AP Physics 1 Ch 20 Notes Name ___________________

Holt Physics Chapter 20 -- Circuits and Circuit Elements

Schematic Diagrams and Circuits

A Schematic Diagram is a graphic representation of an electric circuit, with standardized symbols representing circuit components.

→ Reading schematic diagrams is necessary to determine how the parts in an electrical device are arranged.

Electric Circuits

An Electric Circuit is a set of electrical components connected so that they provide one or more complete paths for the movement of charges.

→ Charges built up on one terminal of the battery have a path to follow to reach the opposite charges on the other terminal. Because there are charges moving uniformly, a current exists. Together, the bulb, battery, switch, and wire form an **electric circuit.**

→Actual current is electrons moving from negative terminal to positive terminal.

Standard Electrical Symbols	
Wire or Conductor – Wires connect elements are conductors	
Resistor or Circuit Load – Resistors are shown as wires with multiple bends, illustrating resistance to the movement of charges.	
Bulb or Lamp – The multiple bends of the filament indicate that the light bulb is a resistor.	
Battery – Differences in line height indicate a potential difference between + and – terminals of the battery.	
Switch – The small circles indicate the two places where the switch makes contact with the wires. Most switches work by breaking only one of the contacts, NOT both.	
Capacitor – The two parallel plates of a capacitor are symbolized by two parallel lines of equal height.	

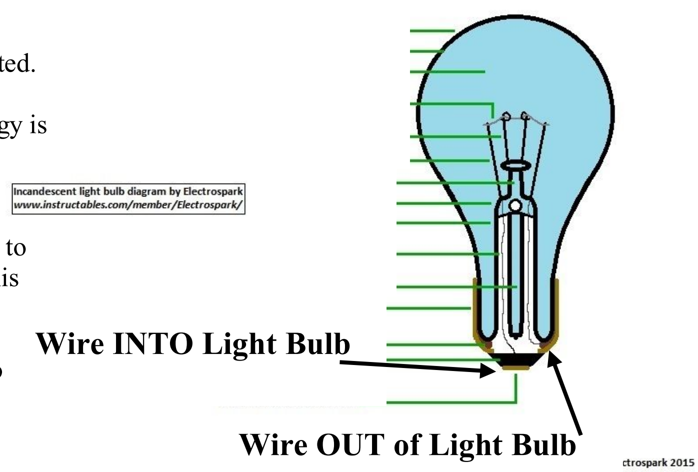
→ Conventional current (Ben Franklin) is positive charges flowing from the Positive terminal of the battery to the negative terminal of the battery. The charges flow from High electric potential (Voltage) to Low electric potential. **CHARGES are conserved!**

→ An electric circuit is a path through which charges can be conducted.

→ Any element or group of elements in a circuit that dissipates energy is called a **load.**

→ If the path from one battery terminal to the other is complete, a potential difference exists, and electrons move from one terminal to the other. There is a closed-loop path for electrons to follow. This called a ***closed circuit***.

→ Without a complete path, there is no charge flow and therefore no current. This situation is an ***open circuit***.



Light bulbs contain a complete conducting path

→ The bulb socket reveals that it has two contacts inside. One contact, in the bottom of the socket, is connected to the wire going to one connected to the wire going to the other side of the filament.

Short circuits can be hazardous

→ Without a load, such as a bulb or other resistor, the circuit contains little resistance to the movement of charges. This situation is called a ***short circuit***.

Potential difference across a load (resistor or light bulb) equals the current through the element times the resistance. V = I*R

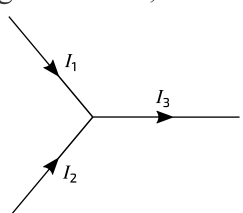
REALLY REALLY IMPORTANT TO FIGURING OUT CIRCUITS

> ***Kirchhoff's laws*** *are fundamental to circuit theory. They quantify how current flows through a circuit and how voltage varies around a loop in a circuit. Kirchhoff's current law (1st Law) states that current flowing into a node (or a junction) must be equal to current flowing out of it. This is a consequence of charge conservation. Kirchhoff's voltage law (2nd Law) states that the sum of all voltages around any closed loop in a circuit must equal zero. This is a consequence of charge conservation and also conservation of energy.*
> *https://isaacphysics.org/concepts/cp_kirchhoffs_laws*

Current flow in circuits is produced when charge carriers travel though conductors. Current is defined as the rate at which this charge is carried through the circuit. A fundamental concept in physics is that charge will always be conserved. In the context of circuits this means that, since current is the rate of flow of charge, the current flowing into a point must be the same as current flowing out of that point.

