# *Chapters 34:* **Ohm's Law**

**Text:**
*Chapter 34*
Think and Explain: 1-3, 6-8, 10
Think and Solve: 1-6

**Vocabulary:**
Ohm's Law, resistance, resistivity, superconductor, current, amps, volts, ohms, kW-h, AC, DC

**Equations:**

$$I = \frac{Q}{t} \qquad V = IR \qquad P = IV \qquad V = \frac{PE_e}{q} \qquad P = \frac{PE_e}{t} \qquad Q = ne$$

*Constants:* $e = 1.6 \times 10^{-19}$ C 1 kW = 1000 W

**Key Objectives:**
*Concepts*
- ❑ correctly interpret a circuit diagram.
- ❑ correctly use ammeters and voltmeters in a circuit. (**Lab Practical**!)
- ❑ compare and contrast an ammeter and a voltmeter.
- ❑ explain what happens to electrons and energy in a circuit.
- ❑ explain how and why most material's resistance have a temperature dependence.
- ❑ compare and contrast an insulator, conductor and superconductor.
- ❑ explain what happens to electrons and energy when a light bulb is on and shining.

*Problem Solving*
- ❑ solve for the missing variable in Ohm's Law.
- ❑ calculate total charge or current given the current or total charge and time.
- ❑ convert between total charge and number of electrons.
- ❑ calculate the total energy from either power and time or voltage and charge.
- ❑ calculate the total cost of running an appliance for a given amount of time.
- ❑ solve for the missing variable in all of the given equations.

NAME: _____

# Circuits Summary

| *Word* | *Variable* | *Units* | *Idea* | *Other* |
|---|---|---|---|---|
| Potential Difference | | | | |
| Power | | | | |
| Charge | | | | |
| Energy | | | | |
| Time | | | | |
| Current | | | | |
| Resistance | | | | |

# Current & Voltage

1. If 15 C of charge flows by in 30 seconds, what is the current?

2. If a charge of 60 C goes by in 3 minutes, what is the current?

3. There is a current of 4 amps in a wire.
   a. How many Coulombs of charge flow through each second?

   b. How many Coulombs of charge flow through each minute?

4. How long will it take a current of 5 A to move 100 C of charge?

5. If $2 \times 10^{20}$ electrons flow by in 45 seconds, what is the current?

6. There is a current of 0.3 A in a resistor.
   a. How much charge will pass through in 5 minutes?

   b. How many electrons is that?

7. A power supply is set for 2.5 V and is connected to a light bulb.
   a. How much energy would 3 C of charge get to go through the light bulb?

   b. How much energy would 15 C of charge get to go through the light bulb?

8. 150 C of charge flows through a resistor and "loses" 450 J of energy.
   a. What is the voltage across the resistor?

   b. What happens to the "lost" energy of the charge?

*9. $15 \times 10^{20}$ electrons pass through a resistor in 1 minute and "lose" a total of 400 J of energy. What is the current and voltage of the resistor?

*Answers: 1) 0.5 A 2) 0.33 A 3. a) 4 C b) 240 C 4) 20 s 5) 0.71 A*
*6. a) 90 C b) $5.63 \times 10^{20}$ 7. a) 7.5 J b) 37.5 J 8. a) 3 V b) heats up resistor*
*9) 4 A & 1.67 V*

# *Lab 34-1:* **Ohm's Law**

**Purpose:** 1. To determine the relationship between voltage and current for a resistor.

**Materials:**

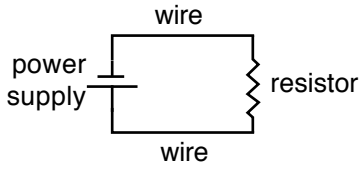
1 power supply 2 wires 2 alligator clips 2 different resistors

**Warnings:** The resistors you are using can become very hot if there are large currents passing through them for any length of time. To prevent burning your fingers, and/or destroying the resistors and meters, observe the following precautions:

1. *Always start with low voltages and currents, and work your way up. Stop if something starts to really heat up.*
2. *If you smell smoke, immediately disconnect the power supply.*

**Procedure:**

1. Turn on your common sense. Then set up the circuit as shown.




2. Vary the voltage until you are reading about .05 A in the resistor. Record the exact current and voltage.
3. Repeat #2 for current readings of up to 0.5 A at .05 A intervals.
4. Repeat for a second resistor, recording your data in the table below.

