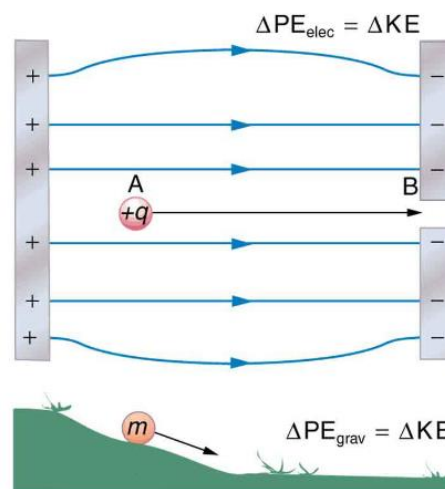


## Unit 10 Handout (current and Circuits)

### Notes - 19.1 Electric Potential Energy: Potential Difference

The diagram on the right presents an analogy comparing electric potential energy to gravitational potential energy. Gravitational and Electrostatic forces are both conservative (i.e. work done against them is not  $W_{nc}$ ), so total energy is conserved in both cases.



1. Where in the diagram would the positive charge have the greatest potential energy?
2. If the charge (+q) were released to travel from A to B, what would happen to its potential and kinetic energy?

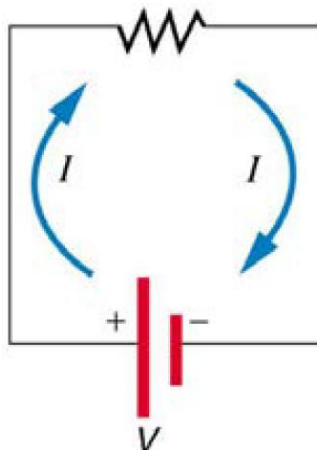
PE: \_\_\_\_\_ KE: \_\_\_\_\_

3. Just as electric field is a force per unit of charge, *Electric Potential* is electric potential energy per unit of charge. This is not the same as electric potential energy. At the same potential (e.g.  $2\text{J/C}$ ), a  $1\text{C}$  charge and a  $3\text{C}$  charge would have  $2\text{J}$  and  $6\text{J}$  of electrical potential energy, respectively.
4. *Voltage = Electrical Potential Difference*. This is the difference between the electrical potentials at two different points.
5. Units and symbols:

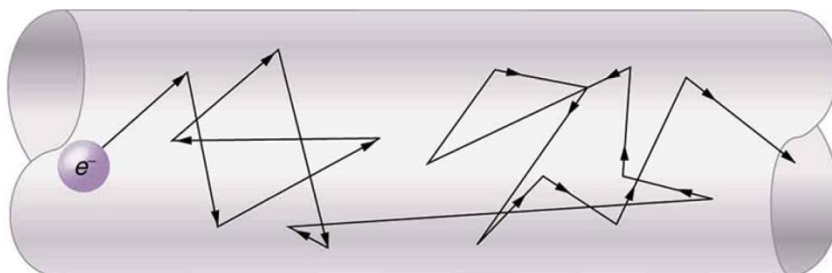
Quantity	Symbol	Formula	Units
Electrical Potential Energy			
Electrical Potential			
Voltage (Electrical Potential Difference)			

## Notes - 20.1 Current

1. Electric current is defined to be the rate at which \_\_\_\_\_ flows.
2. Write the equation for electric current.
3. The unit for electric current is \_\_\_\_\_.
4. 1 ampere = 1 \_\_\_\_\_ /second.
5. Example:
  - A. What is the current involved when a truck battery sets in motion 720 C of charge in 4.00 s while starting an engine? Show your work.
  
  
  
  
  
  
  
  
  
  
  - B. How long does it take 1.00 C of charge to flow through a handheld calculator if a 0.300-mA current is flowing? Show your work.
6. Label the terms and components in this circuit.



