Experiment 14A
Introduction to Electric Current Version 2

Introduction

The primary objective of this lab is to introduce the students to the fundamental concepts which govern the flow of electric charge.

The focus will be on a statement by Paul Hewitt in opening sentence of chapter 23 on Electric Current from Conceptual Physics, 12th ed, **"Electric current is the flow of charge, pressured by voltage and hampered by resistance."** The mathematical relationship between current, voltage & resistance is credited to the German Scientist Georg Simon Ohm.

The emphasis of this lab is threefold. The primary emphasis is to give the student a basic introduction to the concepts of *work*, *energy* (in particular, potential energy), *power* and *thermal losses* using simple mechanical examples. The secondary emphasis is to examine the concepts of voltage, current and resistance by using simple mechanical analogs introduced above. The tertiary focus concerns an evaluation of your basic knowledge of electricity before you perform this lab and then after you do the lab.

It is generally known that heat flows from a region of higher temperature to a region of lower temperature- this is analogous to a ball rolling from a higher elevation (i.e., from a higher potential) to a lower elevation (or lower potential). Similarly, when the ends of a conductor (e.g., a wire) are at different potentials, charges will flow from high to low potential.

Electric current is the flow of electric charges. To maintain a sustained flow of charge (i.e., a constant current) a sustained potential difference must be maintained (e.g., that provided by a battery or an electric generator). The rate of electric flow is measured in amperes**. One ampere (or amp) is a rate of flow equal to 1 coulomb per second.**

Batteries and generators do work to pull negative charges away from positive charges. Batteries usually work by the chemical disintegration of lead or zinc in acid and the energy stored in chemical bonds is converted into *electrical potential energy*. Electric generators separate charges by a process called electromagnetic induction.

The work done by either a battery or generator is available at the terminals (of a battery or generator). "These different values of energy per unit charge create a difference in potential (voltage). This voltage provides the "electrical pressure" to move electrons through a circuit." **The unit of electrical potential difference (voltage) is called a volt.**

There is often confusion about what quantity flows in a circuit. Consider a long pipe filled with water. If there is a pressure difference between the ends of the pipe, water will flow from the higher pressure end of the pipe to the lower pressure end. *Pressure does not flow. Only the water flows.* Similarly, voltage does not flow through a circuit-only charges flow.

If a voltage is impressed across a circuit, the amount of current depends on both the voltage applied and on the resistance of a circuit. **The definition of resistance is the ratio of voltage divided by current. Resistance has units of Ohms.** For a given voltage, the lower the resistance, the higher the current and the higher the resistance, the lower the current. For a given diameter, a long wire has more resistance than a short wire. Correspondingly, for a given length, a wire with a large diameter has a lower resistance than a wire with a small diameter. Electrical is also a function of temperature. **"For most conductors, increased temperature means increased resistance."**

There is a common misconception that electric companies charge customers for power. This is patently untrue. Electric companies sell and charge for energy (use).

The distinction is in the definitions of work, energy and power. Work is defined as force times time (units of joules), energy is defined as the capacity to do work (units of joules also) and power is defined as work divided by time (units of joules per second or watts).

What you are charged for is a unit (or block) of energy called a kilowatt-hour (kilowatt * hour) abbreviated as kWh.

Since energy is simply power × time we see that a kWh is a unit of energy.

To see how many joules a kWh is equal to we must first convert hours to seconds. Since 1 hour is equal to 3600 seconds, we see

1 kWh = 1000 joules/s * 1hr*3600 s/hr.

Canceling units we see

1 kWh is equal to 36,000,000 J.

As of January of 2024, the national cost of a kWh was 11.8 cents or $0.118.

This a rather large amount of work for around 12 cents. **It is the work equivalent to lifting a large SUV (with a weight of 5000 pounds) to a height of 531 feet!** In this experiment we will assume the truck is lifted to the top of a large block with a height of 531 feet. See Part C below.

In the post lab questions you will be asked to calculate the cost of lifting a 5000 lb SUV to a height of 531 feet using an internal combustion engine.

We will utilize the conversion factor of

1kW = 1.34 horsepower or 1 hp= 745.7 W.

On average, an in-tune four-stroke gasoline engine will burn about **0.50 pounds** of fuel per hour for each unit of horsepower.

