switch is flipped.

    e. Commonwealth Edison supplies millions and millions of electrons to our   **T   or   F**
        homes everyday.

4. A current is said to exist whenever _____.
    a. a wire is charged   b. a battery is present
    c. electric charges are unbalanced   d. electric charges move in a loop

5. As a quantity, electric current is defined as the _____.
    a. amount of charge present in a circuit   b. potential energy per charge
    c. rate at which charge moves through a cross-sectional area of a wire
    d. speed at which charge moves from one location to another location

6. Complete the statements:
    a. A current of one ampere is a flow of charge at the rate of
        _____ coulomb per second.

    b. When a charge of 8 C flows past any point along a circuit
        in 2 seconds, the current is _____ A.

    c. If 5 C of charge flow past point A (diagram at right) in 10
        seconds, then the current is _____ A.

    d. If the current at point D is 2.0 A, then _____ C of charge
        flow past point D in 10 seconds.

    e. If 12 C of charge flow past point A in 3 seconds, then 8 C of charge will flow past point E in
        _____ seconds.

    f. **TRUE** or **FALSE**:

        The current at point E is considerably less than the current at point A since charge is being
        used up in the light bulbs.

7. Which sentence best describes what happens to charge as it moves through an electric circuit?
    a. Charge is consumed or used up.
    b. Charge is re-energized and recycled.

8. Which sentence best describes how fast charge moves through an electric circuit?
    a. Charge moves very fast; faster than any human can run.
    b. Charge moves very slow; slower than the *proverbial* snail.

9. When you turn on the room lights, they light immediately. This is best explained by the fact that
    ____.
    a. electrons move very fast from the switch to the light bulb filament.
    b. electrons present everywhere in the circuit move instantly.
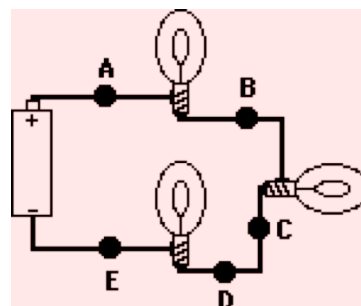
Electrical Resistance

Read from **Lesson 3** of the **Current Electricity** chapter at **The Physics Classroom**:

> **http://www.physicsclassroom.com/Class/circuits/u9l3a.html**
> **http://www.physicsclassroom.com/Class/circuits/u9l3b.html**
> **http://www.physicsclassroom.com/Class/circuits/u9l3c.html**

MOP Connection: Electric Circuits: sublevels 4 and 5

Physics Idea: As charge flows through an electric circuit, it encounters resistance. **Resistance** is a measure of the amount of hindrance to the flow of charge.
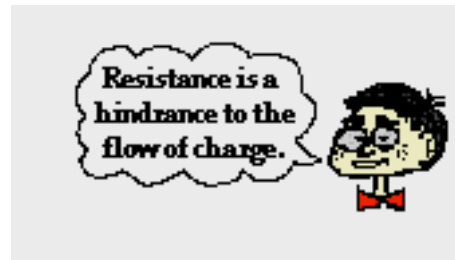
1.   The cause of resistance to the flow of charge within an electrical wire is _____.
     a. mobile charge carriers collide with atoms of the resistor
     b. mobile charge carriers have mass (possess inertia) which resists their motion
     c. the electric field which causes charge flow diminishes with distance
     d. charge is consumed or used up as it flows through the wire

2.   Resistance is quantifiable - that is, it can be measured and calculated. The standard metric unit used to express the amount of electrical resistance is the ____.
     a. Joule   b. Watt   c. Volt   d. Amp   e. Ohm

3.   For the following pairs of wire descriptions, choose the wire which has the greatest resistance.

     Resistance to charge flow will be greatest in … . (Circle the best answer.)
     a. … a wire which is thin   … a wire which is thick
     b. … a wire which is long   … a wire which is short
     c. … a wire which is made of copper   … a wire which is made of plastic
     d. … a wire which is made of copper   … a wire which is made of silver

4.   The rate at which charge flows through a circuit is _____ to the resistance.
     a. inversely related   b. directly related   c. not related

5.   For the following pairs of circuit descriptions, choose the circuit which has the greatest current.

     Given that all other factors are equal, the current will be greatest in a circuit which has … .
     a. … a high resistance   … a low resistance
     b. … wires which are long   … wires which are short
     c. … wires which are wide   … wires which are thin
     d. … 12-gauge wires (1/12th inch diameter)   … 14-gauge wires (1/14th inch diameter)
     e. … copper wiring   … silver wiring

6.   Resistance is not the only variable which effects the current in an electric circuit. The current is also effected by the electric potential difference (**ΔV**) impressed across its ends. The electric potential difference is simply the battery *voltage*. As the battery voltage is increased (by swapping in higher voltage batteries), the current is _____ (increased, decreased).

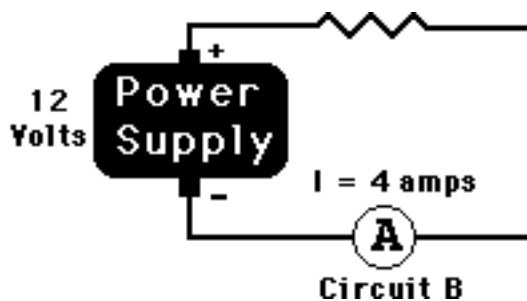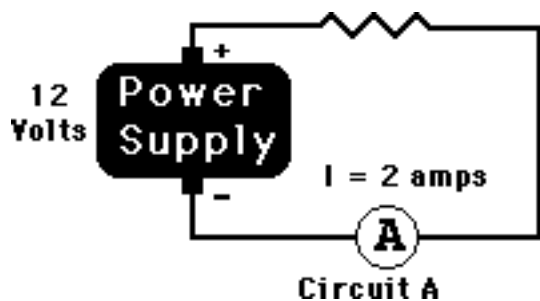The relationship between electric potential difference (**ΔV**), resistance (**R**) and current (**I**) is given be the equation.

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

This equation, sometimes referred to as the Ohm's law equation, is often written as **ΔV = I•R**. Like all equations in physics, it can be used as a recipe for problem-solving and an equation to guide one's thinking about how an alteration in one variable effects another variable.

7. A circuit is set up such that it has a current of 8.0 amps. What would be the new current if ….
   a. … the resistance (**R**) is increased by a factor of 2? _____
   b. … the resistance (**R**) is increased by a factor of 4? _____
   c. … the resistance (**R**) is decreased by a factor of 3? _____
   d. … the battery voltage (**ΔV**) is increased by a factor of 3? _____
   e. … the battery voltage (**ΔV**) is decreased by a factor of 2? _____
   f. … the resistance (**R**) is increased by a factor of 2 and the battery _____
      voltage (**ΔV**) is decreased by a factor of 2?
   g. … the resistance (**R**) is decreased by a factor of 4 and the battery _____
      voltage (**ΔV**) is increased by a factor of 3?