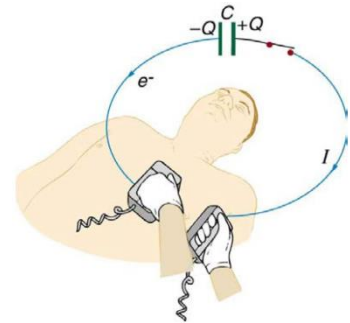
7. By convention, the direction of current flow is from \_\_\_\_\_ to \_\_\_\_\_. The direction of conventional current is the direction that \_\_\_\_\_ charge *would* flow.
8. In metal wires, current is carried by \_\_\_\_\_. So it is \_\_\_\_\_ charges that are moving, and they are moving oppositely to conventional current.
9. The fact that conventional current is taken to be in the direction that positive charge would flow can be traced back to American politician and scientist \_\_\_\_\_. He named the type of charge associated with electrons negative, long before they were known to carry current in so many situations. Franklin, in fact, was totally unaware of the small-scale structure of electricity.
10. It is important to realize that there is an \_\_\_\_\_ in conductors that is responsible for producing the current, unlike static electricity situations, where a conductor in equilibrium cannot have an electric field in it. Conductors carrying a current have an electric field and are not in static equilibrium. An electric field is needed to supply energy to move the charges.
11. If the 0.300-mA current through a wire is carried by electrons, how many electrons per second pass through it? Show your work.
12. Electrical signals are known to move very rapidly. Most electrical signals carried by currents travel at speeds on the order of \_\_\_\_\_ m/s, a significant fraction of the speed of light. However, the actual electrons move much more slowly on average, typically drifting at speeds on the order of \_\_\_\_\_ m/s. Another example of sending messages quickly through a slowly-moving medium is provided by \_\_\_\_\_
- 
13. Show the direction of the drift velocity  $v_d$ , electric field  $E$  and the current  $I$ .



## Practice - 20.1 Current

- Car batteries are rated in ampere-hours ( $A \cdot h$ ). To what physical quantity do ampere-hours correspond (voltage? Charge? Energy? . . .)?
- What is the current in milliamperes produced by the solar cells of a pocket calculator through which  $4.00\text{ C}$  of charge passes in  $4.00\text{ h}$ ?
- What is the current when a typical static charge of  $0.250\ \mu\text{C}$  moves from your finger to a metal doorknob in  $1.00\ \mu\text{s}$ ?
- A large lightning bolt had a  $20,000\text{-A}$  current and moved  $30.0\text{ C}$  of charge. What was its duration?

- A defibrillator passes  $12.0\text{ A}$  of current through the torso of a person for  $0.0100\text{ s}$ . How much charge moves?



- A clock battery wears out after moving  $10,000\text{ C}$  of charge through the clock at a rate of  $0.500\text{ mA}$ .

A. How long did the clock run?

B. How many electrons per second flowed?

**Solutions:**

- |                                   |  |                     |                                   |                     |
|-----------------------------------|--|---------------------|-----------------------------------|---------------------|
| 1. charge                         | 5. $0.278\text{ mA}$                         | 6. $0.250\text{ A}$ | 7. $1.50 \times 10^{-3}\text{ s}$ | 8. $0.120\text{ C}$ |
| 9. A. $2.00 \times 10^7\text{ s}$ | B. $3.13 \times 10^{15}\text{ e}^-/\text{s}$ |                     |                                   |                     |

## Notes - 20.2 Ohm's Law: Resistance and Simple Circuits

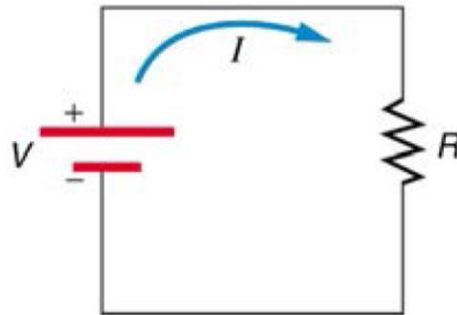
1. What drives current? We can think of various devices—such as batteries, generators, wall outlets, and so on—which are necessary to maintain a current. All such devices create a \_\_\_\_\_ difference and are loosely referred to as voltage sources. When a voltage source is connected to a conductor, it applies a potential difference  $V$  that creates an \_\_\_\_\_, which in turn exerts an \_\_\_\_\_ on the charges, causing a \_\_\_\_\_ to flow.

2. The current that flows through most substances is directly proportional to the \_\_\_\_\_ applied to it. This is known as \_\_\_\_\_ Law.



