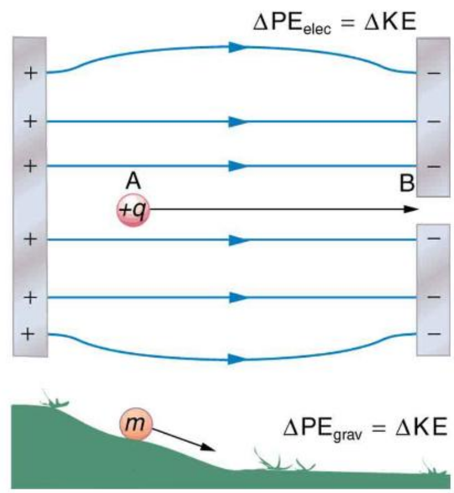
Physics 200 Name: ___________________

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 would ________________. KE would __________________.

3. Whereas electric field is a ratio of *Electric force* per unit of charge, *Electric Potential* is a ratio of *electric potential energy* per unit of charge. This is not the same as electric potential energy. For example, at the same *potential* of 2J/C, a 1C charge would have 2J of electrical potential energy, and a 3C charge would have 6J.

4. *Voltage = Difference in Electrical Potential.* 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 (Difference in Electrical Potential)			

Notes – 20.1 Current

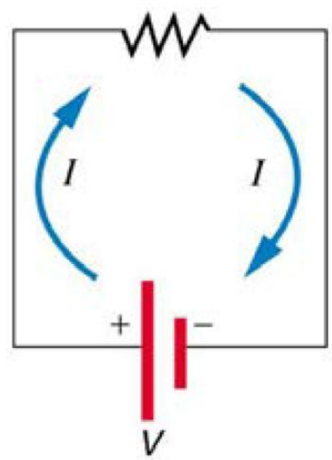
1. Electric current is defined to be the rate at which ___________ flows.

2. Write the equation for electric current.

3. The symbol for electric current is _____, and the unit is __________________.

4. 1 ampere = 1 _______________ /second.

5. Label the terms and components in this circuit.



6. By convention, the direction of current flow is from _____________ to _____________. The direction of conventional current is the direction that _____________ charge *would* flow.

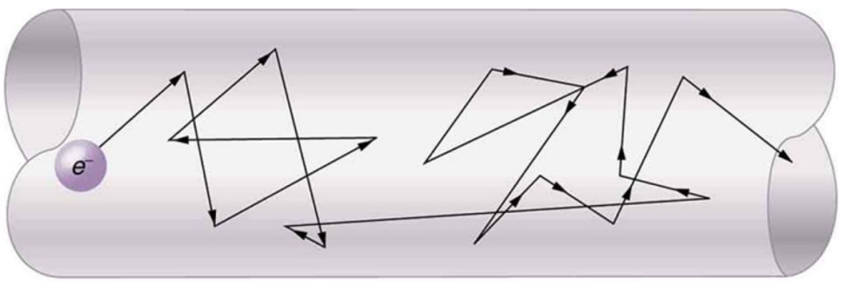
7. In metal wires, current is carried by _____________. So it is _____________ charges that are moving, and they are moving oppositely to conventional current.

8. 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.

9. 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.

10. 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, across great distances, through a slowly-moving medium is provided by ____

11. Show the direction of the drift velocity v_d, electric field E and the current I.



Notes – 20.2 Ohm's Law: Resistance and Simple Circuits

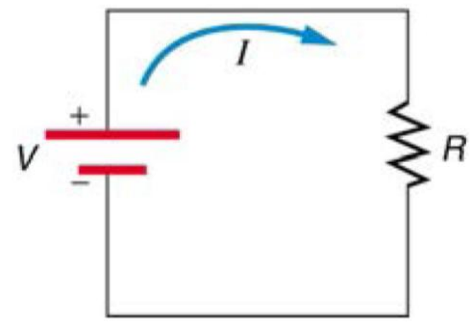
1. What drives current? We can think of various devices—such as batteries, generators, wall outlets, and so on—which are necessary to maintain a current. All such devices create a ____________________ difference and are loosely referred to as voltage sources. When a voltage source is connected to a conductor,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

2. The current that flows through most substances is directly proportional to the ____________________ applied to it and inversely proportional to the sutbstance's ***resistance***. This is known as ____________ Law.

