Name ________________ Class ____________ Date __________

Summary

THE BIG IDEA **Voltage is an "electric pressure" that can produce a flow of charge, or current, within a conductor.**

34.1 Flow of Charge

When the ends of an electric conductor are at different electric potentials, charge flows from one end to the other.

- Charge flows when there is a **potential difference**, or difference in potential (voltage), between the ends of a conductor.
- The flow of charge will continue until both ends reach a common potential. When there is no potential difference, there is no longer a flow of charge through the conductor.
- To attain a sustained flow of charge in a conductor, some arrangement must be provided to keep one end at a higher potential than the other.

34.2 Electric Current

A current-carrying wire has a net electric charge of zero.

- **Electric current** is the flow of electric charge.
- In solid conductors, the electrons carry the charge through the circuit because they are free to move throughout the atomic network. These electrons are called *conduction electrons.*
- In fluids, such as the electrolyte in a car battery, positive and negative ions as well as electrons may compose the flow of electric charge.
- Electric current is measured in **amperes**, for which the SI unit is symbol A. An ampere is the flow of 1 coulomb of charge per second.

34.3 Voltage Sources

Voltage sources such as batteries and generators supply energy that allows charges to move steadily.

- Something that provides a potential difference is known as a **voltage source**.
- The potential energy per coulomb of charge available to electrons moving between terminals is the voltage (sometimes called the *electromotive force*, or *emf*).
- Charges *flow* through a circuit because of an applied voltage *across* the circuit. Voltage doesn't go anywhere, for it is the charges that move. Voltage causes current.

34.4 Electric Resistance

The resistance of a wire depends on the conductivity of the material used in the wire (that is, how well it conducts) and also on the thickness and length of the wire.

- The amount of charge that flows in a circuit depends on the voltage provided by the voltage source. The current also depends on the resistance that the conductor offers to the flow of charge—**the electric resistance.**
- The resistance of some materials becomes zero at very low temperatures, a phenomenon known as **superconductivity.**
- Electric resistance is measured in units called **ohms.**

34.5 Ohm's Law

Ohm's law states that the current in a circuit is directly proportional to the voltage impressed across the circuit, and is inversely proportional to the resistance of the circuit.

- The relationship among voltage, current, and resistance is called **Ohm's law**. In short, current = voltage/resistance.
- The relationship among the units of measurement for current, voltage, and resistance is: 1 ampere = 1 volt/ohm.

34.6 Ohm's Law and Electric Shock

The damaging effects of electric shock are the result of current passing through the body.

- From Ohm's law, we can see that a damaging electric current depends on the voltage applied, and also on the electrical resistance of the human body.
- The resistance of the human body depends on its condition and ranges from about 100 ohms if it's soaked with salt water to about 500,000 ohms if the skin is very dry.
- Drops of water that collect around on/off switches of devices such as a hair dryer can conduct current to the user. Handling electric devices while taking a bath is extremely dangerous.
- If a bird is perched on a highline wire, the bird will not receive a shock unless there is a *difference* in potential between one part of its body and another part.
- Mild shocks occur when the surfaces of appliances are at an electrical potential different from that of the surfaces of other nearby devices.

34.7 Direct Current and Alternating Current

Electric current may be DC or AC.

- **Direct current** is a flow of charge that *always flows in one direction.* Electrons always move through the circuit in the same direction, from the repelling negative terminal and toward the attracting positive terminal.

- **Alternating current** (AC) is electric current that repeatedly reverses direction. Electrons in the circuit move first in one direction and then in the opposite direction, alternating back and forth about relatively fixed positions.
- Nearly all commercial AC circuits in North America involve voltages and currents that alternate back and forth at a frequency of 60 cycles per second. This is 60-hertz current.
- Voltage of AC in North America is normally 120 volts. Power transmission is more efficient at higher voltages, so Europe adopted 220 volts as its standard.
- The primary use of electric current, whether DC or AC, is to transfer energy quietly, flexibly, and conveniently from one place to another.

34.8 Converting AC to DC

With an AC-DC converter, you can operate a battery-run device on AC instead of batteries.

- In addition to a transformer to lower the voltage, an AC-DC converter uses a **diode**, a tiny electronic device that acts as a one-way valve to allow electron flow in only one direction. Since alternating current vibrates in two directions, only half of each cycle will pass through a diode. The output is a rough DC, off half the time.
- To maintain continuous current while smoothing the rough DC, a capacitor is used.

34.9 The Speed of Electrons in a Circuit

In a current-carrying wire, collisions interrupt the motion of the electrons so that their actual *drift speed*, or *net speed* through the wire due to the field, is extremely low.

- Energy is transported through the connecting wires at nearly the speed of light. The electrons that make up the current, however, do not move at this high speed.
- A pulsating electric field can travel through a circuit at nearly the speed of light. The electrons continue their random motions in all directions while simultaneously being nudged along the wire by the electric field. Conduction electrons are accelerated by an electric field.
- Before the electrons gain appreciable speed, they "bump into" the anchored metallic ions in their paths and transfer some of their kinetic energy to them. This is why current-carrying wires become hot.
- In an AC circuit, the conduction electrons don't make any net progress in any direction. They oscillate rhythmically to and fro about relatively fixed positions. When you talk to your friend on a conventional telephone, it is the *pattern* of oscillating motion that is carried across town at nearly the speed of light.