3. Write the equation for Ohm's Law:

4. The units for resistance are \_\_\_\_\_.



5. What is the resistance of an automobile headlight through which 2.50 A flows when 12.0 V is applied to it?

6. Resistances range over many orders of magnitude. Some ceramic insulators, such as those used to support power lines, have resistances of  $10^{12} \Omega$  or more. A dry person may have a hand-to-foot resistance of  $10^5 \Omega$ , whereas the resistance of the human heart is about  $10^3 \Omega$ . A meter-long piece of large-diameter copper wire may have a resistance of \_\_\_\_\_, and superconductors have \_\_\_\_\_ resistance at all.

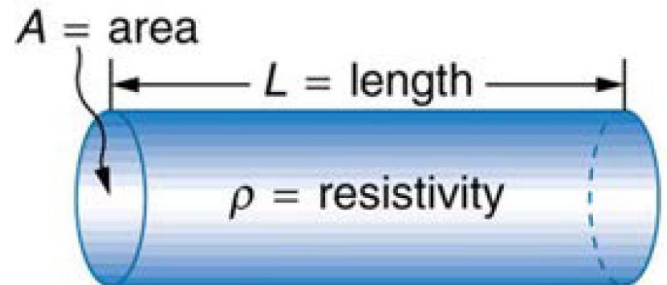
Notes: Chapter Sections 20.3, 20.4, and 21.1

Notes - 20.3 Resistance and Resistivity

1. The resistance of an object depends on its \_\_\_\_\_ and the \_\_\_\_\_ of which it is composed.

2.  $R =$

3. Resistivity  $\rho$  is an \_\_\_\_\_ of the material, independent of its shape or size.



4. In home wiring, currents are limited and minimum wire thicknesses are specified because, as current and resistance increase, more \_\_\_\_\_ is produced in the wires,

4.5 Example Problem: What is the resistance of a 20.0-m-long piece of 12-gauge copper wire having a 2.053-mm diameter? ( $\rho_{Cu} = 1.72 \times 10^{-8} \Omega \cdot m$ )

Notes - 20.4 Electric Power and Energy

5. Power (P) is the \_\_\_\_\_ of energy use or energy conversion.

6. Voltage (electric potential) can be expressed as J/C, and Current (Amperes) can be expressed as C/s. Therefore,  $P =$  \_\_\_\_\_

7. The unit for power is \_\_\_\_\_.

8.  $1 \text{ W} = 1$  \_\_\_\_\_

10. Power companies do not charge for power, they charge for \_\_\_\_\_, which is sold to you in units called kilowatt-hours.  $1 \text{ kWh} =$  \_\_\_\_\_ J.



16. Suppose the voltage output of a battery is 12.0 V, and the resistances for 2 resistors connected in **parallel** with the battery are  $R_1 = 2.00 \Omega$  and  $R_2 = 4 \Omega$ .

A. Draw a diagram of the circuit. What makes it a **parallel** circuit?

B. What is the total resistance? What's the rule for equivalent resistance in a parallel circuit?

C. Find the current. What's the rule for individual and overall currents in a parallel circuit?

D. Calculate the voltage drop in each resistor. What's the rule for individual and overall currents in a parallel circuit?

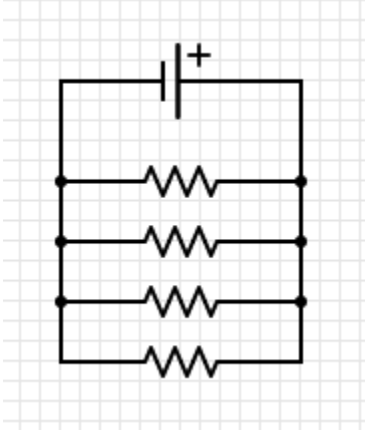
E. Calculate the power dissipated by each resistor. What's the rule for power consumed by individual resistors, and overall, in a parallel circuit?



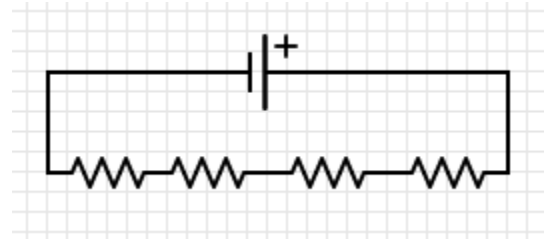
## Circuit Reduction – The Nine Companions

Assume each resistor has a value of 10 Ohms. Find the equivalent resistance of each circuit. Use the space provided to do circuit reductions as necessary.

