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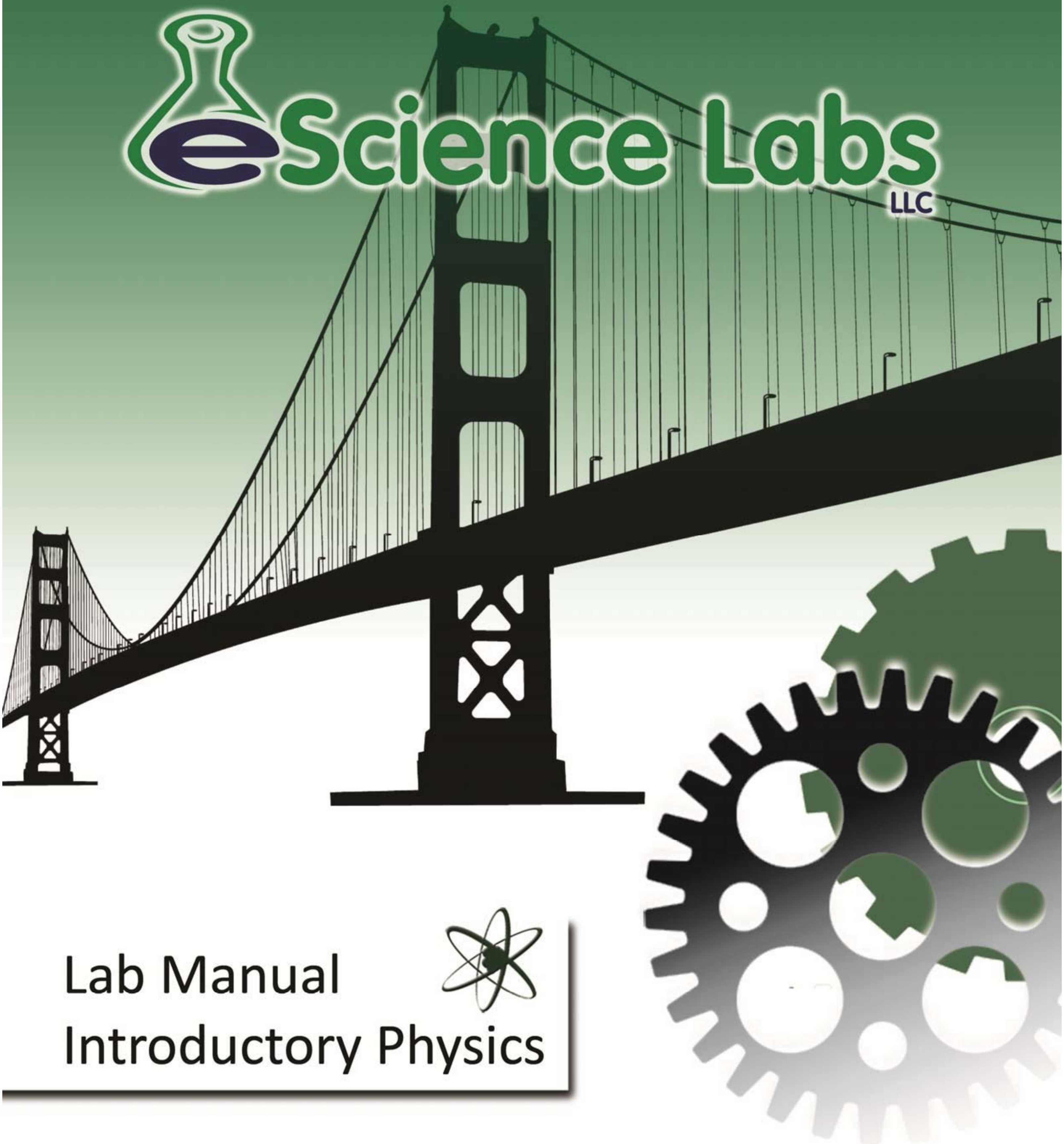

Lab Manual
Introductory Physics

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Introductory Physics V2.3

Introduction

Thermal Physics

Waves and Light

Electricity and Magnetism

Electricity and Magnetism

Lab 13: Electric Current

Concepts to explore:

- Current
- Voltage
- Electric resistance
- Ohm's Law
- Electrons and current

Figure 1: Lighting is one of the most familiar examples of electricity in nature. A single lightning bolt carries a current on the order of 100kA and has a voltage in the millions of volts.

As you saw in the Electric Fields Lab, the atoms in different materials can gain and lose electrons when energy is applied or lost, such as when you rub an object with a piece of fur. While charge can build up on the outside of objects as static electricity, it is also possible for charge to move through certain materials, such as many metals. Conductors allow free electrons to move through them easily, transporting electric charge from one place to another. The movement of charge is called electric current, and is defined as the rate of change in charge per unit time, or

$$I = \frac{\Delta Q}{\Delta t}$$

Figure 2: A battery is nothing more than a device that stores metals and chemicals. Batteries have become an important part of our lives and are used to start cars and to power alarm systems, computers and MP3 players.