8. Express your understanding of the use of the $I = \Delta V / R$ equation by filling in the following blanks.
   a. An electrical device with a resistance of 2.0 Ω has an electric potential difference of 6.0 V impressed across it; the current in the device is _____ amperes.
   b. An electrical device with a resistance of 3.0 Ω has an electric potential difference of _____ V impressed across it; the current in the device is 4.0 amperes.
   c. An electrical device with a resistance of _____ Ω has an electric potential difference of 120 V impressed across it; the current in the device is 6.0 amperes.

9. Resistors are electrical devices designed to have a specific resistance. They are inserted in circuits to modify the actual current flowing through the circuit. When diagramming a circuit, a resistor is represented by the symbol ⎓⋀⋀⋀⎓ .

   Which of the resistors in the two circuits (A or B) has the greatest resistance? Calculate the value.

   12 Volts Power Supply   I = 2 amps   (A)
   Circuit A

   12 Volts Power Supply   I = 4 amps   (A)
   Circuit B

10. Use arrows to show the direction of conventional current flow through the following circuits and use the $I = \Delta V / R$ equation to fill in the blanks.

    I = _____ amps   (A)   12 V   R = _____ Ω   (A)   I = 4 amps

    I = 2 amps   (A)   12 V   R = _____ Ω   (V)   _____ Volts
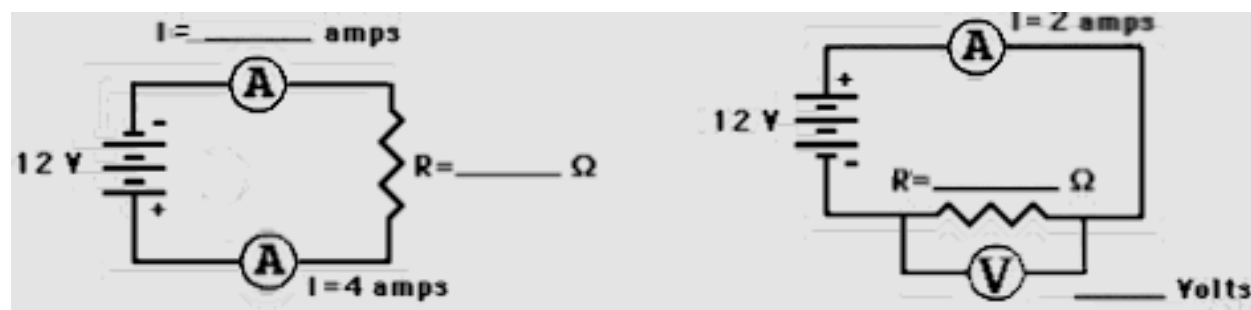
    The three new circuit symbols introduced in the above diagrams are

    ⊣|⋅|⋅|⊢   ⎓(V)⎓   ⎓(A)⎓

    Power Supply   Voltmeter (for measuring **ΔV**)   Ammeter (for measuring **I**)

Electrical Power and Energy

Read from **Lessons 2 and 3** of the **Current Electricity** chapter at **The Physics Classroom**:

> **http://www.physicsclassroom.com/Class/circuits/u9l2d.html**
> **http://www.physicsclassroom.com/Class/circuits/u9l3d.html**

MOP Connection: Electric Circuits: sublevel 3

Review:
1. The electric potential at a given location in a circuit is the amount of _____ per _____ at that location. The location of highest potential within a circuit is at the _____ (+, -) terminal of the battery. As charge moves through the external circuit from the _____ (+, -) to the _____ (+, -) terminal, the charge loses potential energy. As charge moves through the battery, it gains potential energy. The difference in electric potential between any two locations within the circuit is known as the electric potential difference; it is sometimes called the _____ and represented by the symbol _____. The rate at which charge moves past any point along the circuit is known as the _____ and is expressed with the unit _____.

The diagram at the right depicts an electric circuit in a car. The rear defroster is connected to the 12-Volt car battery. Several points are labeled along the circuit. Use this diagram for questions #2-#6.
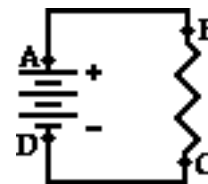
2. Charge flowing through this circuit possesses 0 J of potential energy at point ___.

3. The overall effect of this circuit is to convert ____ energy into ____ energy.
    a. electrical, chemical   b. chemical, mechanical
    c. thermal, electrical   d. chemical, thermal

4. The potential energy of the charge at point A is ___ the potential energy at B.
    a. greater than   b. less than   c. approximately equal to

5. The + charge gains potential energy as it moves between points ___ and ___.
    a. A and B   b. B and C   c. C and D   d. D and A   e. none of these

6. The + charge loses potential energy as it moves between points ___ and ___.
    a. A and B   b. B and C   c. C and D   d. D and A   e. none of these

7. The rate at which energy is delivered to a circuit by the energy source or the rate at which energy is consumed by an electrical device is known as the electric _____.
    a. current   b. potential   c. voltage   d. power

8. The unit of electric power is the _____.
    a. Ampere   b. Volt   c. Watt   d. Joule

9. Mechanical power (discussed in a previous unit) is the rate at which work is done on an object. Electrical power is the rate at which work is done on a charge (by the battery) or on an electrical device (by the charge). In terms of an equation, it is … . (Fill in the numerator and the denominator.)

$$Power = \frac{\qquad}{\qquad}$$

    a. A 60-Watt light bulb uses up _____ J of energy when left on for _____ 1 hour (3600 s).
    b. A 60-Watt light bulb uses up _____ J of energy when left on for _____ 4 hours.
    c. A 1500-Watt hair dryer uses up _____ J of energy when used for _____ 5 min (300 s).
    d. A 120-Watt fan uses up _____ J of energy when left on for _____ a day.

10. Substitution of other electrical equations ($I = Q/t$ and $\Delta V = I \cdot R$ and $\Delta V = W/Q$) into the power equation yields the following three equations.

$$P = I \cdot \Delta V \qquad\qquad P = I^2 \cdot R \qquad\qquad P = \Delta V^2 / R$$

Use these equations to solve the following problems.

a. Calculate the resistance of a toaster oven if its power is 800 W when connected to a 110-V outlet.

b. Calculate the resistance of the 1000 W microwave oven which gets plugged into to a 110-V outlet.

c. The TI-84 calculator uses four 1.5-V batteries and has a power of 0.0008 W. What is the current?