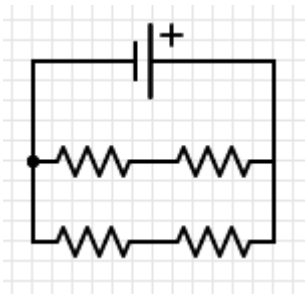
1.



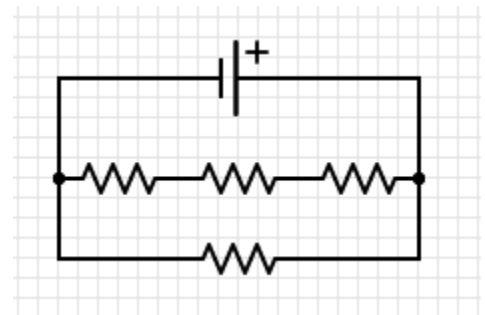
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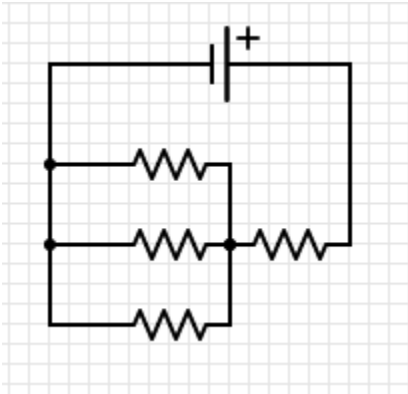
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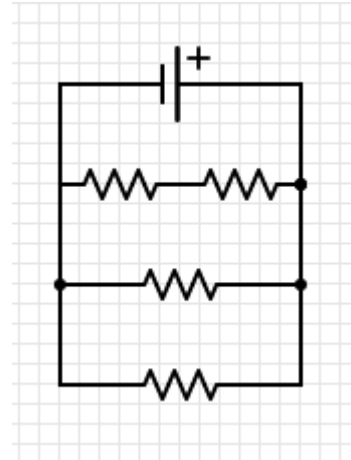
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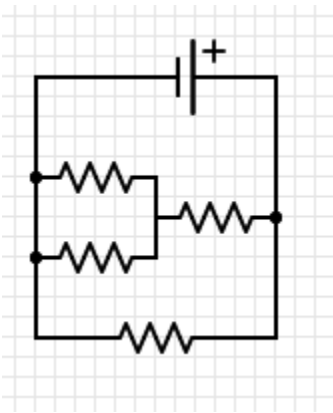
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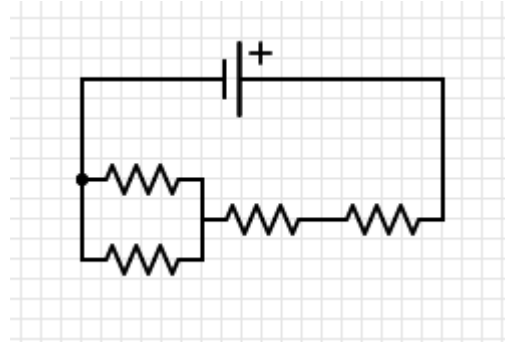
6.



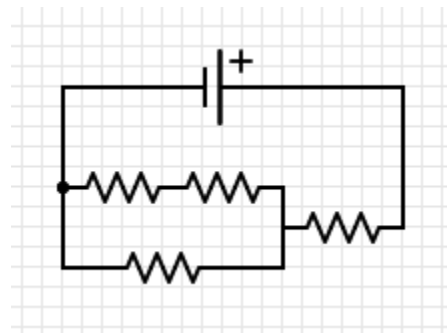
7.



8.



9.