**Data:**

| Resistor #1 | | | |
|---|---|---|---|
| Voltage (V) | Current (A) | Voltage (V) | Current (A) |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

| Resistor #2 | | | |
|---|---|---|---|
| Voltage (V) | Current (A) | Voltage (V) | Current (A) |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

**Calculations:**

1. For each set of data, make a graph of voltage vs. current. These graphs should be straight, so put in the regression lines. Make sure the graphs are labeled and have units.

# *Lab 34-1:* **Ohm's Law**

**Questions:**

1. For the resistors you were given, how does the current in a resistor depend on the applied voltage?

2. Define resistance, both in words and mathematically.

3. Did the resistors become charged in anyway; i.e., do they become positive or negative? Explain.

4. Define each item listed below.
   a. voltage

   b. current

   c. resistance

5. Imagine you have a 20 Ω resistor with a potential difference of 10 volts across the ends.
   a. What is the current in the resistor?

   b. How much charge would pass through the resistor in one minute?

   c. How many electrons would pass through the resistor in one minute?

   d. If there was 40 V across the resistor, what would be the current?

6. How much voltage would it take to create a current of 0.75 A through a 3 Ω resistor?

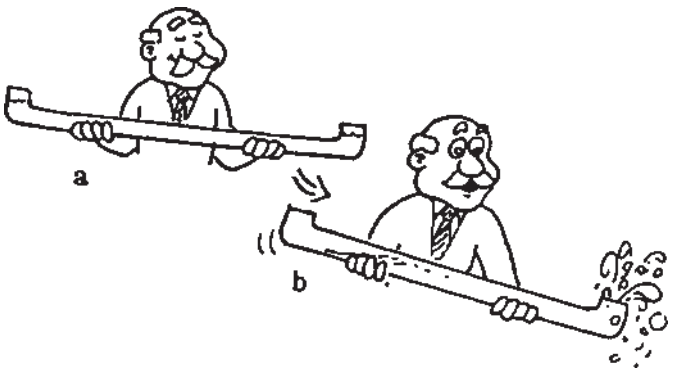
7. What is the resistance of something if 5 V produces a current of 0.8 A?

Name _____ Class _____ Date _____

## Concept-Development Practice Page 34-1

### *Electric Current*

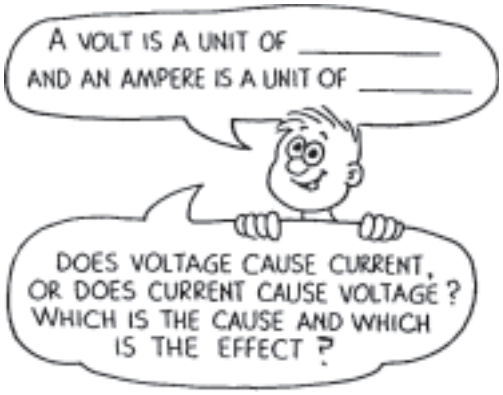
1. Water doesn't flow in the pipe when (a) both ends are at the same level. Another way of saying this is that water will not flow in the pipe when both ends have the same potential energy (PE). Similarly, charge will not flow in a conductor if both ends of the conductor are at the same electric potential. 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.