3. Write the equation for Ohm's Law:

4. The slope of a line plotted on the graph to the right is

   ________________.



5. The unit for resistance is the _______________ and a common symbol in circuit diagrams is the squiggly line.

6. If you apply a voltage of 12.0 V to a light bulb, and this causes 2.5A to flow through the bulb, what is the bulb's resistance?

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

Notes – 20.4 Electric Power and Energy

1. Power (P) is the _______________ of energy use or energy conversion.

2. Voltage (electric potential) can be expressed as J/C, and Current (Amperes) can be

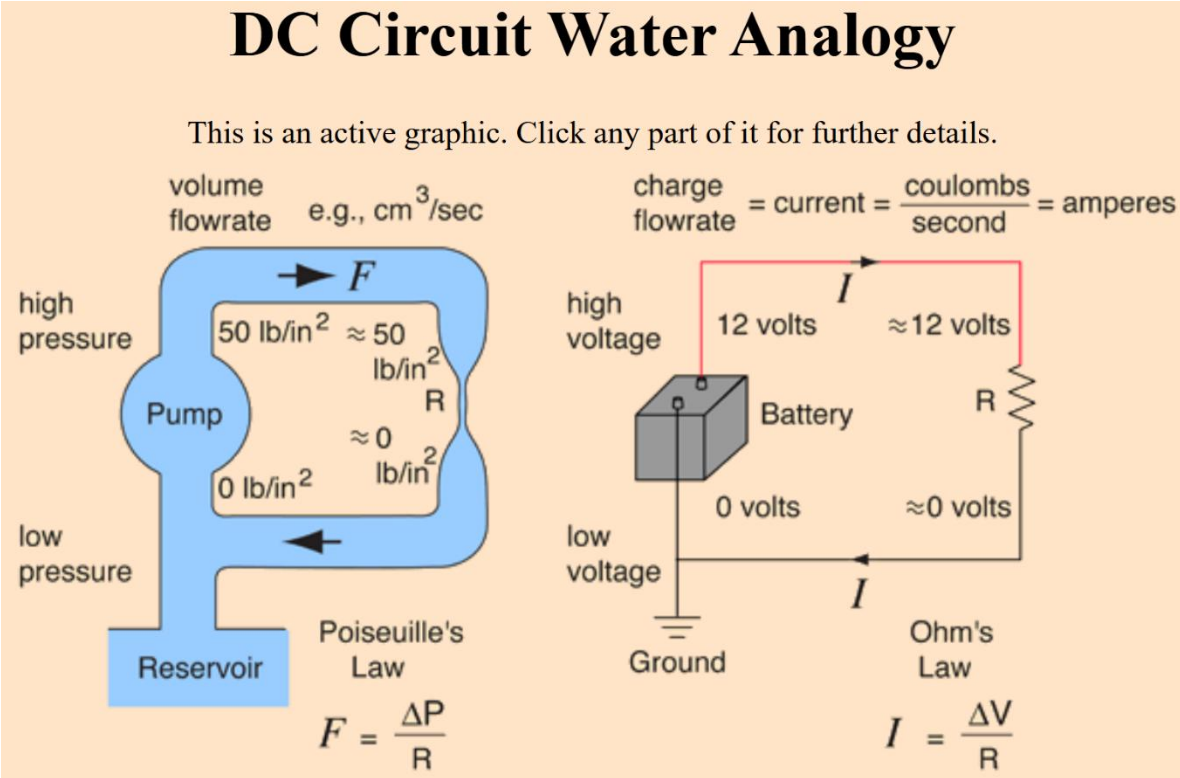
   expressed as C/s. Therefore, P= _______

3. The unit for power is the __________________.

4. 1 W = 1 _______________

5. Power companies do not charge for power, they charge for ______________, which is sold to you in units called kilowatt-hours. 1kWh = ____________J.

