Electric Circuits - Outline

1. Describe the basic properties of electric current, and solve problems relating current, charge, and time.
2. Distinguish between the drift speed of a charge carrier and the average speed of the charge carrier between collisions.
3. Calculate resistance, current, and potential difference by using the definition of resistance.
4. Distinguish between ohmic and non-ohmic materials.
5. Differentiate between direct current and alternating current.
6. Relate electric power to the rate at which electrical energy is converted to other forms of energy.
7. Calculate electric power and the cost of running electrical appliances
8. Interpret and construct circuit diagrams.
9. Identify circuits as open or closed.
10. Deduce the potential difference across the circuit load, given the potential difference across the battery's terminals.
11. Calculate the equivalent resistance for a circuit of resistors in series, and find the current in and potential difference across each resistor in the circuit.
12. Calculate the equivalent resistance for a circuit of resistors in parallel, and find the current in and potential difference across each resistor in the circuit.
13. Calculate the equivalent resistance for a complex circuit involving both series and parallel portions.
14. Calculate the current in and potential difference across individual elements within a complex circuit

Notes

- <u>Current and Charge Movement</u>
  - ✓ Electric Current:
  - ✓ Direction of Electric Current:
  - ✓ Drift Velocity:
- <u>Resistance to Current</u>
  - ✓ Resistance:
  - ✓ Unit of Resistance:
  - ✓ Ohm's Law:
  - ✓ Limitations of Ohm's Law:

- ✓ Variables that affect Resistance of a Wire and their Consequences:

- ✓ Uses of Resistors:

- ✓ Resistance of Your Skin:

- ✓ Potentiometers:

• <u>Sources and Types of Current</u>

- ✓ Sources of Current:

- ✓ Types of Current

• <u>Energy Transfer and Power</u>

- ✓ Where the Energy goes in a Circuit:

- ✓ Electric Power:

- ✓ The Kilowatt-Hour:

- ✓ The Use of High Potential to Transfer Electricity:

- <u>Schematic Diagrams</u>

    - ✓ Symbols used in Schematic Diagrams:

- <u>Electric Circuits</u>

    - ✓ EMF and Terminal Voltage:

- <u>Resistors in Series</u>

    - ✓ Rules and Examples:

• <u>Resistors in Parallel</u>

- ✓ Rules and Examples

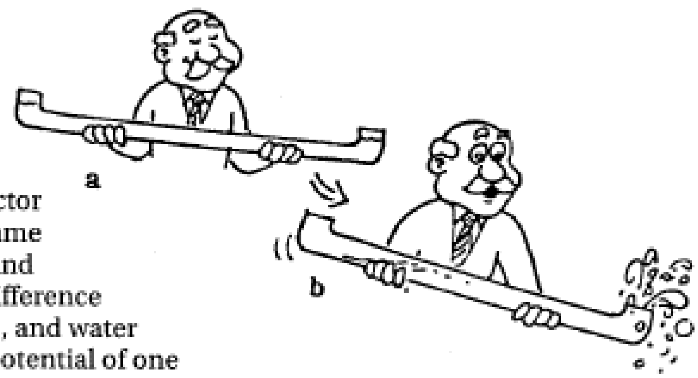
• <u>Combinations of Resistors in Series and Parallel Circuits</u>

- ✓ Examples:

- <u>**Sample/Practice Problems**</u>

A. **Electric Current**

1. Water doesn't flow in the pipe when (a) both ends are at the same level. Another way of saying this is that water will not flow in the pipe when both ends have the same potential energy (PE). Similarly, charge will not flow in a conductor if both ends of the conductor are at the same electric potential. But tip the water pipe and increase the PE of one side so there is a difference in PE across the ends of the pipe, as in (b), and water will flow. Similarly, increase the electric potential of one end of an electric conductor so there is a potential difference across the ends, and charge will flow.



   a. The units of electric potential difference are

      (volts) (amperes) (ohms) (watts)

   b. It is common to call electric potential difference

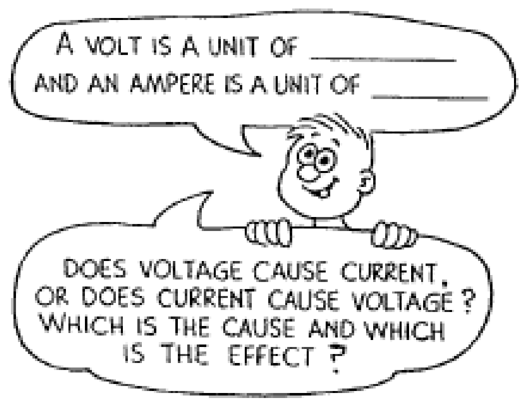
      (voltage) (amperage) (wattage)

   c. The flow of electric charge is called electric

      (voltage) (current) (power),

      and is measured in

      (volts) (amperes) (ohms) (watts)