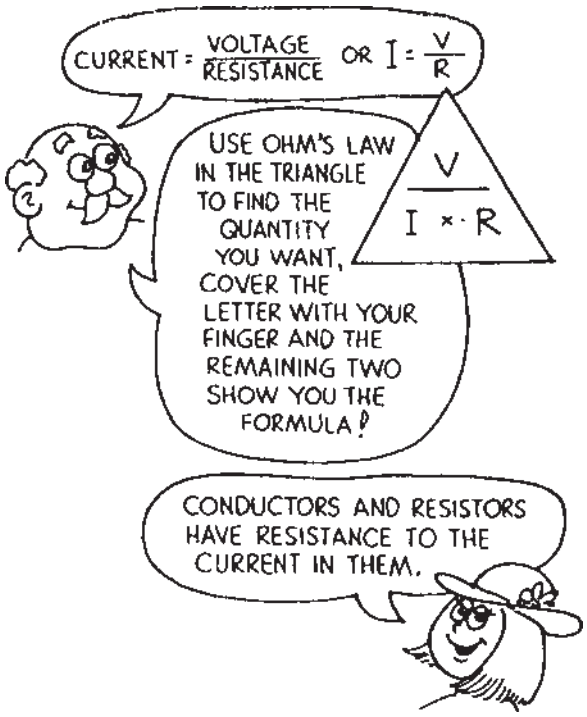
   b. When a charge of 15 C flows through any area in a circuit each second, the current is _____ A.

   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 current 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?
   _____

### *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?

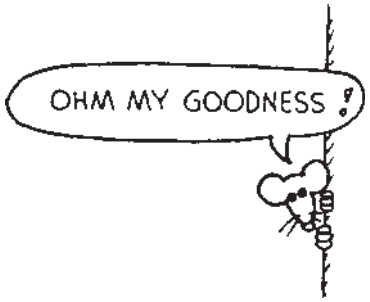
   _____

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.

    _____

    _____

    _____

# Ohm's Law Practice

*Concepts*

A. What is Ohm's Law?

B. If you double the voltage across a resistor, what will happen to the current flowing through the resistor? What if you triple the voltage?

C. If you double the resistance of something, but keep the voltage the same, what will happen to the current? What if you triple the resistance?

D. Do conductors have low resistance or high resistance? Why?

E. Fill out the chart below:

| | *Variable* | *Units* | *Equation* | *Explanation* |
|---|---|---|---|---|
| Charge | | | | |
| Voltage | | | | |
| Current | | | | |
| Resistance | | | | |

*Problems - Just Ohm's Law*

1. How much current would pass through a 3 Ω resistor when there was 6 volts applied to the resistor?

2. What voltage is needed to make 1.5 A of current flow through a toaster with a resistance of 75 Ω?

3. What is the resistance of the heating element in a car lock de-icer that contains a 1.5 V battery supplying a current of 0.5 A to the circuit?

4. What voltage is needed to get a current of 0.25 A to flow through a 75 Ω resistor?

5. Justine's hair dryer has a resistance of 90 Ω when first turned on. How much current does the hair dryer draw from the 110 V line in Justine's house?

6. Dinah's oven uses a 220 V line and draws 8 A of current when heated to its maximum temperature. What is the resistance of the oven when it is fully heated?

# Ohm's Law Practice

$V=IR$ $I=Q/t$ $Q=ne$ $V=PE/Q$ $e = 1.6 \times 10^{-19}$ C

7. 50 C of charge flows through a light bulb in 2 minutes when it is plugged into a 120 V outlet. What is the reistance of the light bulb?

8. An 80 Ω toaster is plugged into a 120 V outlet. How much charge passes through the toaster in the 3 minutes it takes to make your toast?

9. 4 Coulombs of charge lose 8 Joules of energy in 10 seconds when going through a resistor. What is the resistance of the resistor?

10. If $5 \times 10^{20}$ electrons pass through a resistor in 30 seconds when there is 4 volts applied to the resistor, what is the resistance of the resistor?

11. Imagine a radio uses 100 J of energy when 11 C of charge pass through it and that it takes 30 seconds for this to happen. What is the resistance of the radio?

12. A 25 Ω appliance needs 5000 J of energy to push 1500 C of charge through it. How long would it take for that to happen?

