Name: **Section:** **Date:**

Physics 224

General Physics Lab

<u>Experiment Name: Circuit Fundamentals</u>

THEORY

Purpose

Students will build basic circuits to explore the effects of several electronic components. Proper usage of the digital multimeter will be introduced.

Voltage, Current, and Resistance

-- Voltage –

When referring to circuits, the electric potential difference ΔV between two points is often referred to as the voltage between those two points. The S.I. unit is volt, abbreviated V.

-- Current --

Current refers both to the qualitative motion of charged particles, ex: “After connecting the battery, there was a clockwise current in the circuit” and the rate at which charge passes through some area, ex: “The current through the resistor is 5.00 milliamps”. The S.I. unit for current is ampere, which is equivalent to a coulomb per second. Amperes are commonly called “amps” and abbreviated A. The direction of current is defined to be the direction that positively charged particles move (or would move if they could), so current flows from high potential to low potential.

-- Resistance –

If something has high resistance, that means it is difficult for charge to flow through it and the current will be small. The resistance of an insulator (like air or plastic) is usually so large that the current will be negligibly small, close to zero. The resistance of a short length of copper wire or other conductor is usually very small. Circuit elements called resistors are used to add resistance to a circuit. The S.I. unit for resistance is the ohm, abbreviated Ω.

-- Relating All Three –

A potential difference causes charged particles to want to move – in other words, voltage causes current. The resistance determines how large or small the current is overall and in different branches of the circuit – in other words, resistance regulates current.

A useful analogy involves gravity. The gravitational potential is proportional to height, so that the top of a mountain would be a point of high potential and a valley would be low potential. A stream of water would flow down the mountain, in the direction of decreasing potential. The rate at which the water flows is affected by the width and depth of the water channel and how much sediment is clogging up the stream. In this analogy, the difference in height between the top and bottom of the mountain is the voltage, the rate of water flow is the current, and the dimensions of the water channel and amount of sediment are the factors affecting the resistance.

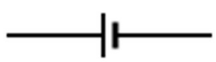
Electronic Components

Electronic components, also called "circuit elements", are the devices used in circuits to manipulate electricity in specific ways. We will use several different components throughout our study of electrical circuits. They will be listed along with their symbols and a brief description here. Some of these components are intrinsically polarized, which means that plugging them into the circuit backwards will damage them. **You MUST be conscientious when plugging polarized components into your circuit!**

-- *Resistor*--

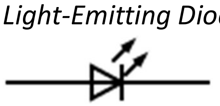
A resistor is a conductor that is manufactured to provide a specific resistance when placed in an electrical circuit. The amount of resistance that a resistor provides is usually denoted on the resistor by three bands of color, called the "resistor code". (A fourth gold or silver band denotes the tolerance of the resistor.) Next week, we will learn to decipher this code. For now, the colors for a certain resistance will be given in the procedure.

-- *Battery* --



The symbol that you see above is the symbol for a "Voltaic Cell", which contains a chemical reaction designed to produce an electrical potential difference between two metallic plates (a positive "anode" and a negative "cathode") in a very reproducible way. When these cells are connected in series, it is called a "Battery". In this course, we will use the above symbol to represent any direct current (DC) voltage source; this could be a Voltaic Cell, a battery, or a DC power supply. **Note that the negative side of the cell is depicted on the right-hand side as depicted in the above symbol.**

-- *Light-Emitting Diode (LED)* --



A light-emitting diode (LED) is a semiconductor device in which, when a voltage is applied, electrons are allowed to fall into lower energy "holes" (a place with a missing electron). When the electron falls into a hole it loses energy, which is emitted in the form of light. **Note that LEDs are polarized, and must not be plugged into the circuit backwards. The negative side of the LED is on the right-hand side as depicted in the above symbol.**

-- *Capacitor* --

Both of the symbols above are used to denote capacitors. The symbol on the left-hand side depicts a polarized capacitor, while the symbol on the right-hand side depicts a non-polarized capacitor. A capacitor is a device which stores electrical potential energy (short-term) as a potential difference between two separated conducting plates. **Note that capacitors are polarized, and must not be plugged into the circuit backwards. The negative side of the capacitor is depicted by the curved line in the above symbol.**

-- *Jumper* --

A "Jumper" is the word that we will use for a piece of wire with negligible resistance that can fill in the discontinuities on your circuit board.

Series vs. Parallel

When electronic components are in series, there is only one path through which the current can flow. This means that the current will be the same through components in series, while the voltage will change.

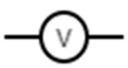
When electronic components are in parallel, the current will split between the multiple parallel branches. This means that the current will differ between components in parallel. However, because each parallel component will be connected across the same potential difference, the voltage will be the same.

Using the Digital Multimeter (DMM)

The Digital Multimeter (DMM) is a tool for measuring and analyzing many different aspects of an electrical circuit.

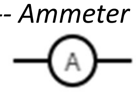
In this experiment, we will use three of the multimeter's functions. We will use its voltmeter, ammeter, and continuity tester.

-- Voltmeter –



The voltmeter will be used to measure the voltage across components in our circuit. **When measuring voltage, it is crucial that the voltmeter ALWAYS be placed in PARALLEL to the ΔV that you are measuring!** The dial on the voltmeter should be set to the lowest voltage possible, but a voltage that is still larger than the voltage that you wish to measure. The schematic symbol for a voltmeter is given above.