11. The following two circuits consist of a power supply, an ammeter (for measuring current), and a light bulb. Use >, <, and = symbols to compare the electric potential at A to B and at C to D. Indicate whether the devices add energy to or remove energy from the charge. Finally, fill in all blanks.
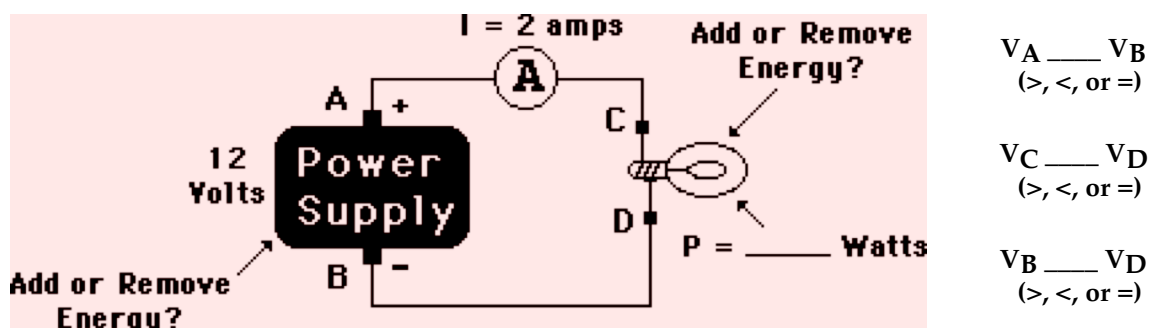
12. **TRUE** or **FALSE**: A kilowatt-hour is a unit of power.

13. Alfredo deDarke often leaves household appliances on for *no good reason* (at least according to his parents). The deDarke family pays 10¢/kilowatt-hour (i.e., $.15/kW•hr) for their electrical energy. Express your understanding of *dollar power* by filling in the following table.

Power Rating (Watt)	Time (hrs)	Energy Used (kilowatt-hour)	Costs ($)
60 Watt Bulb	1	0.060 kW•hr	$0.009
60 Watt Bulb	4		
Ten 60 Watt Bulb	24		
60 Watt Bulb			$10
7 Watt Night Light	168		
7 Watt Night Light	7760		

14. People often claim that an electrical appliance "uses up electricity." Explain what is actually being "used up" and what becomes of this *thing* which is being *used up*.

Mathematical Relationships in Circuits

Read from **Lessons 2 and 3** of the **Current Electricity** chapter at **The Physics Classroom**:

> **http://www.physicsclassroom.com/Class/circuits/u9l2c.html**
> **http://www.physicsclassroom.com/Class/circuits/u9l2d.html**
> **http://www.physicsclassroom.com/Class/circuits/u9l3c.html**
> **http://www.physicsclassroom.com/Class/circuits/u9l3d.html**

MOP Connection: Electric Circuits: sublevels 5 and 6

1. **Matching**: Identify the units on the following electrical quantities by placing a letter in the blank.
    The unit of charge is the ____.   Choices: A. Coulombs
    The unit of electric potential is the ____.   B. Amperes
    The unit of power is the ____.   C. Volts
    The unit of potential energy is the ____.   D. Ohms
    The unit of current is the ____.   E. Joules
    The unit of resistance is the ____.   F. Watts

2. An **electric potential diagram** is a useful means of representing the potential of a positive charge as
    it moves around a circuit. The electric potential of a charge at strategic locations in a circuit is
    represented on a chart. Points on the circuit where the charge has the highest potential are located
    highest on the chart; points of lowest potential are located lowest on the charts. At some points on
    the circuit, charges have approximately the same amount of potential. Construct electric potential
    diagrams for the following circuits. Label the points.

    a.   b.
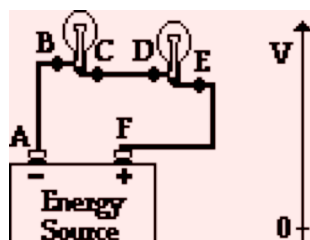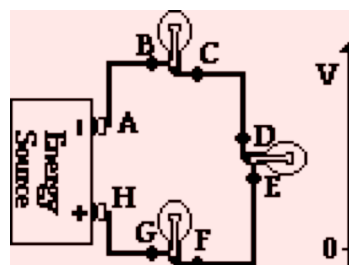
3. Given the circuit at the right with the listed
    current and resistance values, determine the
    electric potential at the indicated positions.
    Note that you are to find the electric potential
    (or voltage) and **NOT** the electric potential
    difference (or voltage drop).

    V_A = _____V V_B = _____V

    V_C = _____V V_D = _____V

    V_E = _____V
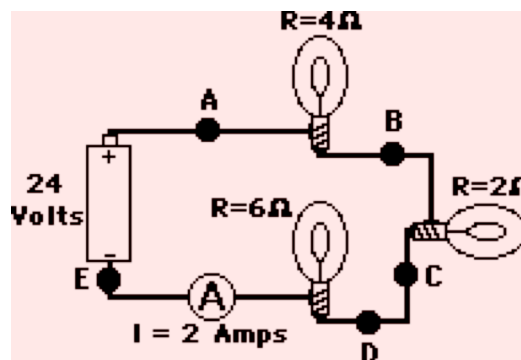
4. Determine the following quantities for the circuit in question #3 above. **PSYW**
    a. The overall power.   b. The power of the 6-ohm light bulb.

    c. The overall resistance.   d. The energy used by the circuit in 10 minutes.

Show your work for the following problems.

5.   a. Determine the amount of energy used when listening to your 5.0-Watt IPod Nano for 10 hours.

      b. Determine the resistance of the IPod if it uses a 5.2 Volt battery.

      c. What quantity of charge passes through the IPod battery during this 10-hr time period?

6.   a. Calculate the energy used and current drawn by a 200-W window fan when plugged into a 110-V outlet and left on for an 8-hr time period.

      b. Calculate the energy used and the current drawn by a 3400-W air conditioner which is wired to a 220-V circuit and left on for an 8-hr time period.

7.   A 2000-W hand dryer in a public bathroom at a zoo runs for 30 seconds per cycle. At a cost of 13 cents per kW•hr, determine the cost of running the dryer 200 times in a day.

      What is the annual cost of the hand dryer assuming it is used on average 200 times per day?

      Calculate the resistance and the current for the hand dryer if it is connected to a 220-V circuit.