Answers:

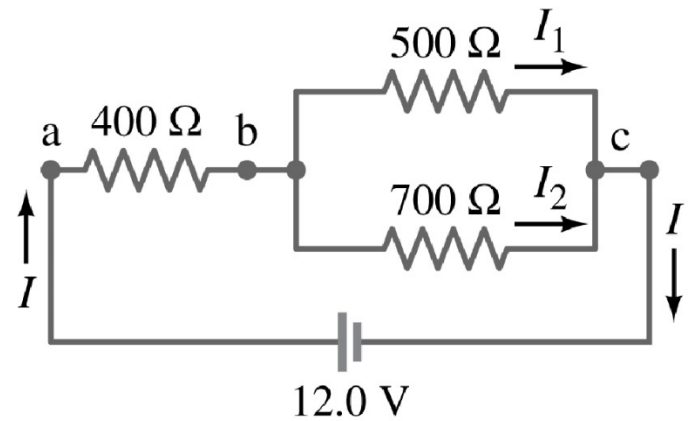
- |                  |                |                |                 |
|------------------|----------------|----------------|-----------------|
| 1. $2.5 \Omega$  | 2. $40 \Omega$ | 3. $10 \Omega$ | 4. $7.5 \Omega$ |
| 5. $13.3 \Omega$ | 6. $4 \Omega$  | 7. $6 \Omega$  | 8. $25 \Omega$  |
| 9. $16.7 \Omega$ |                |                |                 |

Name: \_\_\_\_\_

## Physics 200 (Stapleton) Chapter 21 Equivalent Resistance Challenge

Problem 1

A. Find the equivalent resistance of this circuit.



B. Find the current passing through the battery.

C. 400 Ω Resistor

i. Find V

ii. Find I

iii. Find P

D. 500 Ω Resistor

i. Find V

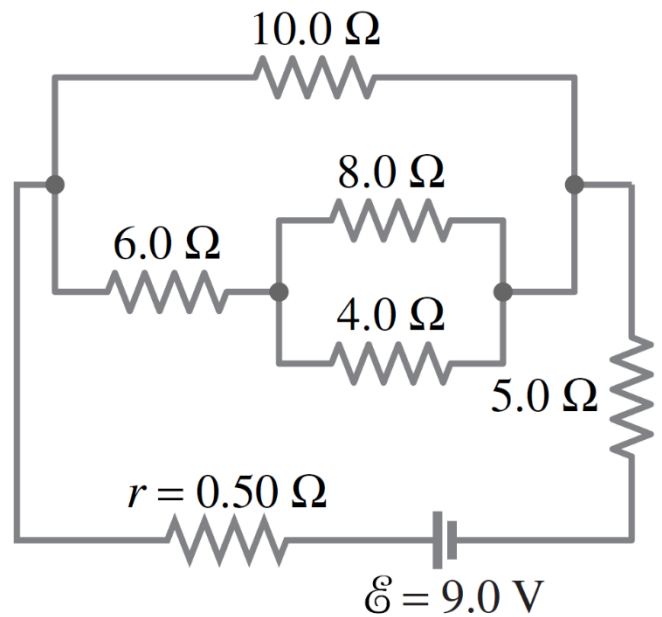
ii. Find I

iii. Find P

Problem 2

A. Find the equivalent resistance of this circuit.

B. Find the current passing through the battery.



C.  $10.0 \Omega$  Resistor

i. Find V

ii. Find I

iii. Find P

D.  $4.0 \Omega$  Resistor

i. Find V

ii. Find I

iii. Find P

Solutions:

Prob 1: A.  $692 \Omega$     B.  $0.0173 \text{ A}$     C.i.  $6.94 \text{ V}$     ii.  $0.0173 \text{ A}$     iii.  $0.120 \text{ W}$     D.i.  $5.06 \text{ V}$     ii.  $0.0101 \text{ A}$     iii.  $0.0512 \text{ W}$

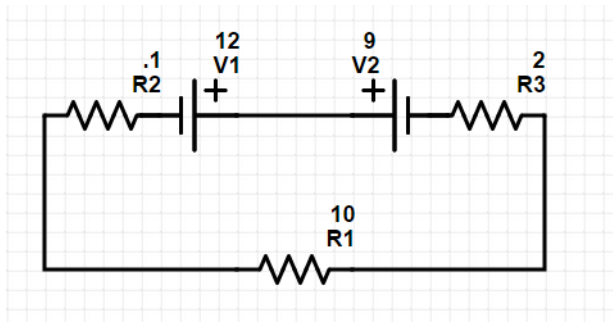
Prob 2: A.  $10.1 \Omega$     B.  $0.887 \text{ A}$     C.i.  $4.12 \text{ V}$     ii.  $0.412 \text{ A}$     iii.  $1.70 \text{ W}$     D.i.  $1.27 \text{ V}$     ii.  $0.317 \text{ A}$     iii.  $0.402 \text{ W}$