2. Complete the statements:

   a. A current of 1 ampere is a flow of charge at the rate of__________coulomb per second.
   b. When a charge of 15 C flows through any area in a circuit each second, the current is

      _______________ A.

   c. One volt is the potential difference between two points if 1 joule of energy is needed to move

      __________coulomb of charge between the two points.

   d. When a lamp is plugged into a 120-V socket, each coulomb of charge that flows in the circuit

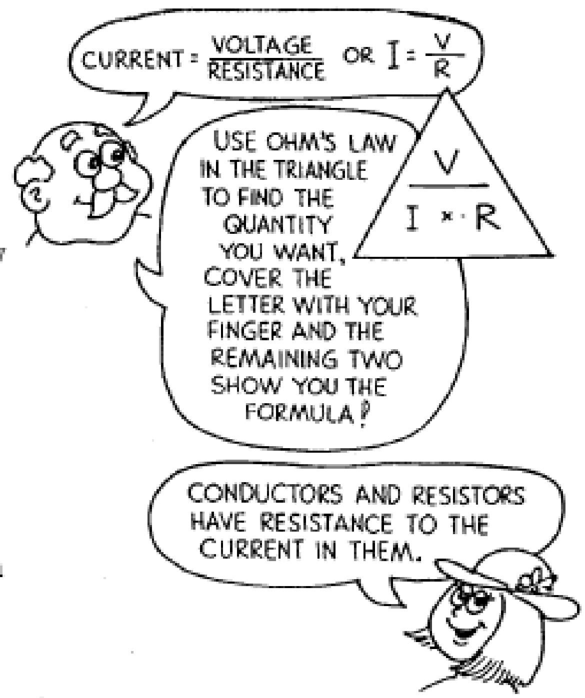
      is raised to a potential energy of __________ joules.

   e. Which offers more resistance to water flow, a wide pipe or a narrow pipe? ____________
      Similarly, which offers more resistance to the flow of charge, a thick wire or a thin wire?

      ____

B. Ohm's Law

Ohm's Law



1. How much current flows in a 1000-ohm resistor when 1.5 volts are impressed across it?

   ____

2. If the filament resistance in an automobile headlamp is 3 ohms, how many amps does it draw when connected to a 12-volt battery?

   ____

3. The resistance of the side lights on an automobile are 10 ohms. How much current flows in them when connected to 12 volts?

   ____

4. What is the current in the 30-ohm heating coil of a coffee maker that operates on a 120-volt circuit?

   ____

5. During a lie detector test, a voltage of 6 V is impressed across two fingers. When a certain question is asked, the resistance between the fingers drops from 400 000 ohms to 200 000 ohms. What is the current (a) initially through the fingers, and (b) when the resistance between them drops?

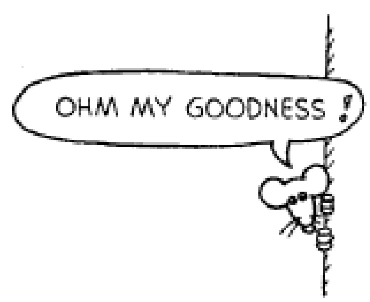
   (a) ____________________ (b) ____________________

6. How much resistance allows an impressed voltage of 6 V to produce a current of 0.006 A?

   ____

7. What is the resistance of a clothes iron that draws a current of 12 A at 120 V?

   ____



8. What is the voltage across a 100-ohm circuit element that draws a current of 1 A?

   ____

9. What voltage will produce 3 A through a 15-ohm resistor?

   ____

10. The current in an incandescent lamp is 0.5 A when connected to a 120-V circuit, and 0.2 A when connected to a 10-V source. Does the resistance of the lamp change in these cases? Explain your answer and defend it with numerical values.