Series Circuits

Read from **Lesson 4** of the **Current Electricity** chapter at **The Physics Classroom**:

> **http://www.physicsclassroom.com/Class/circuits/u9l4a.html**
> **http://www.physicsclassroom.com/Class/circuits/u9l4b.html**

MOP Connection: Electric Circuits: sublevels 7, 9 and 11

1. Electrical devices in circuits can be connected to each other in a number of different ways. The two most common connections are *series* connections and *parallel* connections. Observe the electrical wiring below. Indicate whether the connections are series or parallel.
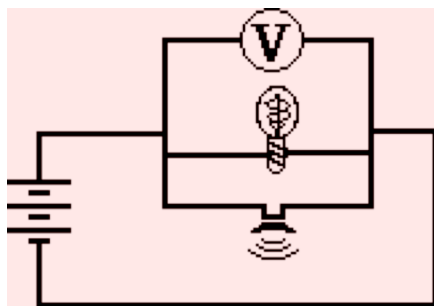
| **Series or Parallel?** | **Series or Parallel?** |
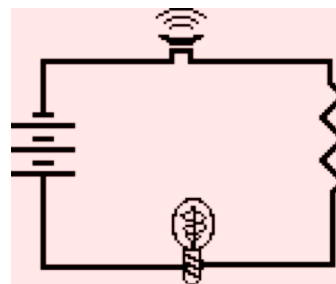
2. Two electric circuits are diagrammed below. For each circuit, indicate which two devices are connected in series and which two devices are connected in parallel.
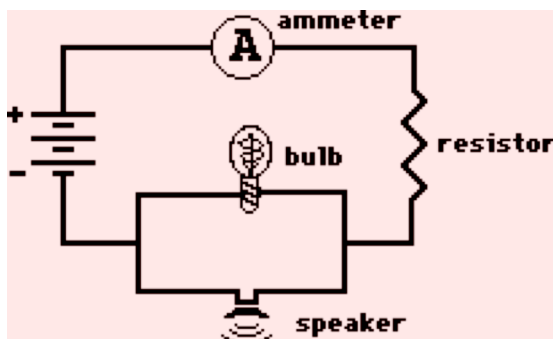
Series _____   **Series** _____
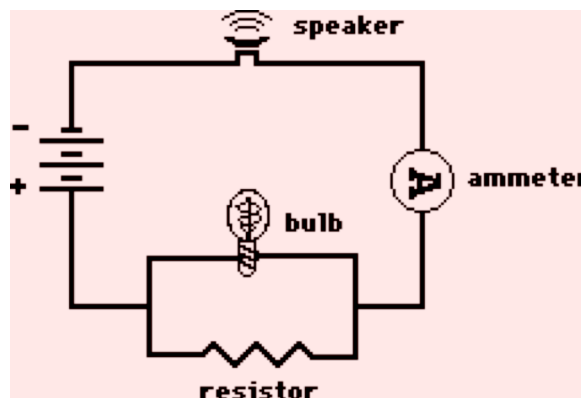
Parallel _____   **Parallel** _____

3. **Comparing Series vs. Parallel Circuits**
   Fill in the table below to indicate the manner in which series and parallel circuits differ.

		Series Circuit	Parallel Circuit
a.	**Definition**: The pathway by which charge loops around the circuit is characterized by _____ pathway.		
b.	**Observation**: If one light bulb goes out, the other light bulbs _____.		
c.	**Observation**: As the number of resistors is increased, the overall current _____.		
d.	**Observation**: As the number of resistors is increased, the overall resistance _____.		

4. The following diagrams represent circuits consisting of two electrical devices connected in series. For each diagram, fill in the blanks to show the voltage drop across the designated device.
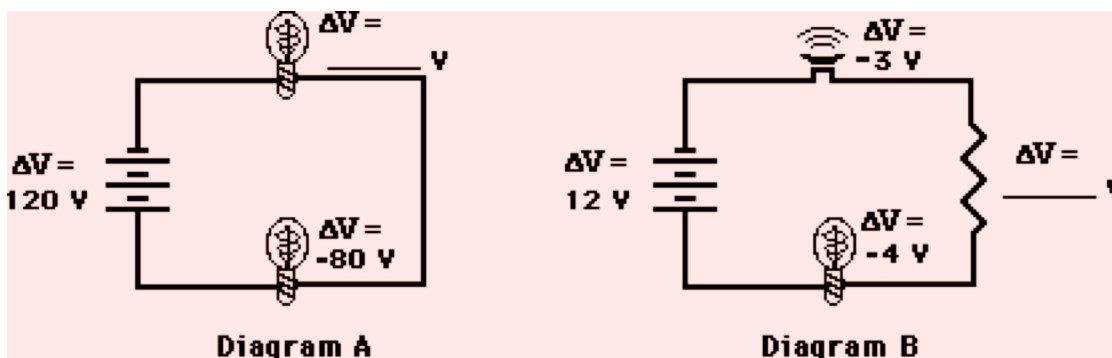
Diagram A   Diagram B

5. Consider the following two diagrams of series circuits. For each diagram, use arrows to indicate the direction of the conventional current. Then, make comparisons of the voltage and the current at the designated points for each diagram.

Diagram A   Diagram B
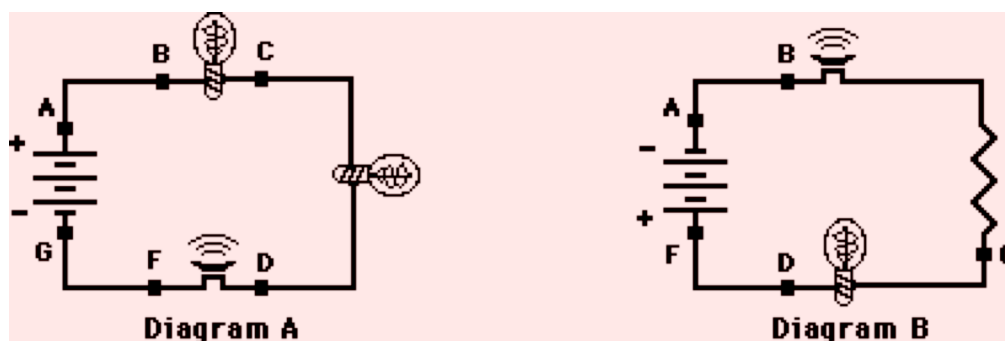
V_A _____ V_G
(>,<, or =)

V_B _____ V_C
(>,<, or =)

V_B _____ V_F
(>,<, or =)

I_A _____ I_G
(>,<, or =)

V_A _____ V_F
(>,<, or =)

V_B _____ V_C
(>,<, or =)

V_D _____ V_F
(>,<, or =)

I_A _____ I_F
(>,<, or =)

5. Express your understanding of equivalent resistance by filling in the blanks.

Having two 4-Ω resistors in series is equivalent to having one _____-Ω resistor.

Having three 4-Ω resistors in series is equivalent to having one _____-Ω resistor.

Having four 4-Ω resistors in series is equivalent to having one _____-Ω resistor.

6. **TRUE** or **FALSE**:

Three light bulbs are connected in series. The filament of one of the light bulbs burns out. The remaining two light bulbs will still be lit; yet, their brightness will be noticeably less.

7. Analyze the following circuit and determine the equivalent or total resistance. Then determine the current at the ammeter location.