Two Analogies for Understanding Circuits (neither is perfect):



Electric Circuits as Distribution Networks

Amazon Distribution Network Component(s)	**Electricity Analog**	**Variables**	Units
Packages	**Energy**	**E**	Joules (J)
		Q	Coulombs (C)
		V	Volts (V)
		I	Amperes (A)
		P	Watts (W)
		R	Ohms (Ω)

Notes – 21.1 Resistors in Series and Parallel

1. Suppose the voltage output of a battery is 12.0 V, and the resistances for 2 resistors connected in **series** 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 ***series*** circuit?

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

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

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

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

2. 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 Ω and R_2 = 4 Ω.

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

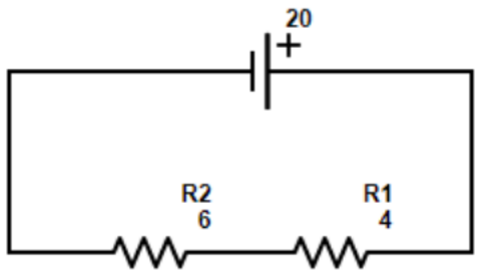
B. What is the total resistance? What's the rule for equivalent resistance in a parallel circuit?

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

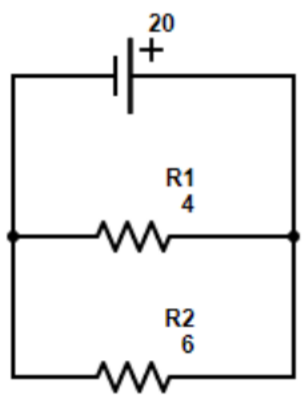
D. Calculate the voltage drop in each resistor. What's the rule for individual and overall currents in a parallel circuit?

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

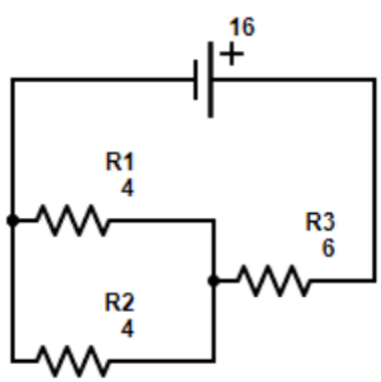
Circuit Reduction and Expansion



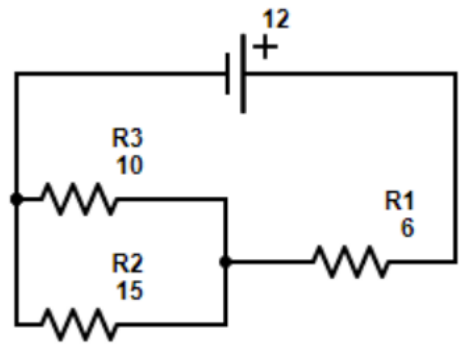
	V	I	R	P
Source	20			
R_1			4	
R_2			6	



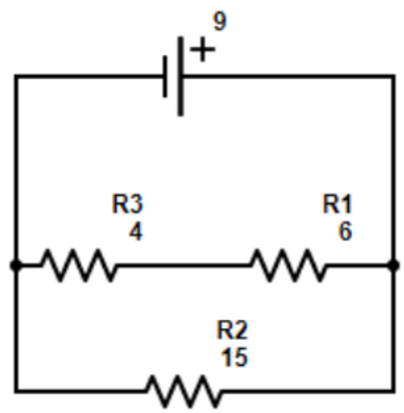
	V	I	R	P
Source	20			
R_1			4	
R_2			6	



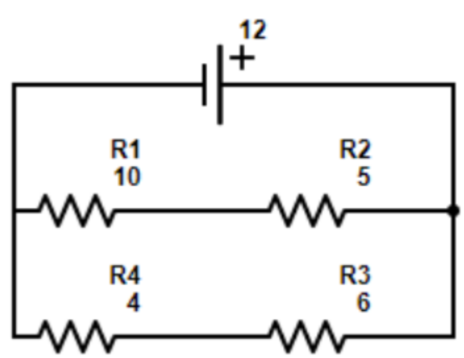
	V	I	R	P
Source	16			
R_1			4	
R_2			4	
R_3			6	