*Answers: 1) 2 A 2) 113 V 3) 3 Ω 4) 18.8 V 5) 1.22 A 6) 27.5 Ω 7) 288 Ω*
*8) 270 C 9) 5 Ω 10) 1.5 Ω 11) 24.8 Ω 12) 3.13 hours*

*side 2*

# Power & Ohm's Law

*Concepts*

1. What is the definition of power? (This was back in December!)

   Power = Units of Power =

2. If a hot plate uses 10000 J of energy in 5 seconds, what is the power of the hot plate?

3. A pump has a power of 1500 W. That means it can do _____ J of work every second. How much work would it do in one minute?

4. A 75 W light bulb is on for 15 seconds. How much energy does it use?

5. A 60 W light bulb is on for one hour. How much energy does it use?

6. For electrical circuits, what is the equation that relates power, voltage and current? Also show how the units all work out correctly.

*Problems*

7. A 75 W light bulb is in a 120 V outlet.
   a. What is the current drawn by the light bulb?

   b. What is the resistance of the light bulb?

   c. How many electrons would pass through the light bulb in one hour?

8. There is a current of 3 amps passing through a 25 Ω resistor.
   a. What is the potential difference across the resistor?

   b. What power is dissipated by the resistor?

   c. How much energy is dissipated by the resistor in 30 minutes?

9. A hair dryer is plugged into a 120 V outlet and draws 4 amps of current.
   a. What is the power of the hair dryer?

   b. What is the resistance of the hair dryer?

# Power & Ohm's Law

10. There is a current of 2 A flowing through a 2700 Ω resistor.
    a. What is the voltage across the resistor?

    b. What is the power rating of the resistor?

    c. How much energy is dissipated at the resistor in 1 second?

    d. How much energy is dissipated at the resistor in 1 minute?

11. A hair dryer has two settings: 600 W and 1200 W. (Household voltage is 120 V)
    a. Calculate the current draw for both settings.

    b. At which setting do you expect the resistance to be higher? Why?

    c. Calculate the resistance at each setting. (Household voltage is 120 V.)

12. What is the resistance and current through a 60 W light bulb if it is connected to its proper source voltage of 120 V?

13. You buy a 60 W light bulb in Europe, where electricity is delivered to homes at 240 V.
    a. If you use the bulb in Europe, what is the current through the light bulb?

    b. What is the resistance of the bulb?

14. A freezer of resistance 10 Ω is connected to a 110 V source.
    a. What is the current?

    b. What is the power delivered to the freezer?

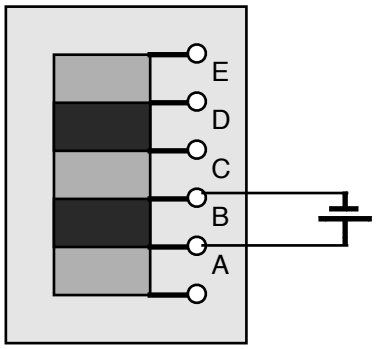
*Answers:* *7.a) 0.63 A b) 192 Ω c) 1.42 x $10^{22}$ 8.a) 75 V b) 225 W c) 405,000 J 9.a) 480 W b) 30 Ω 10. a) 5400 V b) 10,800 W c) 10,800 J d) 648,000 J 11. a) 5 A & 10 A b) 600 W, less current for same voltage c) 24 Ω & 12 Ω 12) 0.5 A & 240 Ω 13. a) 0.25 A b) 960 Ω 14. a) 11 A b) 1210 W*

# *Lab 34-2:* **Resistance of Wires**

**Purpose:** 1. To determine the resistance in five different wires using Ohm's Law.
2. To determine the effect of length, diameter and material on the resistance of a wire.