-- Ammeter –



The ammeter will be used to measure current through components in our circuit. **When measuring current, it is crucial that the ammeter ALWAYS be placed in SERIES with the current that you are measuring!** The dial on the ammeter should be set to the lowest current possible, but a current that still larger than the current that you wish to measure. The schematic symbol for an ammeter is given above.

-- Continuity Tester --

The continuity tester is denoted by the symbol: 

The continuity tester is in essence an Ohmmeter, which measures resistance. It is, however, specifically for measuring small resistances, which are oftentimes negligible. If you want to determine if there is a continuous electrical connection between two points, you can place the continuity tester in parallel to those two points. If the resistance between those two points is less than 100 Ω, an alarm will sound.

PROCEDURE

Part 1: Inspecting the Circuit Board

The circuit board in front of you is not designed for practical, real-world applications; it is designed specifically to give you, the student, an understanding of basic circuitry and a straightforward platform for taking measurements this semester. There are 10 discontinuities on this circuit board where electronic components may be placed, as well as 12 wires to conduct electricity between those components.

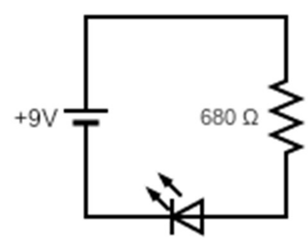
1) Flip the circuit board over so that you can see how the discontinuities and wired connections are arranged. Draw a circuit schematic of this arrangement on your worksheet.

2) Flip the circuit board right-side up. Using the DMM's continuity tester, confirm that electricity can pass freely through the wired connections, and cannot pass through the discontinuities. If there are any problems with the circuit board, notify the TA.

Part 2: Lighting the Light (of Knowledge)

-- Circuit 1 --

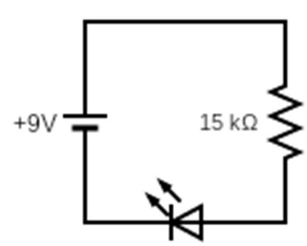
3) Build a series circuit on your circuit board consisting of a 680 Ω resistor (Blue, Grey, Brown), an LED, and a 9 V battery. You will need at least one wire jumper to complete ("close") the circuit! ***Recall that LEDs are polarized!***



4) What do you observe when you close the circuit? Give qualitative reasons for the effect(s) you observe.

-- Circuit 2 --

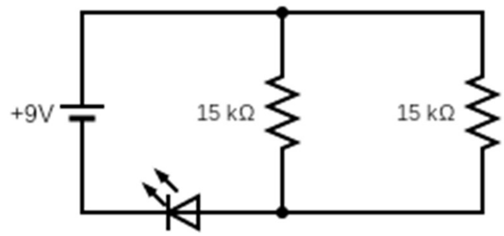
5) Remove the 680 Ω resistor and replace it with a 15 kΩ resistor (Brown, Green, Orange).



6) What do you observe when you close the circuit? How does this differ from Circuit 1? Give qualitative reasons for the effect(s) you observe.

-- Circuit 3 --

7) Add a parallel branch to Circuit 2 which includes an additional 15 kΩ resistor.



8) What do you observe when you close the circuit? Give qualitative reasons for the effect(s) you observe. (You may want to insert and remove the second resistor several times while observing.)

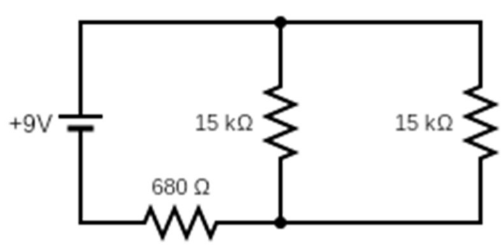
9) Measure and record the voltage drops across both parallel resistors. How do these voltage drops differ? Does this make sense? Does this mean that the equivalent resistance of resistors in parallel is higher or lower than their arithmetic sum? **VOLTAGE IS ALWAYS MEASURED IN PARALLEL!**

10) What do you predict would happen if we continued to add additional parallel 15 kΩ resistors? What do you predict would eventually happen to the LED if we continued to add more parallel 15 kΩ resistors?

11) Simulate the LED burning out by removing it from the circuit board. Measure and record the voltage drops across both parallel resistors. How does this remind you of a fuse or circuit breaker?

-- Circuit 4 --

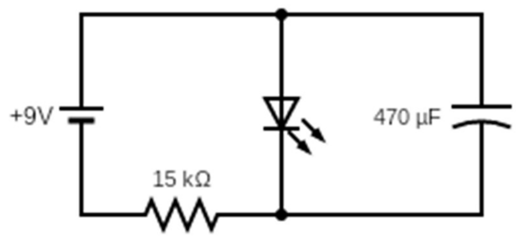
12) Plug the 680 Ω resistor where the LED used to be. Measure and record the current flowing through all 3 resistors. **CURRENT IS ALWAYS MEASURED IN SERIES!**



13) Looking at the schematic, visualize the electric current as something analogous to water that is flowing through the circuit. Using this model, can you make quantitative sense of the current measurements that you took? How do the three current measurements relate to each other?

-- Circuit 5 –

14) Build the following circuit with an LED and a capacitor in parallel. Use a 15 kΩ resistor to regulate the current. ***This capacitor is polarized!***



15) What do you observe when you close the circuit? What do you observe when you open the circuit? How does the behavior of the LED differ from previous circuits? What can you conclude about the behavior of capacitors in circuits? How does this align with what you've learned about capacitors in lecture?