Kirchhoff's 1st Law – Current Law

Three wires connected at a node with different currents travelling down each wire. Kirchhoff's current law states that for the diagram below, the currents in the three wires must be related by:

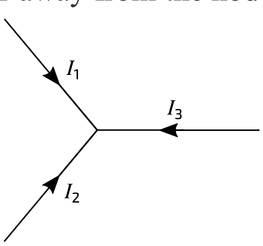


$$I_{in} = I_{out}$$

$$I_1 + I_2 = I_3$$

It is important to note what is meant by the signs of the current in the diagram - a positive current means that the currents are flowing in the directions indicated on the diagram.

The standard way of displaying Kirchhoff's current law is by having all currents either flowing towards or away from the node, as shown below:



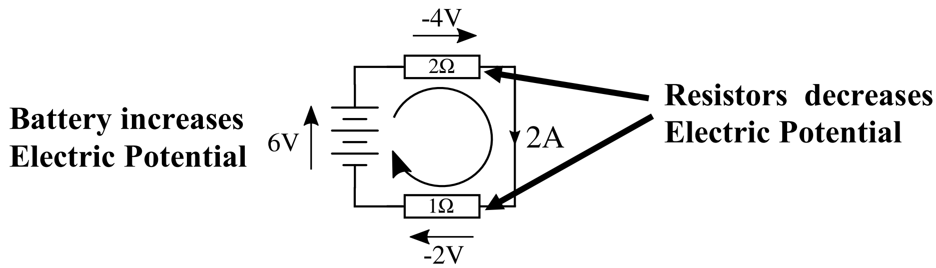
Here, at least one of the currents will have to be negative (i.e, away from the node and in the opposite direction to the arrows on this diagram) and Kirchhoff's current law can be written as:

$$I_1 + I_2 + I_3 = 0$$

Kirchhoff's 2nd Law – Voltage Law

As charge carriers flowing through a circuit pass through a component, they either gain or lose electrical energy, depending upon the component (battery or resistor for example). Microscopically, this is due to the fact that work is done on them by the electric forces inside the circuit components. The negative of the work done by these electric forces on a unit of charge which passes through a component is called the **potential difference**, or **voltage**, across the component. The work done by the electric forces around any closed loop in the circuit must be zero. This means that the sum of all potential differences across the component involved in the loop must be zero. This explains why connecting both ends of a voltmeter to the same point in a circuit gives a zero reading, as expected.

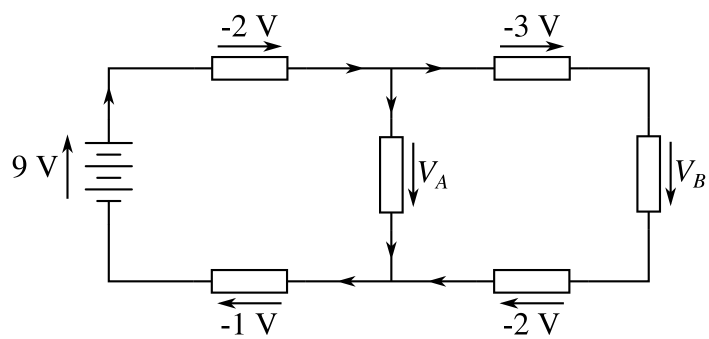
The following figure gives a simple example of this:



Kirchhoff's voltage law can be generalized to any loop containing any number of components. A more formal way of writing it is: $\sum V = 0$

What is the value of V_A? _______

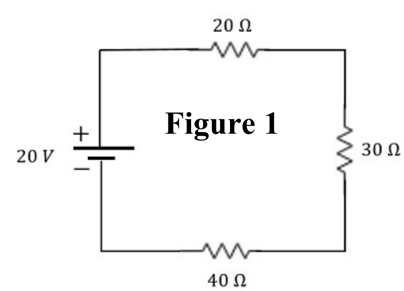
What is the value of V_B? _______



→ Because the ***potential difference*** is the measurement of potential energy per amount of charge, the potential increase across the battery must equal the potential decrease across the load (elements in the circuit that are not power sources).

Resistors in Series or in Parallel

→ **A series circuit** describes a circuit or portion of a circuit that provides a single conducting path without junctions. **Figure 1**



→ **The total current** in the circuit can be found by using the equation $\Delta V = IR$.

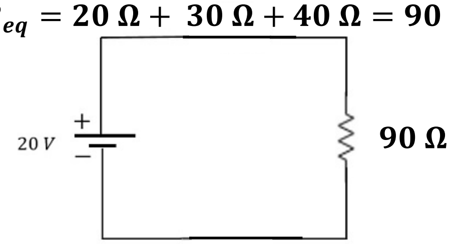
→ Because all charges in the circuit must follow the same conducting path, these bulbs are said to be connected in ***series***.