**Materials:**
1 power supply 2 wires 2 alligator clips 1 spool board

**Procedure:**
1. Set up the power supply, meters and spools as shown.
2. For each spool, apply a voltage and record the resulting current. (The diagram shows the hookup for spool "B.")
3. On the back of the spool thing there is a description of each spool. Record each spool's description. (Note that the numbers for the diameter of the spool are the gauge number of the wire. Larger numbers mean thinner wire.)
4. Calculate the resistance of each spool of wire.




**Data:**

| *Spool* | *Voltage (V)* | *Current (A)* | *Resistance (Ω)* | *Description of spool* | | |
|---|---|---|---|---|---|---|
| | | | | *Length (m)* | *Thickness (g)* | *Material* |
| A | | | | | | |
| B | | | | | | |
| C | | | | | | |
| D | | | | | | |
| E | | | | | | |

**Questions:**
1. Does the length of a wire affect its resistance? If so, how?

2. Does the thickness of a wire affect its resistance? If so, how?

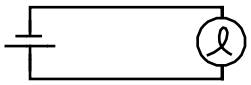
3. If two wires have the same dimensions, but one is made of copper and the other of nickel-silver, which one will have more resistance?

# *Lab 34-3:* **Light Bulb**

**Purpose:** 1. To determine the relationship between voltage and current for a light bulb.
2. To investigate the resistance of a light bulb.

**Materials:**
1 power supply 2 wires 2 alligator clips 1 light bulb & holder

**Procedure:**
1. Turn on your common sense. Then set up the circuit as shown.



2. Record the voltage and current for the light bulb at the 5 indicated voltages.
3. After the required 5 values, take data for the remaining 5 places by turning up the voltage each time so that you can see a change in the brightness of the bulb. You want to end with the bulb bright – but not so bright that you can't look at the bulb. Maximum of 6 Volts!

**Data:**

| light bulb | | | |
|---|---|---|---|
| *V (V)* | *I (A)* | *V (V)* | *I (A)* |
| 0.0 | 0.0 | | |
| 0.1 | | | |
| 0.2 | | | |
| 0.4 | | | |
| 0.7 | | | |

**Calculations:**
1. Make a graph of voltage vs. current. This should be curved so do NOT put in a regression line. Make photocopies as needed.

**Questions:**
1. From Lab 34-1, the graphs of voltage vs current were straight lines because the resistance was constant. What happened with the light bulb?

2. What happens to the resistance of a light bulb as the current through it increases?

3. Why does the resistance of the light bulb increase with increased current?

4. It took a certain amount of voltage to push electrons through the light bulb – which means the electrons lost some potential energy going the bulb. What happened to this potential energy?

# Electric Bills

1. Power is the rate at which energy is converted and is measured in watts. One watt is equal to one _____ per _____. There are _____ W in 1 kW.

2. Given the power of something, you calculate the amount of energy it used by multiplying _____ and _____. Therefore, a "kilowatt-hour" (kWh) is a unit of _____.

3. A 60 W light bulb runs all day for 3 days.
   a. What is the power rating of the light bulb in kW?

   b. How many total hours is the light bulb in use?

   c. What is the total energy used in kWh?

   d. If the electric company charges $0.12 per kWh, how much does it cost to keep the light bulb on day and night for 3 days?

4. A 1500 W air conditioner is in operation for 5 hours.
   a. What is the power rating of the air conditioner in kW?

   b. What is the total energy used in kWh?

   c. If you pay 14 cents per kWh, how much does it cost to run your air conditioner for 5 hours?

5. How many kWh (kilowatt-hour) of energy does a 550 W toaster use in the morning if it is in operation for a total of 10 min? At a cost of 12 cents/kWh, how much would this add to your monthly electric bill if you made toast everyday for 1 week?

6. At $0.110 per kWh, what does it cost to leave a 40 W porch light on day and night for a year?

*Answers: 1) Joule, second, 1000 2) power, time, energy 3. a) 0.06 kW b) 72 hrs c) 4.32 kWh d) $0.52 4. a) 1.5 kW b) 7.5 kWh c) $1.05 5) $0.077 6) $38.54*