    ____

    ____

C. Electric Power

Electric Power

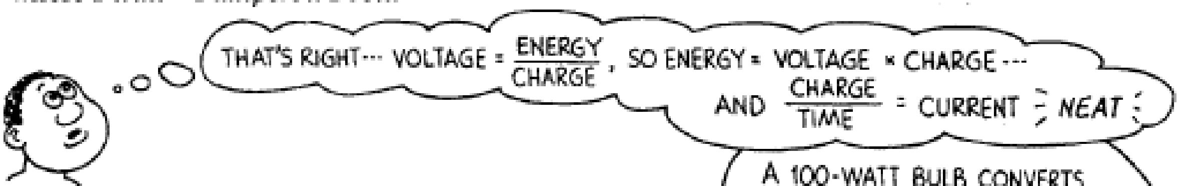
Recall that the rate energy is converted from one form to another is *power*.

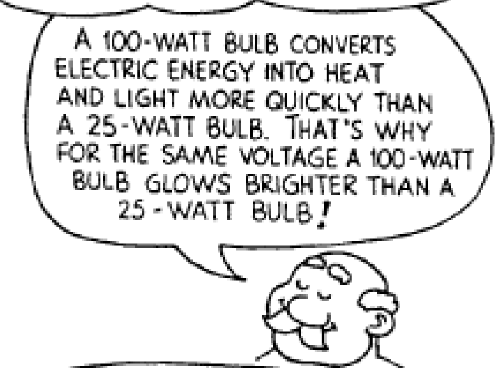
$$\text{power} = \frac{\text{energy converted}}{\text{time}} = \frac{\text{voltage x charge}}{\text{time}} = \text{voltage x } \frac{\text{charge}}{\text{time}} = \text{voltage x current}$$

The unit of power is the *watt* (or *kilowatt*). So in units form,

Electric power (*watts*) = current (*amperes*) x voltage (*volts*),

where 1 *watt = 1 ampere x 1 volt.*



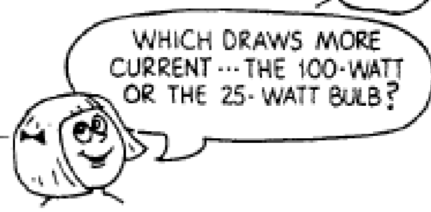


1. What is the power when a voltage of 120 V drives a 2-A current through a device?

   ____

2. What is the current when a 60-W lamp is connected to 120 V?

   ____

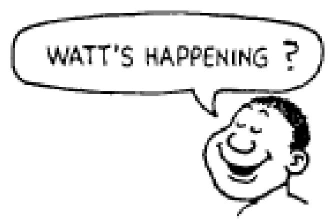


3. How much current does a 100-W lamp draw when connected to 120 V?

   ____

4. If part of an electric circuit dissipates energy at 6 W when it draws a current of 3 A, what voltage is impressed across it?

   ____



5. The equation

$$\text{power} = \frac{\text{energy converted}}{\text{time}}$$

   rearranged gives

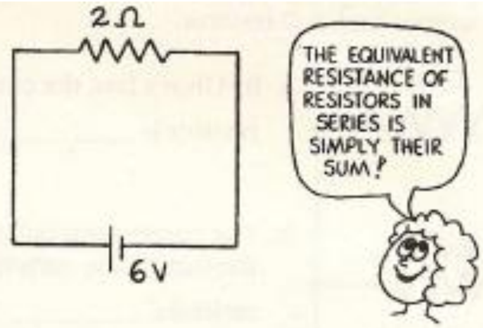
   energy converted = ______________

6. Explain the difference between a kilowatt and a kilowatt-hour.

   ____

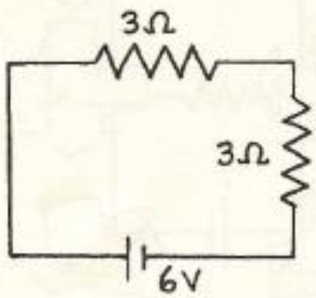
7. One deterrent to burglary is to leave your front porch light on all the time. If your fixture contains a 60-W bulb at 120 V, and your local power utility sells energy at 8 cents per kilowatt-hour, how much will it cost to leave the bulb on for the whole month? Show your work on the other side of this page.

D. Series Circuit



1. In the circuit shown at the right, a voltage of 6 V pushes charge through a single resistor of 2 Ω. According to Ohm's law, the current in the resistor (and therefore in the whole circuit) is

   ______________ A.

2. 

   If a second identical lamp is added, as on the left, the 6-V battery must push charge through a total resistance of _______ Ω. The current in the circuit is then ____ A.