The SI units for current (I) is the ampere, where 1 A = 1 Coulomb/s.

When you connect the positive and negative terminals of a battery, chemical energy converts to electrical energy. A gradual chemical reaction inside the battery tends to make one side positively charged and the other side negatively charged. This difference in charge is called electric potential, or voltage (1 V = 1 Joule/Coulomb). Voltage is essentially a measure of the potential energy for charge to move between two points in space; a higher voltage will cause more current to flow through a conductor than a low one.

Electricity is typically used and produced as either alternating current (AC) or direct current (DC). When the power company produces electric current using a generator, the voltage rises and falls over time, alternating the direction of charge flow. While it is convenient to produce and distribute an alternating current, most electric devices you are familiar with are designed only to handle direct current. Therefore, most home appliances have a small converter inside or on their power cord which changes the 120 V AC from your wall socket to safer DC power. For the purposes of this lab, you will only need to be familiar with DC circuits.

Different materials allow more or less current to flow through them; thus the amount of current that flows depends on both the voltage and the electrical resistance of the material. The relationship between current, resistance, and voltage was determined experimentally by Georg Simon Ohm in the early 19th century. Ohm's Law states that the current is proportional to the applied voltage, and varies depending on the resistance of the conductor carrying the current:

$$V = IR$$

Because of his work, resistance is measured in Ohms (1 Ω = 1 V/A). This relationship allows us to find the amount of current in a conductor (such as a wire in a circuit) knowing the resistance of different elements that use electricity, and the voltage supplied by a battery or wall outlet. As you can see, a higher voltage means a higher current, while a higher resistance creates less current.

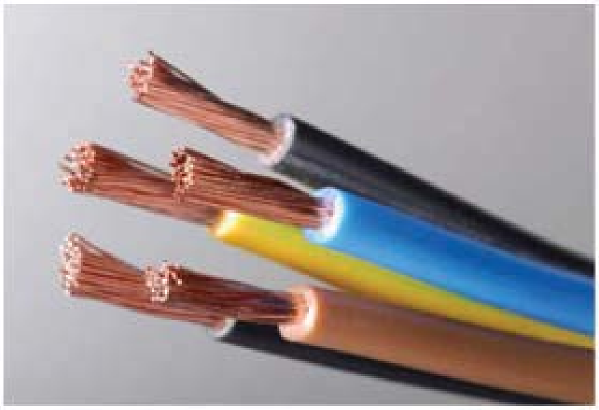


Figure 3: Copper is a typical metal used for standard electrical wire due to its high conductivity (low resistance). Other common wire metals are gold, silver and aluminum. The colored material on the outside of each wire is the insulation, which prevents electricity from flowing into anything that isn't in contact with the stripped portion on the end.

In order for electricity to flow a voltage must exist across a conducting material, creating a circuit. When a wire is connected across the terminals of a battery, for example, free electrons gradually move from the negative terminal to the positive terminal. Unfortunately, the direction of current was originally defined as the flow of positive charge (an arbitrary distinction), so the conventional current is actually in the direction opposite the flow of electrons. To put it simply, current flows from positive to negative voltage, but electrons in a conductor actually move from the negative terminal to the positive one. In some materials, such as a salt-water solution, the movement of charge is not due to electrons, but positively charged ions that are created in a chemical reaction. In general the term current refers to the flow of positive charge in a conductor.

Similar to what happens when a mass falls a certain distance in a gravitational field, electrons experience a change in energy as they travel through a voltage difference. As electrons travel through a light bulb, for instance, they lose energy as the filament heats up and gives off light. Across any circuit element that is powered by electricity there will be a drop in voltage corresponding to this loss in energy. This means that the more elements you add to a circuit, the more voltage you will need (a bigger battery!) to power all of them. Similarly, circuits made with higher resistance materials lose more electrical energy due to heat, limiting the amount of current distributed to any electric devices.

In the following experiments you will build your own simple DC circuits, and use them to test out electric conduction and resistance.

Lab 13: Electric Current

Experiment 1: Electric Current and Conduction

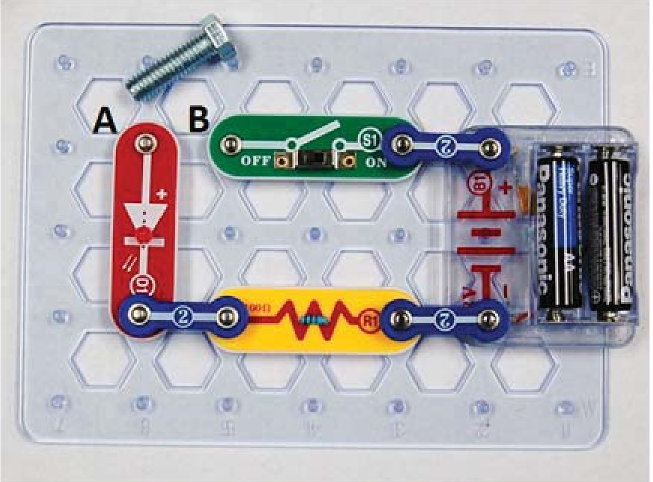
In this lab you will test the electrical conductivity of different materials using Snap Circuits ®. You might be surprised to hear that some liquids can even conduct electricity! In the circuit that you build, you will leave an open section across which you can lay different objects to test their conductivity. These two points can be called terminals—there will be a voltage across the terminals depending on which end of the battery they are connected to. As soon as a conductor lies across the terminals, this voltage will translate to an electric current in the ---material!