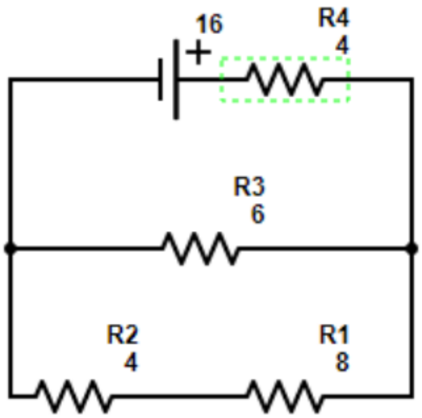
	V	I	R	P
Source	12			
R_1			6	
R_2			15	
R_3			10	



	V	I	R	P
Source	9			
R_1			6	
R_2			15	
R_3			4	



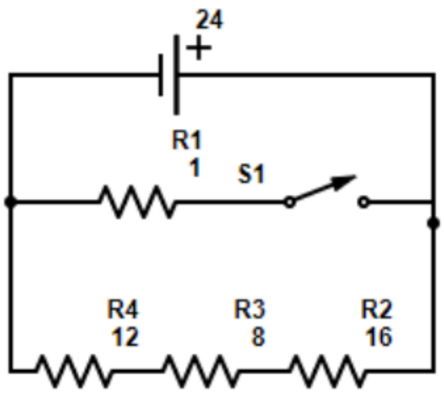
	V	I	R	P
Source	12			
R_1			10	
R_2			5	
R_3			6	
R_4			4	