Circuit A

Circuit B

R$_{tot}$ = _____   R$_{tot}$ = _____
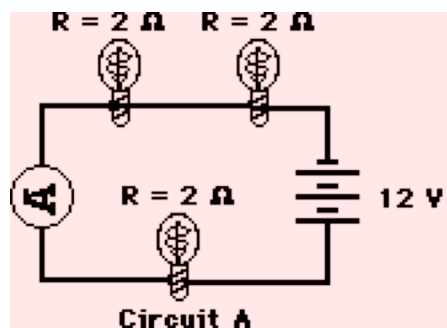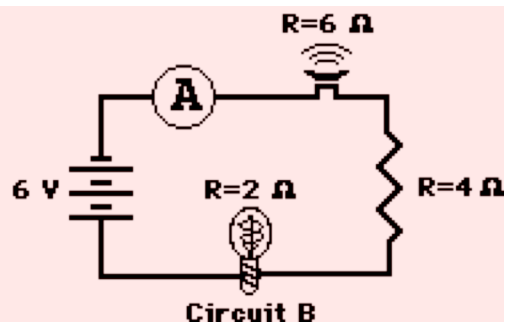
I = _____   I = _____

8. For the following diagrams, utilize the concept of equivalent resistance and Ohm's Law in order to fill in the blank.
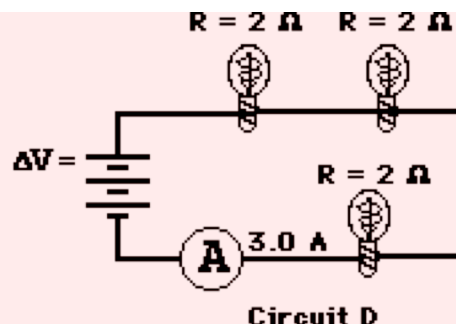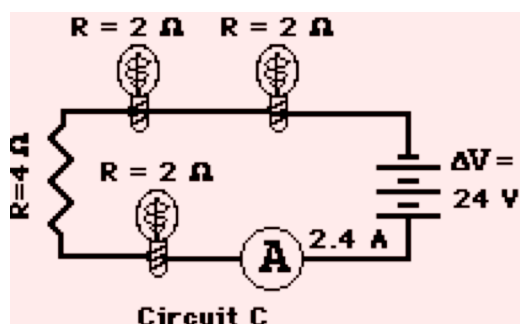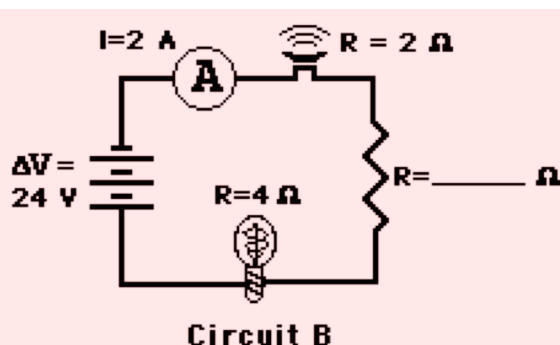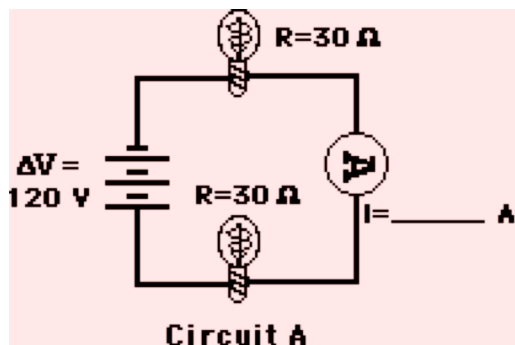
Circuit A

Circuit B

Circuit C

Circuit D

9. Compare circuits X and Y. Consider circuits X and Y below. Each circuit is powered by the same battery and contains identical resistors. Circuit X has one resistor and circuit Y has two resistors. The equivalent resistance of circuit X will be _____ (> or < or =) that of circuit Y. The current in the battery in X will be _____ (> or < or =) that in the battery in Y.
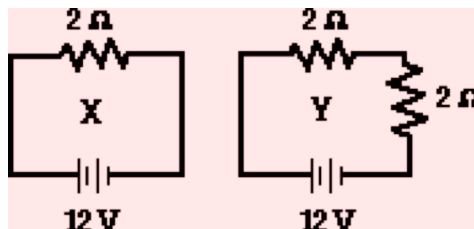
10. Three identical light bulbs are connected to a battery as shown below. Which adjustments could be made to the circuit that would increase the current being measured at X? Circle all that apply.
    a. Increase the resistance of one of the bulbs.
    b. Decrease the resistance of two of the bulbs.
    c. Increase the resistance of two of the bulbs.
    d. Decrease the voltage of the battery.
    e. Increase the voltage of the battery.
    f. Remove one of the bulbs.
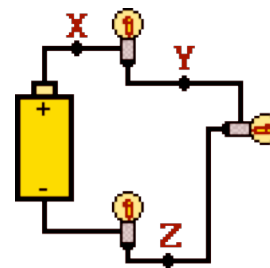
11. Three identical light bulbs are connected to a battery as shown below. W, X,Y and Z represent locations along the circuit. Which one of the following statements is true?
    a.   The potential difference between X and Y is greater than that between Y and Z.
    b.   The potential difference between X and Y is greater than that between Y and W.
    c.   The potential difference between Y and Z is greater than that between Y and W.
    d.   The potential difference between X and Z is greater than that between Z and W.
    e.   The potential difference between X and W is greater than that across the battery.
    f.   The potential difference between X and Y is greater than that between Z and W.
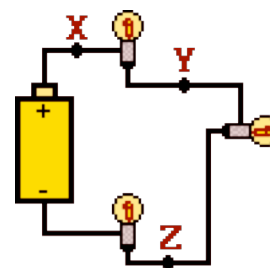
12. Three identical light bulbs are connected to a battery as shown below. Which one of the following statements is true?
    a. All three bulbs will have the same brightness.
    b. The bulb between X and Y will be the brightest.
    c. The bulb between Y and Z will be the brightest.
    d. The bulb between Z and the battery will be the brightest.

    Justify your answer to this question using the language of physics.
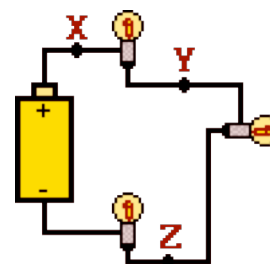
13. Compare a circuit with three light bulbs to a circuit with two light bulbs. All light bulbs are identical. In which circuit will the overall power be the greatest? Intelligently defend your answer.