Thus, we see that a 1.34 hp engine uses 0.5 lbs * 1.34 or 0.67 lbs of gasoline per hour.

Since gasoline has an average density of 6.2 lbs/gallon, we can divide mass (in this case weight) by density to get the volume and see that our **1.34 hp motor uses around 0.11 gallons to raise car to 531 feet.**

In the first part of this lab, you will be shown a number of demonstrations and devices to assess your knowledge or preconceived notions about electricity and electrical circuits. Some of these you will have seen before either in class or from life experiences. Some of these will be unfamiliar to you. It will not count against you if you do not know something in the first part of the lab-what is important is that you use simple logic and fundamental concepts to try to explain what you have observed.

You are reminded that if you are trying to explain a physics (or any other) physical phenomena, the concept of conservation of energy will almost always be the simplest path to an explanation.

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Pre-Experiment Evaluation

Part A: Colliding Steel Ball Demo

In this part of the lab will smash two one-pound steel balls together while a piece of paper is between them. See figure below.

1. You are to predict what you think you might see when you do this and explain why you think this is the case. Write your predictions below.

Part B: Measurement of the Coefficient of Restitution

The **coefficient of restitution** is the ratio of the relative velocity of separation after collision to the relative velocity of approach before collision.

In this part of the lab you will be asked to drop a rubber ball from a known height and then measure how high it bounces. See figure below.

2. You are to predict what you think you will observe and explain why. Write your predictions below.

Part C: Work, Energy and Power. What are the differences?

Work is defined as force times distance. Energy is defined as capacity to do work. Power is defined as work divided by time.

In this part of the lab you will shown the following setup. See figure below.

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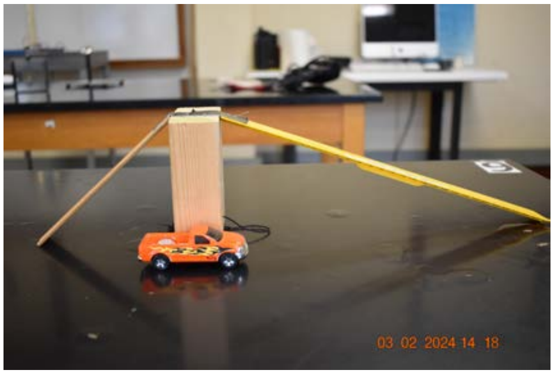


You are to imagine what would happen you did the following.

It is assumed that there is no friction or any other type of energy loss.

The car is placed on the short ramp at the top of the block and allowed to roll down to the bottom.

The car is placed on the long ramp at the same height as above at the top of the block and allowed to roll down to the bottom.

You are to answer the following questions**. Be sure and explain your answers.**

3. Is the kinetic energy of the car at the bottom of the ramps in both cases the same?

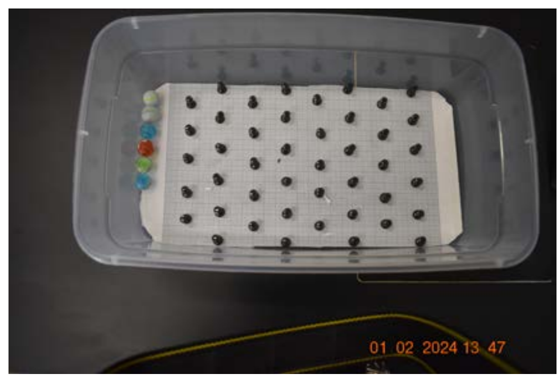
   Is the time to fall same in both cases?

   Is the power dissipated by the car in both cases the same?

Part D: Electric Current Model

In this part of the lab you will given the following setup that models the flow of electrons in a conductor.

It contains marbles to simulate charges and push pins to simulate the atoms of a conductor (or a resistor). See figure below.



If the container is placed on a level surface the balls will not move.

If the left-hand side of the container is elevated the balls will roll from left to right while colliding with the pins.

If the right-hand side of the container is elevated the balls will roll from right to left while colliding with the pins.

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Please answer the following questions for Part D.

4. Why do the balls only roll when the container is raised on one end? How is this analogous to the flow of charges in a conductor?