Name ______________________ Class ______________ Date ____________

Chapter 34 Electric Current

34.10 The Source of Electrons in a Circuit

The source of electrons in a circuit is the conducting circuit material itself.

- When you plug a lamp into an AC outlet, *energy* flows from the outlet into the lamp, not electrons. Energy is carried by the electric field and causes a vibratory motion of the electrons that already exist in the lamp filament.
- When you are jolted by an AC electric shock, the electrons making up the current in your body originate in your body. Electrons do not come out of the wire and through your body and into the ground; energy does.

34.11 Electric Power

Electric power is equal to the product of current and voltage.

- **Electric power** is the rate at which electrical energy is converted into another form such as mechanical energy, heat, or light. In equation form, electric power = current × voltage.
- If the voltage is expressed in volts, and the current in amperes, then the power is expressed in watts: 1 watt = (1 ampere) × (1 volt).
- A *kilowatt-hour* represents the amount of energy consumed in 1 hour at the rate of 1 kilowatt, or 1000 watts.

Name ______________________ Class ______________ Date __________

Exercises

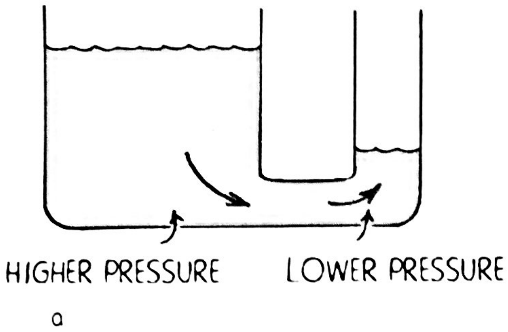
34.1 Flow of Charge (page 681)

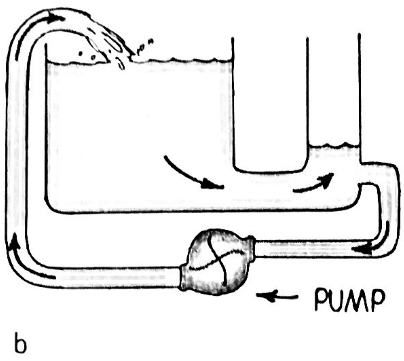
1. Charge flows when there is a ______________ between the ends of a conductor.
2. Explain what would happen if a Van de Graaff generator charged to a high potential was connected to a ground wire.

____

____

3. Explain how the sustained flow of charge is analogous to the flow of water from a higher reservoir to a lower one, as shown in the illustration below.





____

____

____

____

____

____

____

34.2 Electric Current (page 682)

Match each phrase with the correct term or terms. Terms may be used more than once.

Phrase

_____ 4. the flow of electric charge

_____ 5. particles within a solid conductor that carry charge through a circuit

_____ 6. SI unit used to measure electric current

_____ 7. equivalent to 1 coulomb of charge per second

_____ 8. the net charge in a current-carrying wire

Terms

a. ampere

b. zero

c. conduction electrons

d. electric current

34.3 Voltage Sources (page 683)

9. What is a voltage source? ______________________________

____

10. How do batteries and generators supply electrical energy?

____

____

____

11. Is the following sentence true or false? The potential energy per coulomb of charge available to electrons moving between the terminals of a battery or generator is the voltage. ______________

12. Charges flow ______________ a circuit because of an applied voltage ______________ the circuit.

34.4 Electric Resistance (page 684)

13. Is the following sentence true or false? The amount of charge that flows in a circuit does not depend on the voltage provided by the voltage source. ______________

14. What is electric resistance?

____

____

15. Circle the letter of each statement that is true.
    a. The resistance of a wire depends on the conductivity of the material used in the wire.
    b. The resistance of a wire does not depend on the thickness of the wire.
    c. Longer wires have less resistance than short wires.
    d. Electric resistance depends on the temperature of the wire.

16. The resistance of some materials becomes zero at very low temperatures, a phenomenon known as ______________.

17. Electric resistance is measured in units called ______________.

34.5 Ohm's Law (page 685)

18. The relationship among current, voltage, and ______________ is called Ohm's law.

19. State Ohm's law.

____

____

20. How can you express Ohm's law mathematically?

____

21. What is the relationship among the units of measurement for the three quantities related by Ohm's law?

____

22. What are resistors?

____

34.6 Ohm's Law and Electric Shock (pages 686–688)

23. The damaging effects of electric shock are the result of ____________ passing through the body.

24. Is the following sentence true or false? The resistance of your body is much greater when you're soaked with water than when your skin is dry. ____________

25. Explain why it is dangerous to handle electric devices while taking a bath.

____

____

____

____

26. Is the following sentence true or false? A bird perched on a high-voltage wire is not shocked because there is not a potential difference between one part of its body and another part. ____________

27. What is the purpose of the third prong on a three-prong electric plug?

____

34.7 Direct Current and Alternating Current (pages 688–689)

28. Circle the letter of each statement that is true.
    a. Direct current refers to a charge that always flows in one direction.
    b. In a DC circuit, electrons always move from the positive terminal toward the negative terminal.
    c. A battery produces direct current.
    d. AC is current that repeatedly reverses direction.