Parallel Circuits

Read from **Lesson 4** of the **Current Electricity** chapter at **The Physics Classroom**:

> **http://www.physicsclassroom.com/Class/circuits/u9l4a.html**
> **http://www.physicsclassroom.com/Class/circuits/u9l4c.html**

**MOP Connection:**   Electric Circuits: sublevels 8, 10 and 11

Review:
1.   A circuit in which all charge follows a single pathway is a ____ circuit; a circuit in which charge follows multiple pathways is a ____ circuit.
     a. series, parallel   b. parallel, series

2.   For a parallel circuit: as the number of resistors being used within the same parallel circuit increases, the overall resistance value _____ (increases, decreases) and the overall current value _____ (increases, decreases).

3.   Household circuits are connected in parallel so that _____. Select all that apply.
     a. houses get the same effect with less current and thus save on energy costs.
     b. the turning off of one appliance does not result in the shut down of others.
     c. the hazard of electrocution and overheating of circuits is avoided.

Water Analogy:
4.   When the water flow (or charge flow) is divided into two or more separate pathways (as in a parallel circuit) the sum of the current in each individual pathway equals the total current. Utilize this principle to fill in the blanks in the following two diagrams. The meters in the diagram are measuring water flow rates in gallons per minute ("gpm").
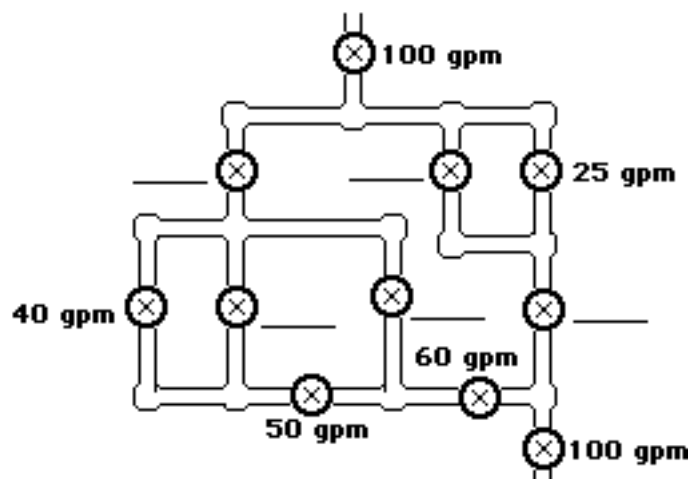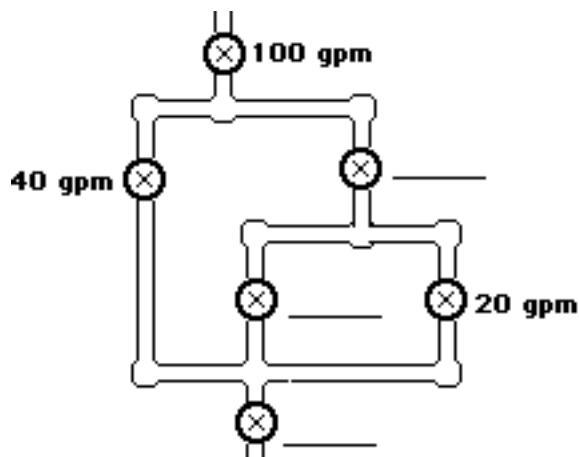
5.   Apply the same principle to fill in the blanks in the following diagrams for charge flow (i.e., current) through a parallel circuit.
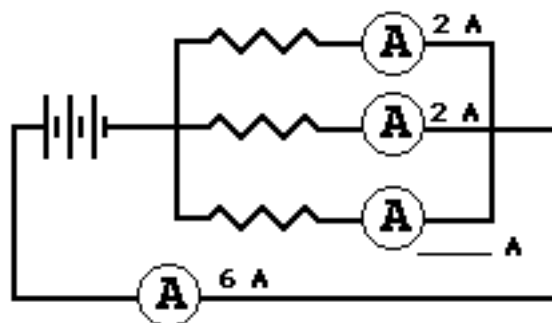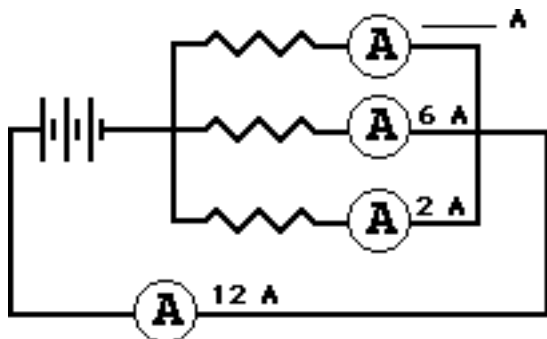
> **The Staircase Analogy**
> Electric charge dividing into multiple pathways in a parallel circuit is analogous to people walking down stairs which divide up into separate paths.
>
> Imagine being at a large shopping mall; you are descending a rather wide stairway when all of a sudden it breaks up into several smaller stairways. Being in a hurry, you scan the different pathways down the stairs to see which path is least crowded. You finally decide that the left stairway is least crowded and make a "dash" towards it. You know that your "flow rate" will be greatest along the stairway with the least resistance. When the "people flow" divides up into multiple pathways, each pathway has the same change in height (or same gravitational potential drop); yet, the pathway which offers the least resistance will have the greatest flow rate.
>
> In an analogous manner, as charge flow divides up into multiple pathways in a parallel circuit, each pathway has the same electric potential drop; yet, the pathway with the least resistance will have the greatest rate of charge flow (i.e., current).

6.   In the following circuits, fill in the blanks to indicate the current through the different pathways. Calculate the resistance of each resistor. Then rank the resistance of the resistors (labeled **A**, **B**, and **C**) in order from smallest to largest.
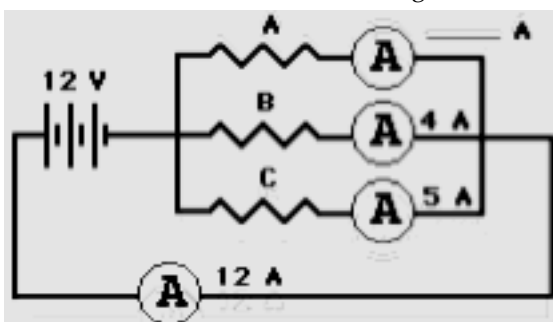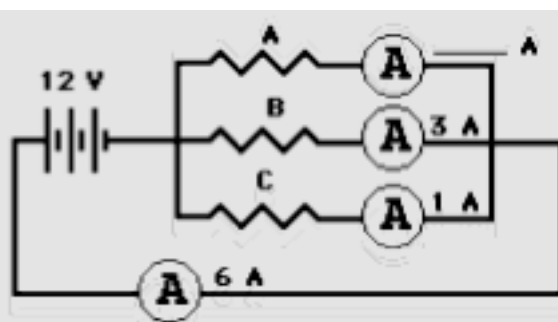
   Ranking of Resistance   **Ranking of Resistance**