3. The equivalent resistance of three 4-Ω resistors in series is ____________ Ω.

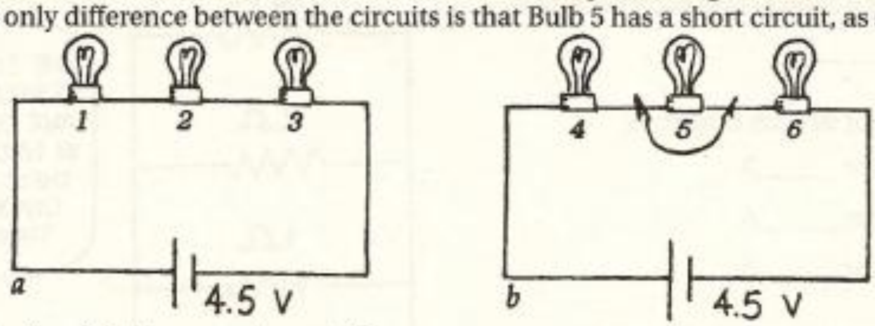
4. Does current flow *through* a resistor, or *across* a resistor? __________________

   Is voltage established *through* a resistor, or *across* a resistor? __________________

5. Does current in the lamps occur simultaneously, or does charge flow first through one lamp, then the other, and finally the last in turn?

   ____

6. Circuits *a* and *b* below are identical with all bulbs rated at equal wattage (therefore equal resistance). The only difference between the circuits is that Bulb 5 has a short circuit, as shown.

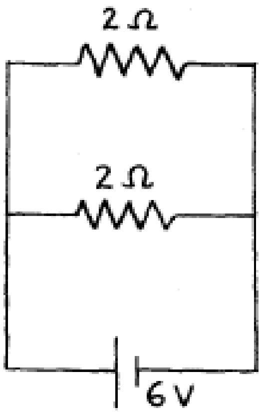


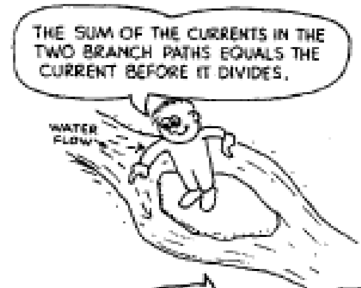
   a. In which circuit is the current greater? __________________
   b. In which circuit are all three bulbs equally bright? __________________
   c. What bulbs are the brightest? __________________
   d. What bulb is the dimmest? __________________
   e. What bulbs have the largest voltage drops across them? __________________
   f. Which circuit dissipates more power? __________________________
   g. What circuit produces more light? __________________

E. Parallel Circuits

Parallel Circuits

1. In the circuit shown below, there is a voltage drop of 6 V across *each* 2-Ω resistor.

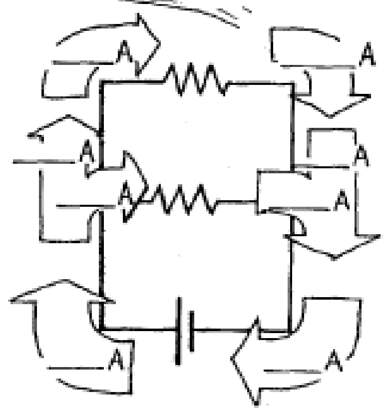




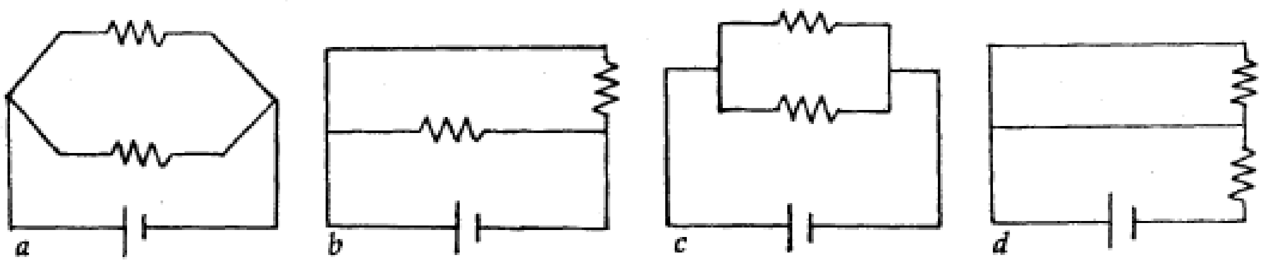
   a. By Ohm's law, the current in *each* resistor is __________ A.

   b. The current through the battery is the sum of the currents in the resistors, __________ A.

   c. Fill in the current in the eight blank spaces in the view of the *same circuit* shown again at the right.