29. Circle the letter of the correct answer. A 60-hertz current means that the current
    a. equals 60 amperes.
    b. alternates back and forth at 60 cycles per second.
    c. changes direction once every 60 seconds.
    d. travels at a speed of 60 meters per second.

30. Circle the letter of the correct answer. What is the standard voltage of AC in the United States?
    a. 9 V
    b. 12 V
    c. 110–120 V
    d. 220–240 V

31. Will an appliance that operates on 220–240 volts work when plugged into a wall socket in the United States? Explain your answer.

____

____

____

____

____

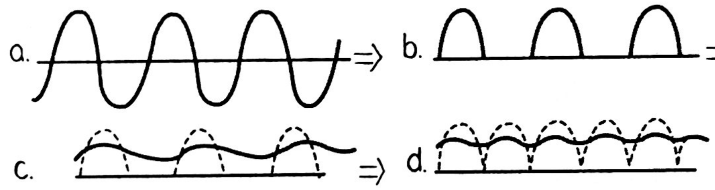
34.8 Converting AC to DC (page 690)

32. The current in laptops and cell phones is ______________.

33. With an ______________, you can operate a battery-run device on AC instead of batteries.

34. In addition to a transformer to lower the voltage, an AC-DC converter uses a ______________, which acts as a one-way valve to allow electron flow in only one direction.

The diagrams below show the effect of an AC–DC converter on alternating current. Match the letter of each diagram to the correct description.



_____ 35. Charging and discharging of a capacitor provides continuous but bumpy current.

_____ 36. Only half of each cycle of AC passes through the diode, resulting in a pulsating DC.

_____ 37. The input to the diode is AC.

_____ 38. By using a pair of diodes, there are no gaps in the current output.

34.9 The Speed of Electrons in a Circuit (pages 691–692)

39. Circle the letter of each statement that is true.

a. Energy is transported through connecting wires of a circuit at nearly the speed of light.

b. The electrons that make up an electric current travel at the speed of light.

c. The electric field inside a current-carrying wire has no effect on the motion of conduction electrons.

d. The random thermal motion of the electrons inside a wire is what produces current.

40. Is the following statement true or false? A pulsating electric field can travel through a circuit at nearly the speed of light. ______________

41. Explain why current-carrying wires become hot.

____

____

____

____

42. In a current-carrying wire, collisions interrupt the motion of the electrons so that their actual ______________, or net speed through the wire due to the field, is extremely low.

43. In an AC circuit, do the conduction electrons make any net progress in a single direction? Explain your answer.

____

____

34.10 The Source of Electrons in a Circuit (page 693)

44. The source of electrons in a circuit is the

____.

45. When you plug a lamp into an AC outlet, ______________ flows from the outlet into the lamp, not ______________.

46. If 120 volts AC are impressed on a lamp, then an average of ________ joules of energy are dissipated by each coulomb of charge that is made to vibrate.

47. When you turn on an electric lamp, what two forms of energy are produced? ______________

48. Explain what happens in your body when you are jolted by an AC electric shock.

____

____

____

34.11 Electric Power (pages 693–694)

49. Define electric power.

____

____

50. Electric power = current × ______________

51. Express the equation in Question 50 in terms of units.

____

52. One kilowatt-hour is the amount of energy consumed in ______________ hour at the rate of ______________ watts.

53. If the power and voltage on a lightbulb read "60 W, 120 V," how much current will flow through the bulb?

____

Name ______________________ Class ______________________ Date ______________

Calculating Power

If four 1.5-V batteries deliver 1.25-A current to a small motor, what is the power provided to the motor?

1. **Read and Understand**

   What information are you given?

   voltage = $V = 4 \times 1.5\text{ V} = 6.0\text{ V}$

   current = $I = 1.25\text{ A}$

2. **Plan and Solve**

   What unknown are you trying to calculate?

   power = P = ?

   What mathematical expression can you use to calculate the unknown?

   $P = VI$

   $P = (6.0\text{ V})(1.25\text{ A}) = 7.5\text{ W}$

3. **Look Back and Check**

   Is your answer reasonable?

   Yes, the number calculated is a product of current and voltage and the units indicate power.

Math Practice

On a separate sheet of paper, solve the following problems.

1. An 8.0-V power supply delivers a 1.75-A current to a circuit. Calculate the power provided to the circuit.

2. How much power is used by a set of lights operating on a 12-V battery and 2.75 A?

3. A 15-W motor draws a current of 1.25 A. What is the voltage impressed across the circuit?