   ____ < ____ < ____   ____ < ____ < ____

7.   A three-resistor parallel circuit is created. The resistance of the resistors are 3 Ω, 6 Ω, and 9 Ω. Suppose that one observes the current through the 3 Ω resistor to be 6 Amperes. The voltage drop across this 3 Ω resistor must be _____ V. This provides sufficient evidence to conclude that the voltage drop across the 6 Ω resistor is _____ V and the voltage drop across the 9 Ω resistor is _____ V. Therefore, the current in the 6 Ω resistor is _____ Amperes and the current in the 9 Ω resistor is _____ Amperes. When these three branch currents combine, one would observe that the current in the _____ V battery is _____ Amperes. In summary:

$$R_1 = 3\ \Omega \qquad\qquad R_2 = 6\ \Omega \qquad\qquad R_3 = 9\ \Omega$$

$$I_1 = 6\ \text{Amps} \qquad\qquad I_2 = \_\_\_\_\ \text{Amps} \qquad\qquad I_1 = \_\_\_\_\ \text{Amps}$$

$$\Delta V_1 = \_\_\_\_\ V \qquad\qquad \Delta V_2 = \_\_\_\_\ V \qquad\qquad \Delta V_3 = \_\_\_\_\ V$$

$$I_{battery} = \_\_\_\_\ \text{Amps} \qquad \Delta V_{battery} = \_\_\_\_\ V \qquad \Delta V_{battery} / I_{battery} = _____$$

8.   Consider the circuit at the right.
   a.   There is a voltage drop of _____V across each 2-Ω resistor.

   b.   By Ohm's law, the current in each 2-Ω resistor is _____ amps.

   c.   The current through the battery is _____ amps.

   d.   The resistors in parallel offer a combined resistance of _____ Ω to the charge being pumped by the battery.
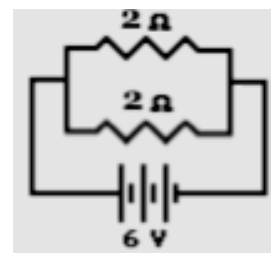
> **Equivalent Resistance**
> Devices connected in parallel offer a resistance to the flow of charge through the circuit. The total resistance (or *equivalent resistance*) is related to the resistance of the individual devices which are connected in parallel. The equivalent resistance can be determined with the equation
>
> $$\frac{1}{R_{equivalent}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$
>
> The electric potential difference across each branch is the product of the equivalent resistance and the total current (outside the branches).

Use the diagram below at the right in order to answer questions #9-#13. **PSYW**

9.   Determine the equivalent resistance of the circuit at the right.
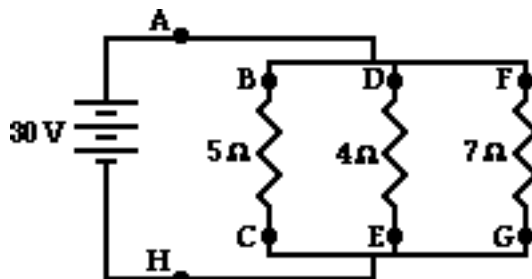
10. Determine the overall current in the circuit (as determined at position A or H).

11. Determine the electric potential difference (i.e. voltage drop) across the 5-Ω resistor (from B to C).

12. Determine the current through the 5-Ω resistor (from B to C).

13. Determine the current through the 7-Ω resistor (from B to C).

14. **TRUE or FALSE:**

     If resistors are connected in parallel, then the electric potential difference (i.e., voltage drop) will be greatest across the resistor with the greatest resistance.

14. **TRUE or FALSE:**

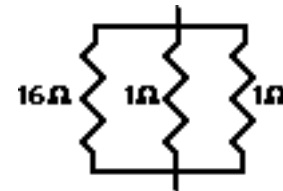   If resistors are connected in parallel, then the current will be the same through each resistor.
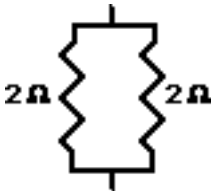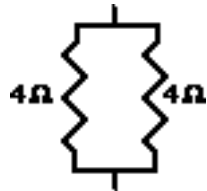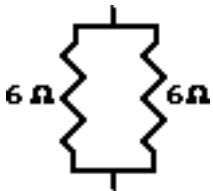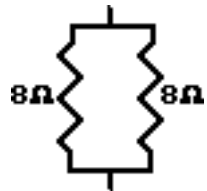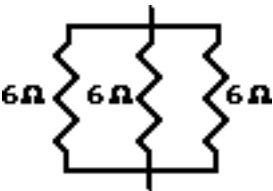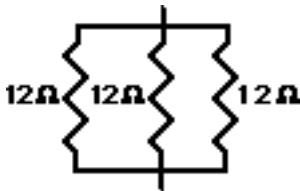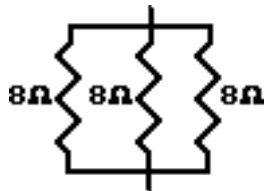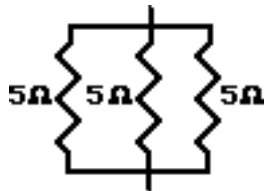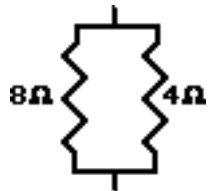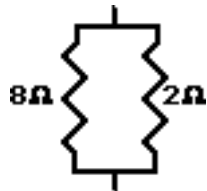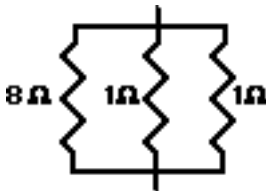
15. A 2-Ω and a 4-Ω resistor are connected in a parallel circuit. The electric potential difference (i.e., voltage drop) across the 4-Ω resistor will be ___ the electric potential difference across the 2-Ω resistor.
     a. two-times more than   b. two times less than   c. the same size as

16. A 2-Ω and a 4-Ω resistor are connected in a parallel circuit. The current through the 4-Ω resistor will be ___ the current through the 2-Ω resistor.
     a. two-times more than   b. two times less than   c. the same size as

17. For each of the following branched systems, determine the equivalent resistance.

a.	b.
2Ω 2Ω is equivalent to _____ Ω	4Ω 4Ω is equivalent to _____ Ω
c.	d.
6Ω 6Ω is equivalent to _____ Ω	8Ω 8Ω is equivalent to _____ Ω
e.	f.
6Ω 6Ω 6Ω is equivalent to _____ Ω	12Ω 12Ω 12Ω is equivalent to _____ Ω
g.	h.
8Ω 8Ω 8Ω is equivalent to _____ Ω	5Ω 5Ω 5Ω is equivalent to _____ Ω
i.	j.
8Ω 4Ω is equivalent to _____ Ω	8Ω 2Ω is equivalent to _____ Ω
k.	l.
8Ω 1Ω 1Ω is equivalent to _____ Ω	16Ω 1Ω 1Ω is equivalent to _____ Ω

18. Four resistors are connected in a parallel circuit. Three of the resistance values are known - 3 Ω, 4 Ω and 6 Ω. The overall or equivalent resistance of the four resistors must be ____ Ω. (Choose the one answer which is most informative.)
    a. greater than 3
    b. greater than 6
    c. greater than 13
    d. less than 13
    e. less than 3
    f. ... it is impossible to tell.