2. Cross out the circuit below that is *not* equivalent to the circuit above.



3. Consider the parallel circuit at the right.
   a. The voltage drop across each resistor is _____________V.

   b. The current in each branch is:

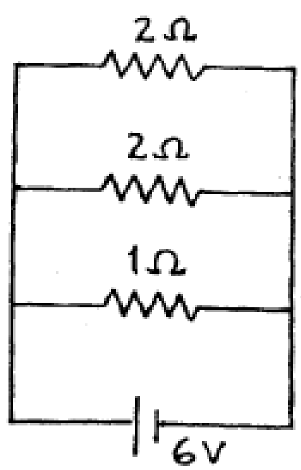
      2-Ω resistor ______A

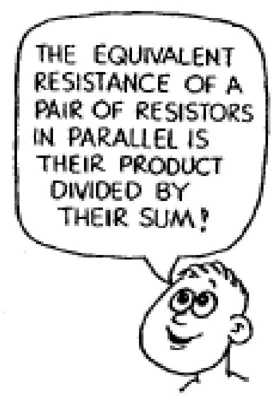
      2-Ω resistor ______A

      1-Ω resistor ______A

   b. The current through the battery equals the sum of the currents which equals ______ A.

   c. The equivalent resistance of the circuit equals ______ Ω.

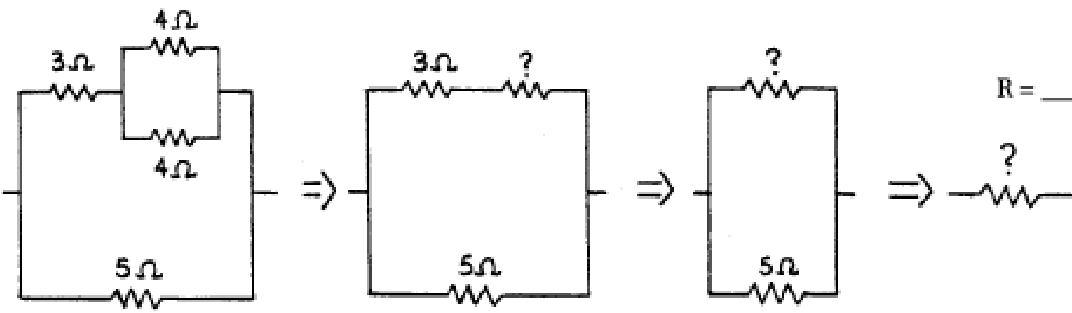




F. Compound Circuits

Compound Circuits

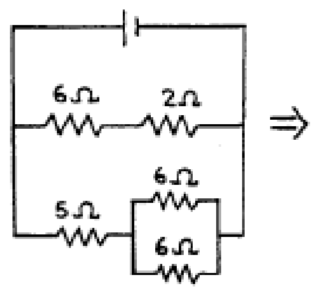
1. The initial circuit, below left, is a compound circuit made of a combination of resistors. It is reduced to a single equivalent resistance by the three steps, the circuits to its right, *a, b, c.* In step *a,* show the equivalent resistance of the parallel 4-Ω resistors. In step *b* combine this in series with the 3-Ω resistor. In step *c,* combine the last parallel pair to obtain the equivalent resistance of the circuit. (Note the similarity of this circuit and Figure 35.10 in your textbook.)



R = ____________

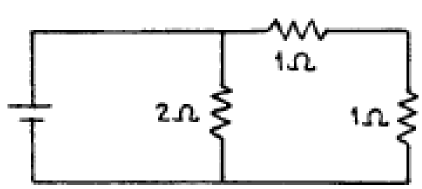
Initial Circuit *a.* *b.* *c.*

2. The circuit below is similar to Figure 35.11 in your textbook. In three successive steps, as in Question 1, replace each pair of resistors by a single resistor of equivalent resistance.