	V	I	R	P
Source	16			
R_1			8	
R_2			4	
R_3			6	
R_4			4	

S1 is Open

	V	I	R	P
Source	24			
R_1			1	
R_2			16	
R_3			8	
R_4			12	

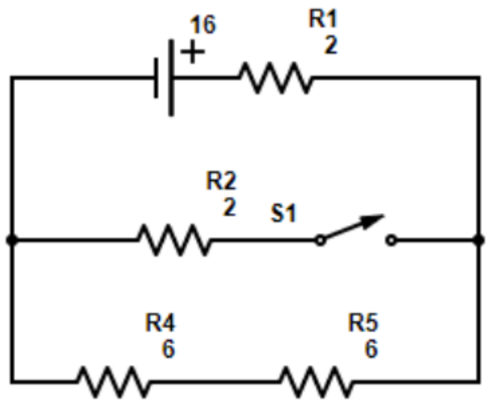


S1 is Closed

	V	I	R	P
Source	24			
R_1			1	
R_2			16	
R_3			8	
R_4			12	

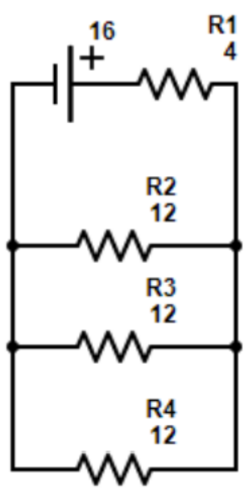
S1 is Open

	V	I	R	P
Source	16			
R_1			2	
R_2			2	
R_3			6	
R_4			6	

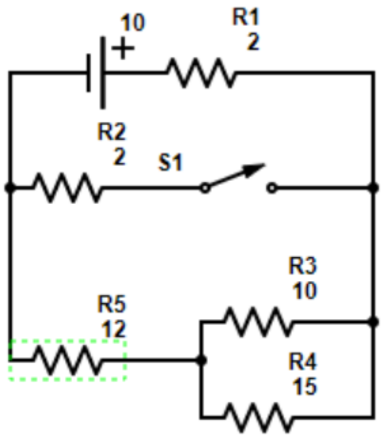


S1 is Closed

	V	I	R	P
Source	16			
R_1			2	
R_2			2	
R_3			6	
R_4			6	



	V	I	R	P
Source	16			
R_1			4	
R_2			12	
R_3			12	
R_4			12	

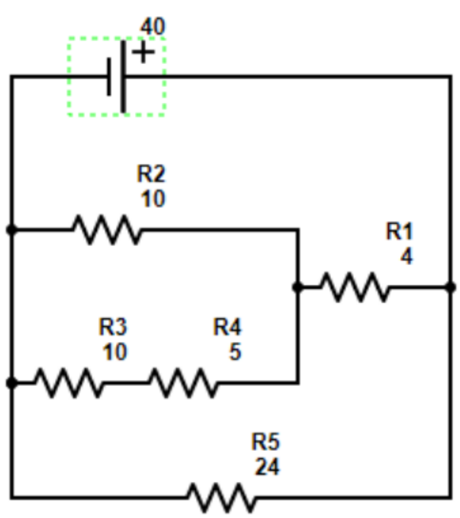


S1 is Open

	V	I	R	P
Source	10			
R_1			2	
R_2			2	
R_3			10	
R_4			15	
R_5			12	

S1 is Closed

	V	I	R	P
Source	10			
R_1			2	
R_2			2	
R_3			10	
R_4			15	
R_5			12	



	V	I	R	P
Source	40			
R_1			4	
R_2			10	
R_3			10	
R_4			5	
R_5			24	

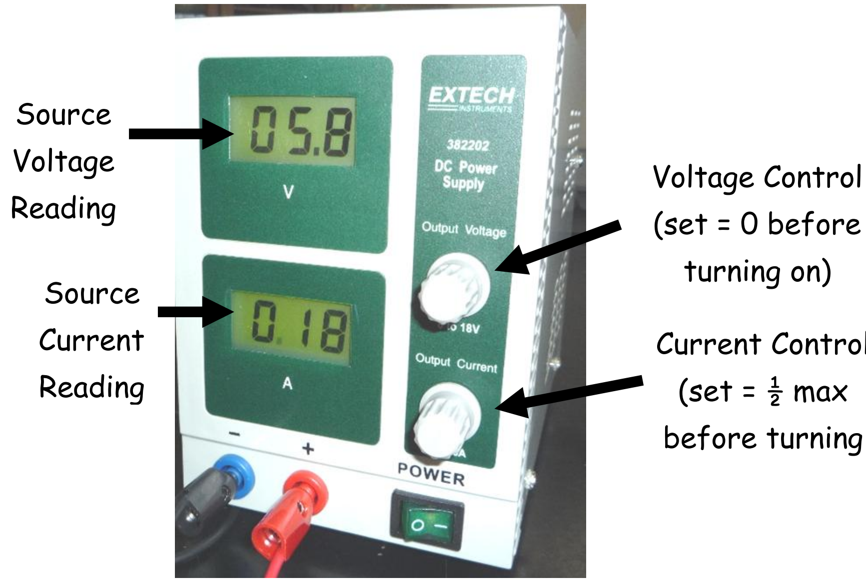
<u>Using the Power Supply:</u>

<u>Step 1:</u> Set Voltage to Zero

<u>Step 2:</u> Set current to ½ of maximum.

<u>Step 3:</u> Turn on power supply. <u>Keep voltage at or below 6V – keep an eye on changes!</u>

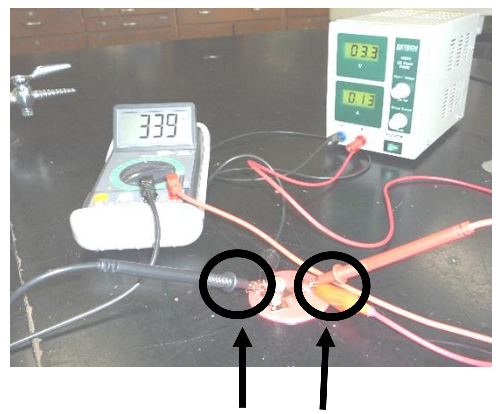
Measuring Source Voltage and Current: See Power Supply Readout



<u>Using the Multimeter for Individual Voltage Drops and continuity:</u>

Set the Digital Multimeter (DMM) to measure DC **voltage** (solid line over dotted line). To measure voltage drop across a resistor (bulb), touch the two probes to each terminal on the bulb holder. This measures the potential difference between the two sides of the bulb. Adjust the meter range until you get a reasonable reading (or ask the teacher what range has been working).