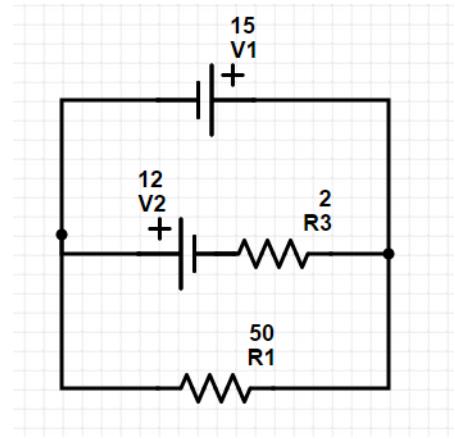
## KIRCHHOFF'S RULES

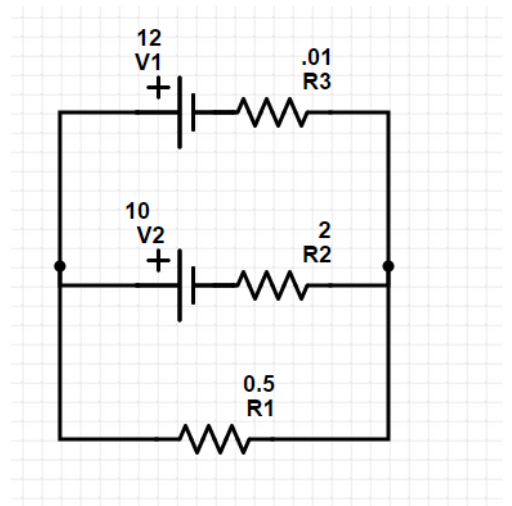
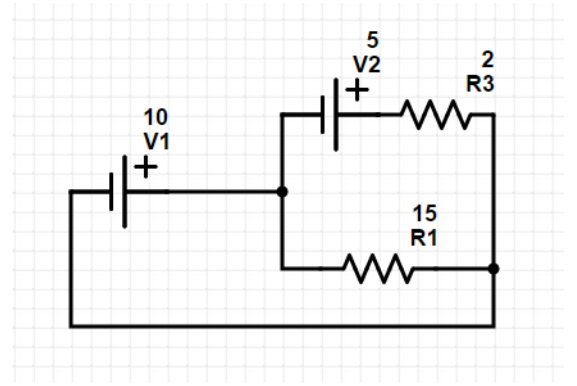
- Kirchoff's first rule—the junction rule. The sum of all currents entering a junction must equal the sum of all currents leaving the junction.
- Kirchoff's second rule—the loop rule. The algebraic sum of changes in potential around any closed circuit path (loop) must be zero.

1. When applying Kirchoff's first rule, the junction rule, you must label the current in each branch and decide in what direction it is going. For example, in [Figure](#), [Figure](#), and [Figure](#), currents are labeled  $I_1$ ,  $I_2$ ,  $I_3$ , and  $I$ , and arrows indicate their directions. There is no risk here, for if you choose the wrong direction, the current will be of the correct magnitude but negative.
  2. When applying Kirchoff's second rule, the loop rule, you must identify a closed loop and decide in which direction to go around it, clockwise or counterclockwise. For example, in [Figure](#) the loop was traversed in the same direction as the current (clockwise). Again, there is no risk; going around the circuit in the opposite direction reverses the sign of every term in the equation, which is like multiplying both sides of the equation by  $-1$ .
- When a resistor is traversed in the same direction as the current, the change in potential is  $-IR$ . (See [Figure](#).)
  - When a resistor is traversed in the direction opposite to the current, the change in potential is  $+IR$ . (See [Figure](#).)
  - When an emf is traversed from  $-$  to  $+$  (the same direction it moves positive charge), the change in potential is  $+\text{emf}$ . (See [Figure](#).)
  - When an emf is traversed from  $+$  to  $-$  (opposite to the direction it moves positive charge), the change in potential is  $-\text{emf}$ . (See [Figure](#).)