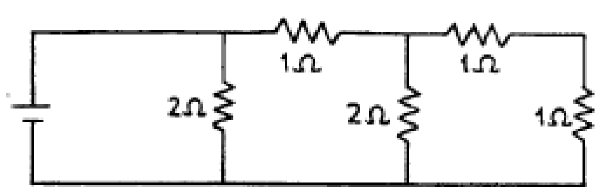


R = ____________

3. Find the equivalent resistance of these three circuits.

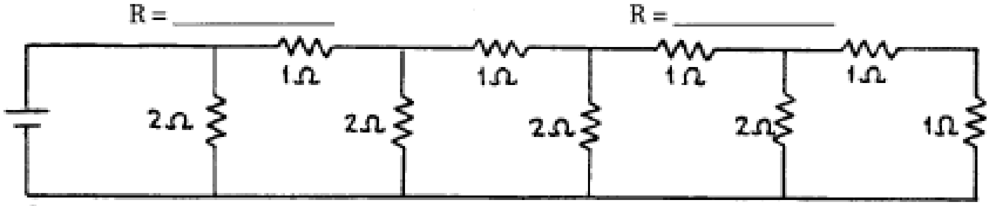


a



b

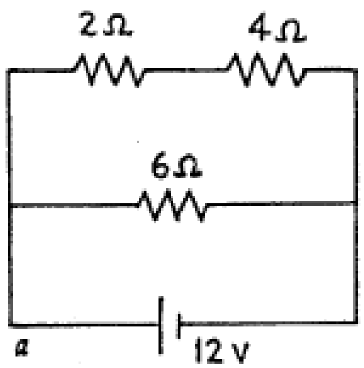
R = ____________ R = ____________



c

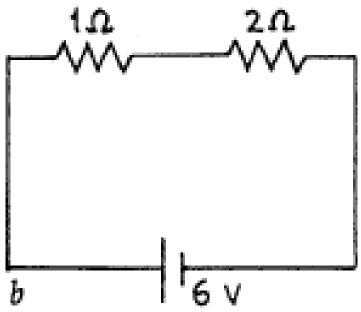
R = ____________

4. The table beside circuit *a* below shows the current through each resistor, the voltage across each resistor, and the power dissipated as heat in each resistor. Find the similar correct values for circuits *b*, *c*, and *d*, and put your answers in the tables shown.



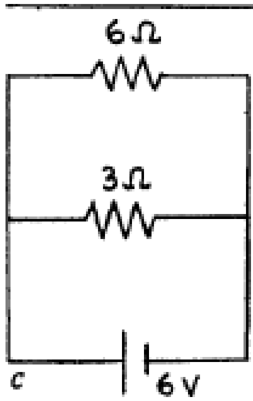
a

RESISTANCE	CURRENT ×	VOLTAGE =	POWER
2 Ω	2 A	4 V	8 W
4 Ω	2 A	8 V	16 W
6 Ω	2 A	12 V	24 W



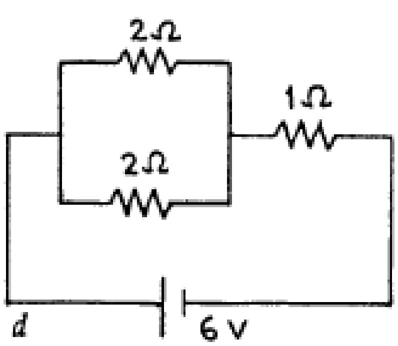
b

RESISTANCE	CURRENT ×	VOLTAGE =	POWER
1 Ω			
2 Ω			



c

RESISTANCE	CURRENT ×	VOLTAGE =	POWER
6 Ω			
3 Ω			



d

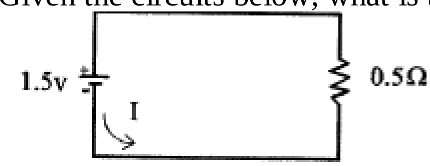
RESISTANCE	CURRENT ×	VOLTAGE =	POWER
2 Ω			
2 Ω			
1 Ω			

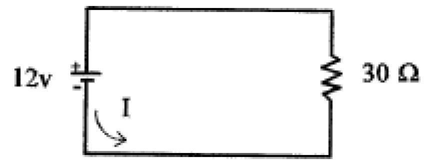
Homework Problems:

I. Ohm's Law

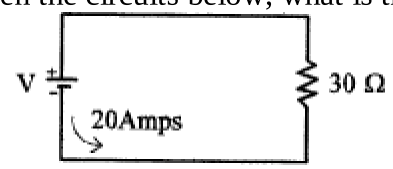
1. A resistor is often the general representation of real life items, what are 5 things a resistor could be?

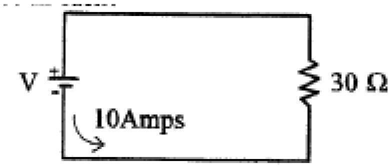
2. Given the circuits below, what is the current in each circuit?