<u>Do NOT use the DMM to measure current</u>! You can use the voltage source for finding total current. You must infer the current through each resistor (bulb).



Measure Voltage Drop by touching the two probes of the voltmeter to each terminal of the bulb holder.

<u>Use the Continuity Tester (sound wave symbol)</u> to check for burned out bulbs or broken alligator clip wires. If it beeps, there is continuity (a continuous conductor between the two points), which means the bulb or wire *should* work.

<u>Important reminders about real vs theoretical circuits:</u>

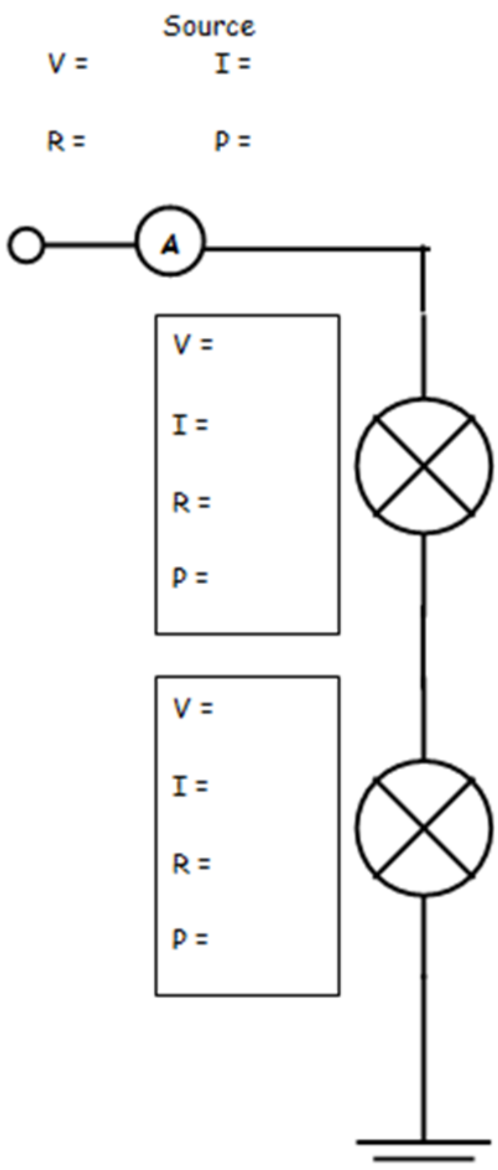
1. Real wires have resistance. This means they will take a little bit of the power (I^2R) and a little bit of the voltage drop (in series). Since $R = \rho L/A$, longer wires have more resistance. So, if your calculations are a little bit off, this may be why.

2. Incandescent bulbs are non-ohmic. This means their resistances vary depending on the amount of voltage they receive. So, when you are collecting data, keep the voltage constant! **One trick for determining a bulb's resistance at a particular voltage is to create a simple circuit with just that bulb, and adjust the voltage to the voltage in question. Then read the current from the power source.**