Resistors in Series have the SAME Current. **– VERY IMPORTANT!**

→ When many resistors are connected in series, the **current in each resistor is the same.**

→ The total current in a series circuit depends on how many resistors are present and on how much resistance each offers. To find the total current, use the individual resistance values to find the total resistance of the circuit, called the ***equivalent resistance***. Then, the **equivalent resistance can be used to find the current**.

$$R_{eq} = R_1 + R_2 + R_3$$
$$R_{eq} = 20\ \Omega + 30\ \Omega + 40\ \Omega = 90\ \Omega$$



The equivalent resistance in a series circuit is the sum of the circuit's resistances

Resistors in Series → $R_{eq} = R_1 + R_2 + R_3 \ldots$ ***Equivalent resistance equals the total of individual resistances is series.***

→ The equivalent resistance of a series combination of resistors is ***ALWAYS GREATER*** than any individual resistance.

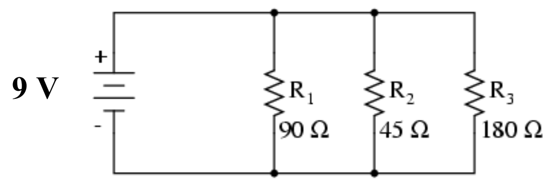
Series circuits require all elements to conduct.

→ When the circuit is not closed, there is no current in it and all bulbs go out.
→ Resistors can be placed in series with a device in order to regulate the current in that device.

Resistors in Parallel

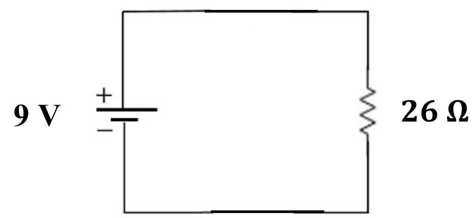
→ **A Parallel Circuit** describes two or more components in a circuit that are connected across common points or junctions, providing separate conducting paths for the current.

→ A wiring arrangement that provides alternative pathways for the movement of a charge is **parallel arrangement**.



$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$

$$\frac{1}{R_{eq}} = \frac{1}{90\ \Omega} + \frac{1}{45\ \Omega} + \frac{1}{180\ \Omega}$$



Resistors in Parallel have the SAME POTENTIAL DIFFERENCES across them.

The *sum of currents* in parallel resistors equals the *Total Current.*

Resistors in Parallel

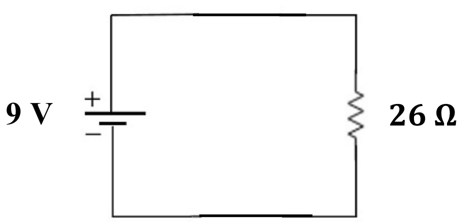
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$

The equivalent resistance of resistors in parallel can be calculated using a reciprocal relationship.

Parallel Circuits do not Require all elements to conduct.

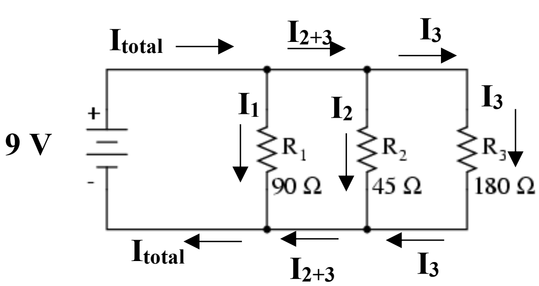
→ When resistors are wired in parallel with an emf source, the potential difference across each resistor always equals the potential difference across the source.

Once you know the equivalence resistance of a circuit you can use Ohm's Law to figure out the total current out of the battery.



$$I_{total} = \frac{\Delta V}{R} \qquad I_{total} = \frac{9\ V}{26\ \Omega} = 0.35\ A$$

Now you can figure out the current through each branch using Kirchhoff's Loop Laws and Ohm's Law



$$I_1 = \frac{\Delta V}{R_1} \qquad I_1 = \frac{9\ V}{90\ \Omega} = 0.10\ A$$

$$I_2 = \frac{\Delta V}{R_2} \qquad I_2 = \frac{9\ V}{45\Omega} = 0.20\ A$$

$$I_3 = \frac{\Delta V}{R_3} \qquad I_3 = \frac{9\ V}{180\ \Omega} = 0.05\ A$$

$I_{Total} = I_1 + I_2 + I_3 \quad I_{Total} = 0.10\ A + 0.20\ A + 0.05\ A$ = 0.35 A