What happens to the temperature of the pins as the balls collide with them?

What happens to the temperature of a conductor or resistor when a potential is applied and charges move through it?

Part E: How to Construct a Circuit

You will be given the following items and asked to construct a working flash light. See figure below.

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5. Draw a diagram and explain how you would make a flashlight. Be sure and show where on the light bulb you would place any wires.

Part F: How to Construct a Circuit using an electric generator

A generator is a device that converts mechanical energy into electrical energy.

You will be given a generator with wires & a light bulb. You are to explain (include a diagram) how set up a flashlight circuit and then make the bulb light up. See figure below.

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Post-Experiment Evaluation

Your TA will now guide you through how to correctly perform the parts A through E and then you will do post experiment responses to the various parts of the lab.

If your answers are the same, you should note that on this part.

Part A: Colliding Steel Ball Demo

Part B: Measurement of the Coefficient of Restitution (COR)

Use $COR = \sqrt{\frac{Height\ of\ bounce}{Height\ of\ drop}}$

Part C: Work, Energy and Power. What are the differences?

Part D: Electric Current Model

Part E: How to Construct a Circuit using battery.

Part F: How to Construct a Circuit using an electric generator

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Part G. Measurement of current and how to calculate the power of a circuit element.

The circuit consists of a 9V battery (**not connected)** and two DMMs set to measure current (i.e., two ammeters) & a light bulb. The DMM on the right measures the current before it reaches the light bulb & the right hand DMM measures the current after it goes through the light bulb.

Complete the circuit as shown in right-hand figure and record the current in both DMMs. The units are in amperes or amps.

Current (in left-side DMM) = ______amps.   Current (in right-side DMM) = ______amps

Does the current change after the current goes through the bulb?

Power is defined as current times voltage (i.e., Power (Watts) = current (A)* voltage (V)

Calculate the power dissipated by the light bulb. Show work. **Power = ___________Watts**

Exp 14 Post Lab questions:

1. Which of the following forms of energy were involved in your experiment, identify them, and describe which form(s) of energy transform into which form(s) of energy.
   Kinetic Energy(energy associate with motion)
   Gravitational Potential Energy (energy associate with height)
   Thermal Energy (energy associate with temperature)
   Sound Energy (energy associate with sound wave)
   Chemical Energy (energy associate with chemical reaction)
   Electric Energy   **Light Energy**

   Part A: Colliding steel ball:
   Energy form(s): ____
   transform into
   Energy form(s): ____

   Part C: Toy car slides down slopes:
   Energy form(s): ____
   transform into
   Energy form(s): ____

   Part E: Construct a circuit of battery and light bulb:
   Energy form(s): ____

transform into
Energy form(s): ____
Part F: Construct a circuit with electric generator:
Energy form(s): ____
transform into
Energy form(s): ____

2. A friend of yours tells you that when an electric current flows through a light bulb, the current is "used up" in the light bulb.
   Do you think your friend's conclusion is reasonable? Which of the measurements you did in the lab today can help you reject or support your friend's conclusion?

3. A power strip you use at your dorm to connect to the 110 V outlet has an allowance of 3A maximum current. You and your roommates use that power strip to connect your laptops that have a power rating of 65W.
   Is it safe to connect 4 of those laptops to this power strip at the same time? Explain your reasoning. Use the relationship **power = current times voltage**. Show all work.

4. To provide the energy of 1 kWh (or the energy equivalent to lifting a 5000 pounds SUV to a height of 531 feet), you can either :
   (a) Use electricity where the cost of electricity recently ranged from a low of 8.34 cents per kWh to a high of 37.3 cents per kWh.
   (b) Use a 1.34 hp gasoline engine for an hour, which burns **0.11 gallons of gasoline**. The national cost of gasoline ranges from a low of $2.29/gallon (Oklahoma) to a high of $4.71 (California).
   Discuss in your group which method is more expensive (One lab partner can compare the lower prices & the other can compare the higher prices).

5. Paul Hewitt (the author of your text) makes a point to emphasize that the electrical outlets are not the source of the electrons. People often incorrectly assume that electrons flow from the power utility through the power lines to your home. This can readily be seen not to be the case if you rock the electric current model back and forth and observe the behavior of the marbles. Explain what you see.