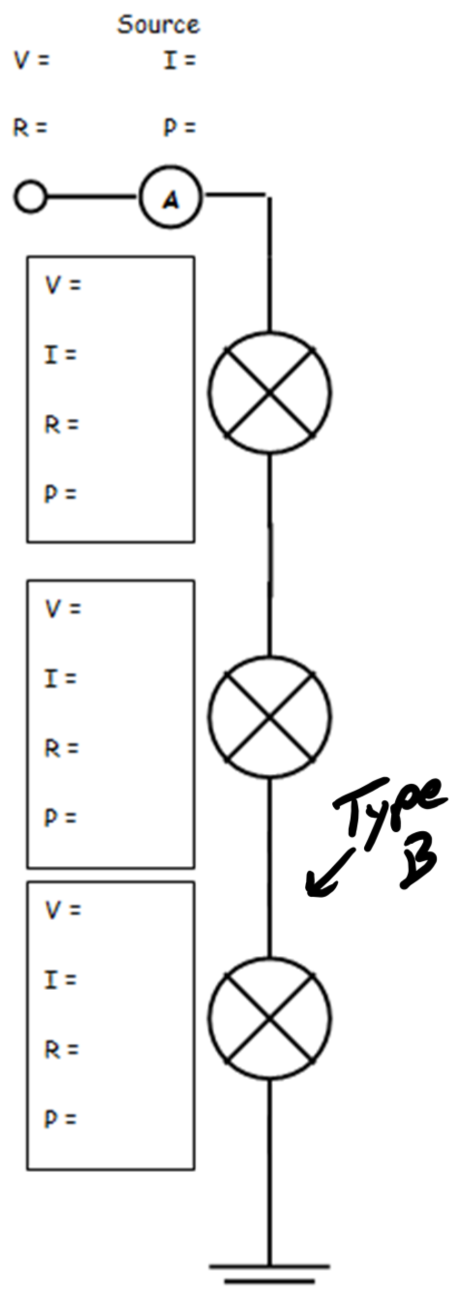
Directions: Build a circuit. Use the power source readout to determine the source current and voltage drop [**keep it at 6V or less]. Next use a multimeter to determine the voltage drop across each bulb (X symbol). Use your circuit knowledge to find the rest of the information.

About The Circuit Diagrams: The small circle at the top left end of the circuit represents the red (positive) terminal of the power source. Each X represents a bulb (resistor). The ground symbols (three dashes of diminishing length) represent connections to the black (negative) terminal on the power source. The "A" represents the presence of the internal ammeter that is built into the power source. "Type B" means you are supposed to use a different type of bulb (compared to the other bulbs) in this position.

#1.



#2.

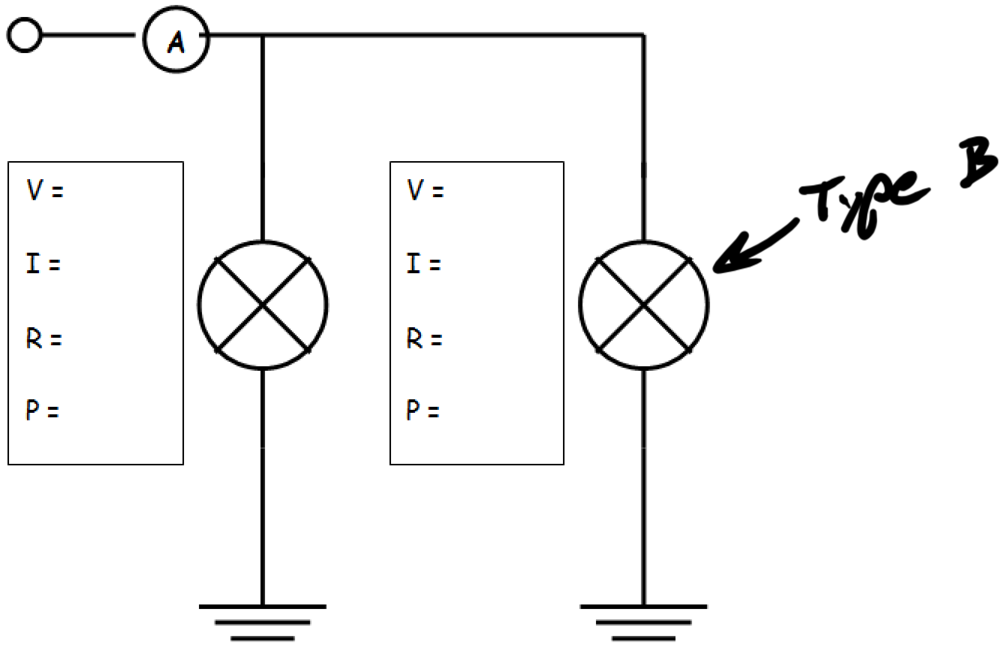


#3.