Materials

Snap Circuits ™ Kit
Batteries
Styrofoam cup
Salt
Paperclip, steel bolt, or other small objects
Water*
* You must provide

Procedure

1. Set up the Snap Circuits so that you have the circuit shown below:
   With the switch set to “on,” place a bent paperclip across the terminals as shown in Figure 4—the LED should light up.
2. Place any other objects you would like to test between the terminals marked A and B in the diagram. Test materials like wood, metal and plastic.
3. Connect the Snap Circuit wire leads to terminals A and B. Fill the Styrofoam cup about three-fourths full with water, and submerge one end of each lead in the cup. Turn the switch to “on” and note any changes in the LED.
4. Turn the switch to “off,” and add 2 teaspoons of table salt to the cup; mix until it’s dissolved. Flip the switch and note any changes in the LED brightness



Note: Always make sure the positive end of the diode connects to the positive side of the battery—diodes only allow current to flow in one direction!

Figure 4: Circuit diagram for Experiment 1

Questions

1. Which terminal is positive and which one is negative in the setup above? What could you do to quickly reverse the polarity of the terminals?

2. What is the voltage across the terminals? (Hint: look for the voltage of a single AA battery—are the batteries connected in series or parallel?)

3. What types of materials caused the LED to light up? Did any of your materials make the LED light up only slightly?

4. Did the LED light up when you placed the wires in the regular water? What about after you added the salt?

5. Salt water does not conduct electricity in the same way as metals, where free electrons can move throughout the material easily. Instead, when sodium chloride dissolves in water its molecules are broken up into charged particles called ions. Based on how much the LED lit up in Step 5, what can you conclude about how well the ions in the solution carry charge compared with electrons in a metal conductor?

Experiment 2: Electric Resistance

Materials

Snap Circuits ™ Kit
Batteries

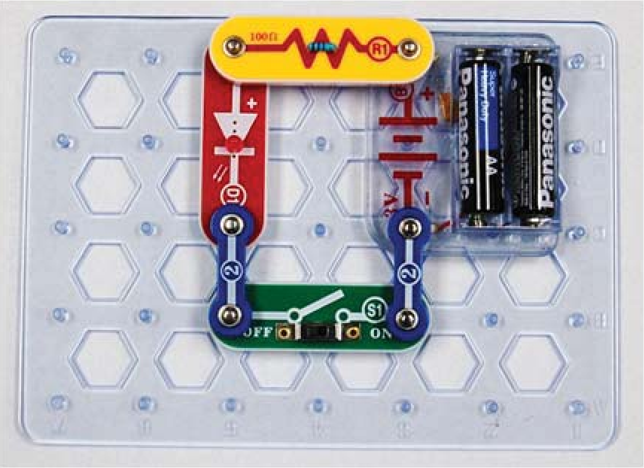


Figure 5: Circuit diagram for Experiment 2

Procedure

1. Set up the Snap Circuits as shown in Figure 5 using one LED and the 100 Ω resistor.
2. Flip the switch to the ‘on’ position, and note the brightness of the LED.
3. Replace the 100 Ω resistor with the 1 kΩ resistor from the Snap Circuits materials. Switch back and forth a few times to notice any differences in the brightness of the LED.

Questions

1. Draw a circuit diagram for the setup in the space below using the following symbols to represent different circuit elements. Similar symbols can be found on the top of each Snap Circuit piece.

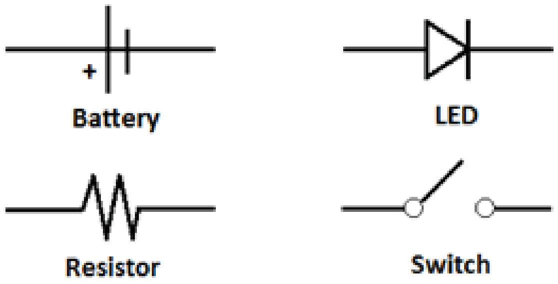


Figure 6: Circuit diagram elements

2. How does the current through the LED change when you switched between the two resistors? What does this tell you about how quickly charge is moving in the LED for each case?

3. Explain why the LED changes brightness when the resistors are switched according to Ohm's Law.

4. Use Ohm's Law to calculate the current (in Amps) traveling through a 100Ω resistor in series with a 3 V battery. Compare this to the current travelling through a 1 kΩ resistor.

5. How much would you have to increase the voltage using the 1 kΩ resistor to create a current equal to that you calculated with the 100 Ω resistor? (Assume the resistance of the LED is zero). How many more batteries is this equivalent to?

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