Combination Circuits

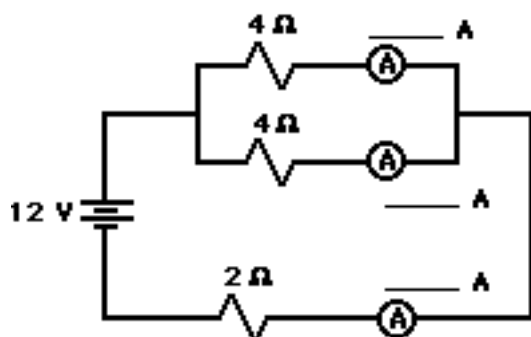Read from **Lesson 4** of the **Current Electricity** chapter at **The Physics Classroom**:

http://www.physicsclassroom.com/Class/circuits/u9l4d.html

MOP Connection: Electric Circuits: sublevel 12

1.   **Review**: Determine the equivalent resistance for the following sets of resistors.
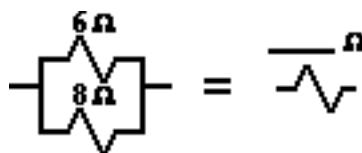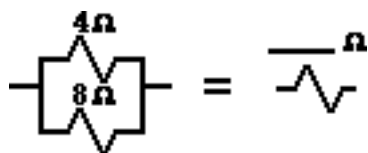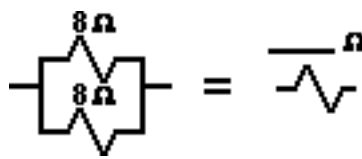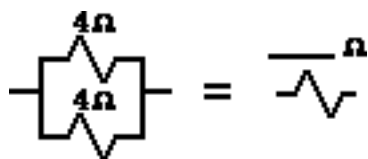
2.   The circuits below are known as combination or compound circuits; they are composed of resistors which are arranged both in parallel with each other as well as other resistors arranged in series with each other. In each circuit, the resistors which are arranged in parallel have the same resistance value. For each combination circuit shown below, determine the equivalent resistance for the combination of three resistors, the total current (i.e., at the battery), and the current at each of the three indicated locations.

R_{eq} = _____
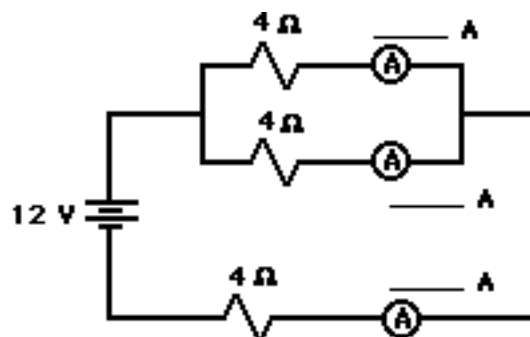
I_{tot} = _____

R_{eq} = _____

I_{tot} = _____

R_{eq} = _____

I_{tot} = _____

R_{eq} = _____
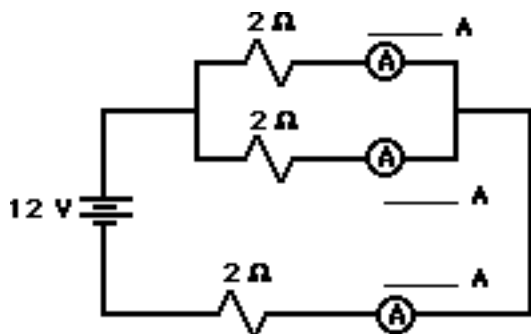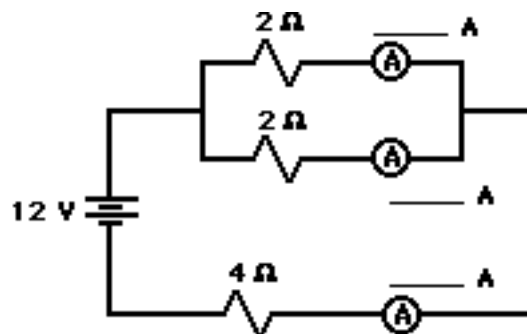
I_{tot} = _____

Circuit Analysis

Read from **Lesson 4** of the **Current Electricity** chapter at **The Physics Classroom**:

> **http://www.physicsclassroom.com/Class/circuits/u9l4b.html**
> **http://www.physicsclassroom.com/Class/circuits/u9l4c.html**
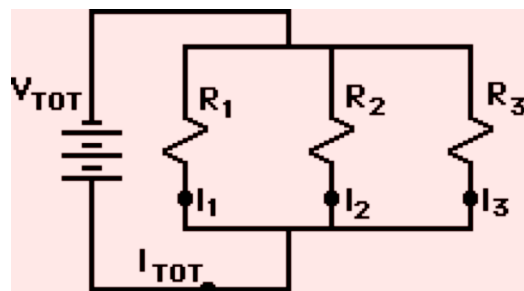> **http://www.physicsclassroom.com/Class/circuits/u9l4d.html**

MOP Connection: Electric Circuits: sublevel 11

1.   Fill in the blanks in the following diagram. Show appropriate units.

$R_{Tot}=$ _____ $I_{Tot} =$ _____

$\Delta V_1=$ _____ I_1 _____

$\Delta V_2=$ _____ I_2 _____

$\Delta V_3=$ _____ I_3 _____

$V_{Tot} = 60$ V

$R_1 = 12.5$ Ω $R_2 = 14.7$ Ω $R_3 = 19.1$ Ω

2.   Fill in the blanks in the following diagram. Show appropriate units.

$R_{Tot}=$ _____ $I_{Tot} =$ _____

$\Delta V_1=$ _____ I_1 _____

$\Delta V_2=$ _____ I_2 _____

$\Delta V_3=$ _____ I_3 _____

$V_{Tot} = 60$ V

$R_1 = 12.5$ Ω $R_2 = 14.7$ Ω $R_3 = 19.1$ Ω

3.   Fill in the blanks in the following diagram. Show appropriate units.

$R_{Tot}=$ _____ $I_{Tot} =$ _____

$\Delta V_1=$ _____ I_1 _____

$\Delta V_2=$ _____ I_2 _____

$\Delta V_3=$ _____ I_3 _____

$V_{Tot} = 120$ V

$R_1 = 16.0$ Ω $R_2 = 16.0$ Ω $R_3 = 6.0$ Ω