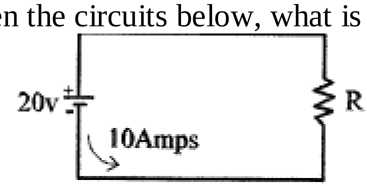


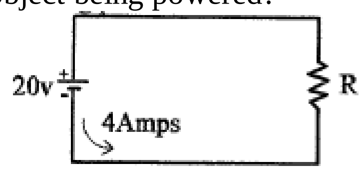
3. Given the circuits below, what is the potential of the source in each?





4. Given the circuits below, what is the resistance of the object being powered?





II. Electric Power

5. A toaster operates at 120 volts (you can assume anything that plugs into the wall operates at 120 V unless otherwise specified) draws 8.75 A of current. What is the power rating of the toaster?

6. Using the same toaster from #5, if it takes 45 s to toast a slice of bread, how much electrical energy is used?

7. If an electric blender develops 900 watts of power, how much current does the blender draw when plugged in and used.

8. If the blender from #7 is used to make milkshake and is run for 35 s, how much energy is expended?

III. Series and Parallel Circuits

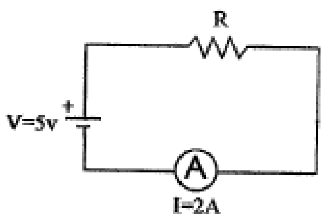
Directions: Using the information regarding series and parallel circuits, determine the values for the unknown quantities.

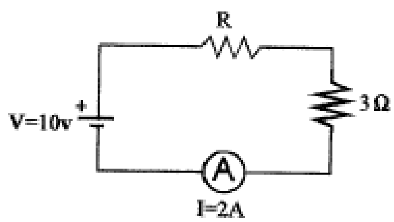
In a series circuit:

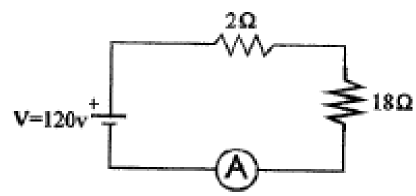
A. The current is the same in all parts of the circuit.

B. Each resistance gets only a fraction of the total voltage supplied by the source. The sum of all of these fractional voltages equals the voltage of the source.

C. The total resistance of the circuit, called the *effective resistance* (R_{eff}), is equal to the sum of the individual resistances.







R= ____________

R_{eff} = ________

R_{eff} = ________

R= ___________

R_{eff} = ________

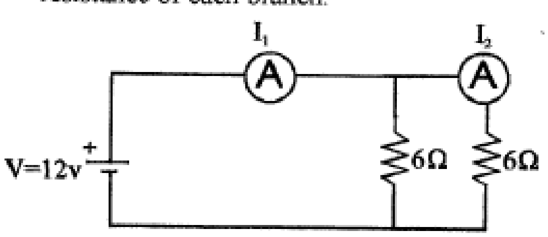
I= ___________

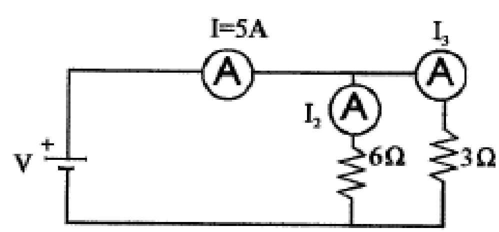
In a parallel circuit:

A. The current divides at each junction such that the sum of the currents entering the junction equal the sum of the currents leaving the junction. -- *{Kirchoff's first law}* This implies that the sum of the currents in each branch equals the total current.

B. The voltage (potential drop) across each branch remains unchanged and equals the voltage of the source.

C. The effective resistance of the circuit is less than the smallest resistance of a single branch. For *n* branches, the effective resistance of the entire circuit can be calculated using $\frac{1}{R_{eff}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n}$ where R*x* is the resistance of each branch.





R_{eff}= ______________

I_1= ______________

I_2= ______________

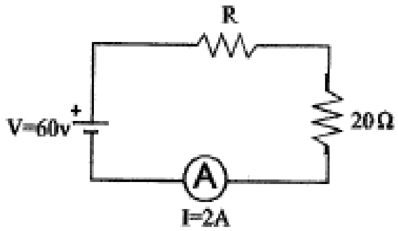
R_{eff}= ______________

V= ______________

I_2= ______________

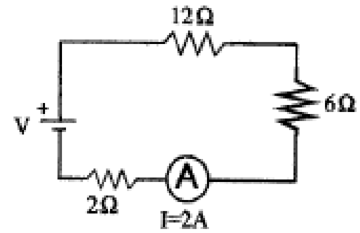
I_3= ______________

Directions: Using what you know regarding series and parallel circuits, determine the values for the unknown quantities.