Source

V = I =

R = P =

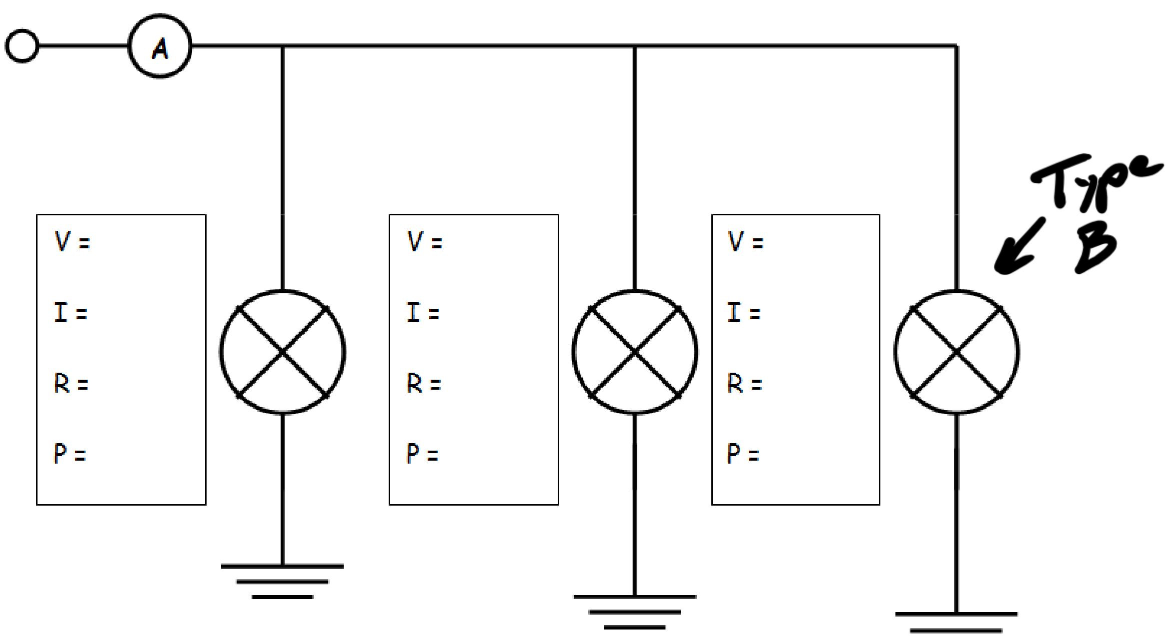


#4.

Source

V = I =

R = P =



Challenge Page: Try it if you think the other pages were easy.

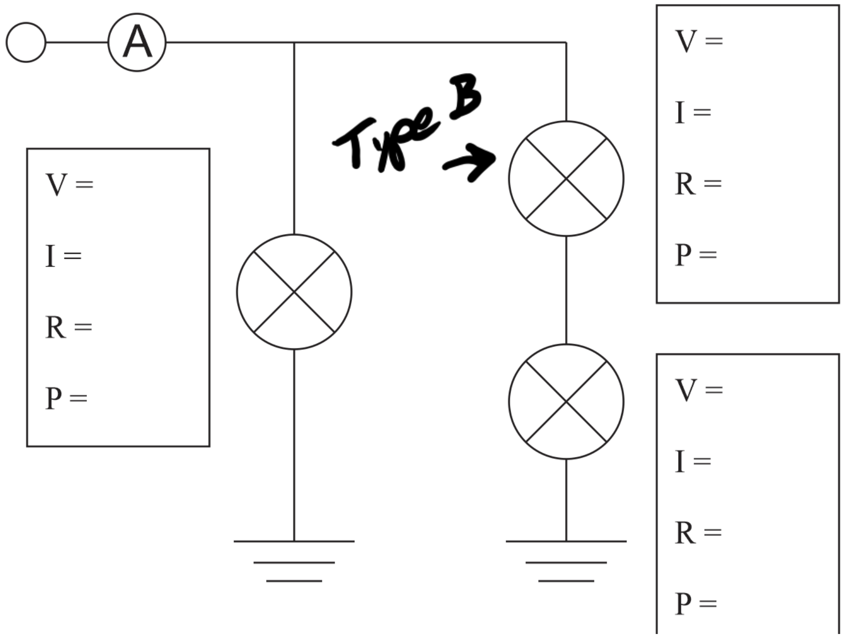
#5.

Name:

Source

V = I =

R = P =



#6.

Source

V = I =

R = P =