**Kirchoff's Laws #1. Find the correct current in each branch of each circuit.**







Name: \_\_\_\_\_

**Chapters 20-21 Practice Test 2016-2017**

**(\*\*\* The actual test will also have at least one problem requiring Kirchoff's Rules.)**

**I. Matching:**

A. Match each SI unit with the correct electrical parameter.

- |                  |                         |
|------------------|-------------------------|
| 1. kilowatt-hour | A. current              |
| 2. volt          | B. potential difference |
| 3. ohm           | C. power                |
| 4. watt          | D. resistance           |
|                  | E. energy               |

B. Match each SI unit with the correct electrical parameter.

- |                      |                   |
|----------------------|-------------------|
| 5. ampere            | A. resistivity    |
| 6. coulomb           | B. drift velocity |
| 7. ohm-meter         | C. resistance     |
| 8. meters per second | D. current        |
|                      | E. charge         |

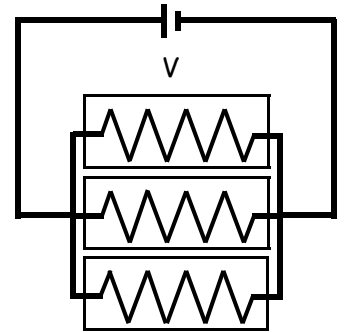
**II. Multiple Choice:** Select the one best answer for each question.

9. In a circuit, the indicated direction of the current is in the
- A. same direction as the net electron flow.
  - B. direction from the negative battery terminal to the positive battery terminal.
  - C. opposite direction as the net electron flow.
  - D. is in the same direction that protons are moving through the wire.
10. If the potential difference across a resistor is doubled,
- A. only the current is doubled.
  - B. only the current is halved.
  - C. only the resistance is doubled.
  - D. only the resistance is halved.
  - E. both the current and resistance are doubled.



11. Three identical light bulbs are connected to a battery. What will happen if the top bulb burns out?

- A. All the bulbs will go out.
- B. The light intensity of the other two bulbs will decrease (but they won't go out).
- C. The light intensity of the other two bulbs will increase.
- D. The light intensity of the other two bulbs will remain the same.
- E. More current will be drawn from the battery.



12. Which of the following appliances consumes the most power when operating?

- A. Appliance #1: 120 V      1.0 A
- B. Appliance #2: 240 V      0.5 A
- C. Appliance #3: 240 V      2.0 A
- D. Appliance #4: 120 V      3.0 A

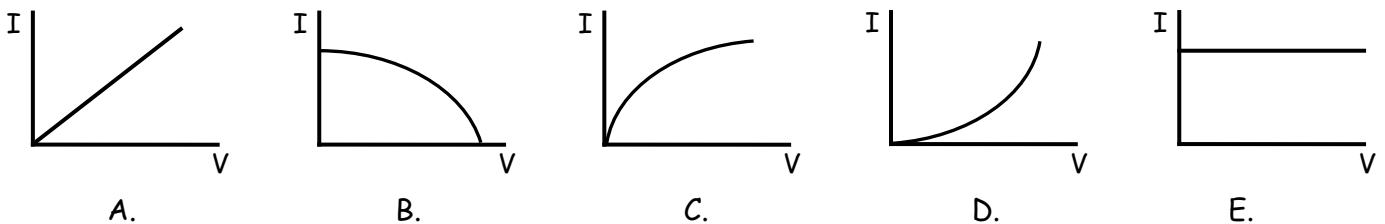
13. To measure the potential difference across a resistor, a voltmeter is connected in \_\_\_\_\_ because it has the \_\_\_\_\_.

- A. series, same current flowing through it as the resistor
- B. series, same potential difference across it as the resistor
- C. parallel, same current flowing through it as the resistor
- D. parallel, same potential difference across it as the resistor

14. Which of these equations is Ohm's Law?

- A.  $V = IR$
- B.  $I = VR$
- C.  $R = IV$
- D.  $P = IV$

15. Which graph represents the current through a resistor that obeys Ohm's Law?



16. The resistivity of a conductor depends upon:

- A. the length of the conductor.
- B. only on the specific material of the conductor.
- C. the cross-sectional area of the conductor.
- D. the current flowing through the conductor.