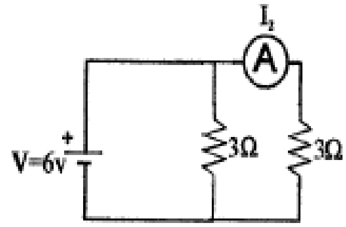
R_{eff} = ________

R= ________



R_{eff} = ________

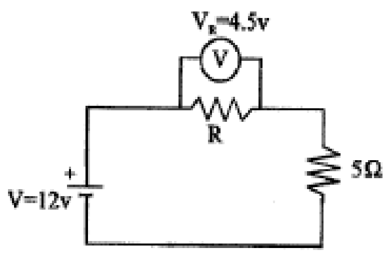
V= ________



R_{eff} = ________

I_T = ________

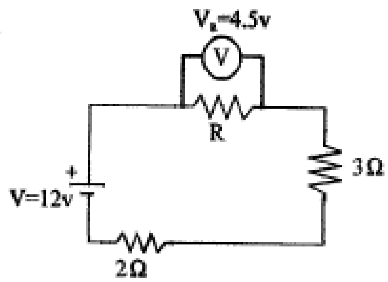
I_2 = ________



I= ________

R= ________

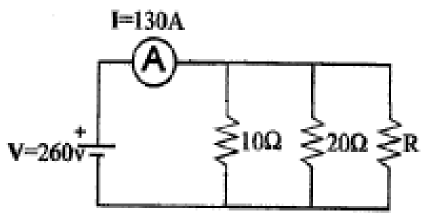
R_{eff}= ________



I= ________

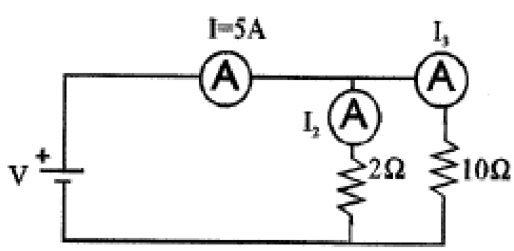
R= ________

R_{eff}= ________



R_{eff}= ________

R= ________

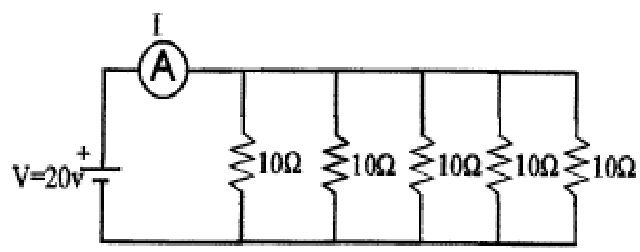


R_{eff}= ________

V= ________

I_2= ________

I_3= ________

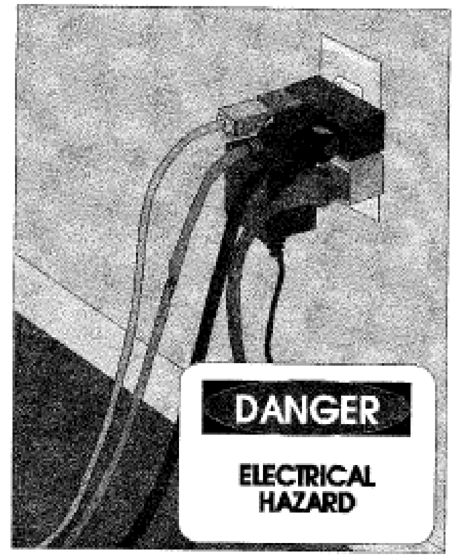


R_{eff}= ________

I= ________

IV. Electrical Safety

Directions: Embark on a search & learn mission to answer the following questions related to electrical safety and safety devices.



1. What is the purpose of a *fuse* or *circuit breaker*?

2. What is the difference between a *fuse* and a *circuit breaker*?

3. Why do some devices (appliances) have a third prong *{called a ground wire}* on their electrical plug?

4. What is the purpose of a *Ground Fault Interrupter* (GFI) on some electrical outlets?

5. What does a *Ground Fault Interrupter* look like?

6. How is it that electric current typically kills people? *{Not the type of accident, but the actual effect it has on our body that makes us dead?)*

7. If electricity can kill people, why do doctors and rescue workers use electric shock paddles *(called a defibrillator)* to save people's lives?