17. Current is a measure of:
- force that moves a charge past a point
  - resistance to the movement of a charge past a point
  - energy used to move a charge past a point
  - amount of charge that moves past a point per unit time
  - speed with which a charge moves past a point
18. In a simple circuit consisting of a battery and a resistor, if the resistance of the resistor increases, the current through the resistor will:
- increase
  - decrease
  - stay the same
19. If a circuit consists of a battery and two resistors connected in parallel with the battery and a third identical resistor is added in parallel, the current in the two initial resistors will:
- increase
  - decrease
  - stay the same
20. If a circuit consists of a battery and two resistors connected in series to each other and a third identical resistor is added in series, the current in the circuit will:
- increase
  - decrease
  - stay the same
21. In a string of holiday lights, when one bulb burns out the rest of the bulbs stay lit, the bulbs must be connected in
- series
  - parallel

**III. Problems:** Answers all of these problems on a separate sheet of paper. Your answers should flow from top to bottom. Do not skip around or place answers horizontally next to previous work. Show your work. Circle or box your answer. Answers must have the correct number of significant figures and the correct units.

**5 points each:**

**Starting equation: 1 point**

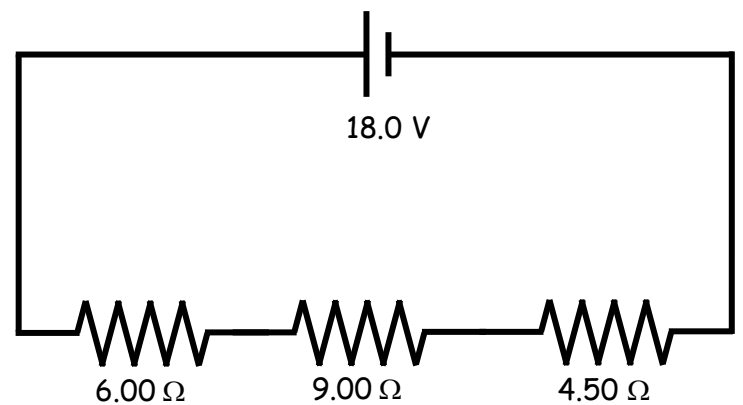
**Work and correct answer: 3.5 points**

**Boxed answer: 0.5 points**

1. You have a 15.0-m-long piece of 14-gauge copper wire having a radius of 0.814 mm? ( $\rho_{Cu} = 1.67 \times 10^{-8} \Omega \cdot m$ )
- What is the resistance of this wire?
  - How much current will flow through the wire if there is a 12.0 V potential difference between the ends (i.e. if it is hooked up to a 12.0 V battery)?

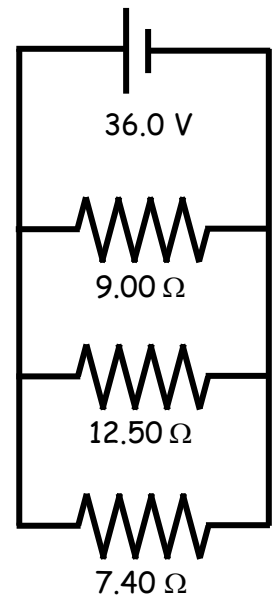
2. A clock battery wears out after moving  $2.40 \times 10^4 \text{ C}$  of charge through the clock with an average current of  $0.330 \text{ mA}$ .
- How long did the clock run?
  - How many electrons per second on average flowed through the clock?

3. A. Calculate the total equivalent resistance of this circuit.
- B. Calculate the current flowing through this circuit.



4. How much does it cost to run a  $200.0 \text{ watt}$  floodlight  $13.00 \text{ hours}$  a day for  $30.00 \text{ days}$  if the local electric company charges  $14.00 \text{ cents}$  per kilowatt-hour?

5. A. Calculate the total equivalent resistance of this circuit.  
 B. Calculate the total current flowing through this circuit.  
 C. Calculate the current flowing through the  $7.40\text{-}\Omega$  resistor.  
 D. Calculate the power dissipated as heat through the  $7.40\text{-}\Omega$  resistor.



6. A. Calculate the total equivalent resistance of this circuit.  
 B. Calculate the total current flowing through this circuit.  
 C. Calculate the potential difference across the  $5.30\text{-}\Omega$  resistor.  
 D. Calculate the current flowing through the  $24.0\text{-}\Omega$  resistor.  
 E. Calculate the total power dissipated as heat in this circuit.

