

1. Measuring Motion of a Magnet

MW January 4, 2013

Objectives

1. Construct an electric circuit that contains a simple switch for turning a Light Emitting Diode (LED) on or off.
 2. Construct an electronic circuit using a magnetic field sensor (or Hall effect sensor) to determine the presence and orientation of a magnetic field.
 3. Use the Hall effect sensor in an electronic circuit to measure the position of a magnet as it drops through a copper tube and use the measurements to characterize the magnet's velocity and acceleration.
 4. Formulate conclusions on the nature of the net force on the magnet.
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Equipment

1. 9V battery and clip-on battery harness,
 2. resistor,
 3. light emitting diode (LED),
 4. Hall switch,
 5. White breadboard,
 6. Purple solid core wire,
 7. Pipe apparatus and associated magnet,
 8. Power supply
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Equipment Warning

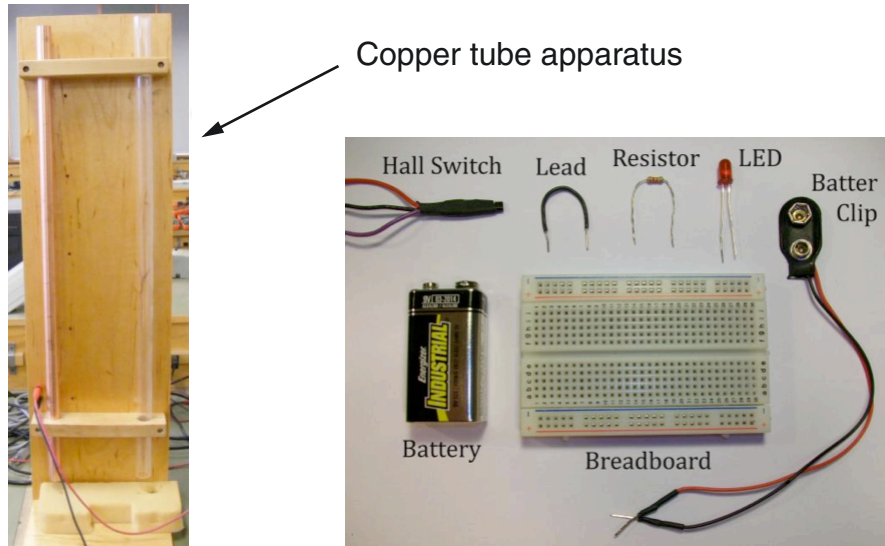
Please do not try to take the magnets apart. They are quite powerful, smooth and slippery, and brittle. If you try to take them apart they may snap back together with great force and shatter in the process. They can also pinch you and cause blood blisters. The broken magnet fragments have sharp edges.

Preparation

The following are examples of two-terminal electrical devices:

- Battery: uses chemical energy to do work to separate electric charge across its plates.
 - Resistor: restricts or limits current flow.
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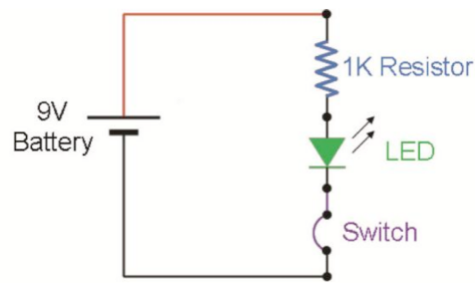
- Light emitting diode (LED): converts electrical energy into light and heat (when current flows).
- Switch: when open, no current flows and the circuit is off; when closed, current flows and the circuit is said to be “energized”.



Experiment

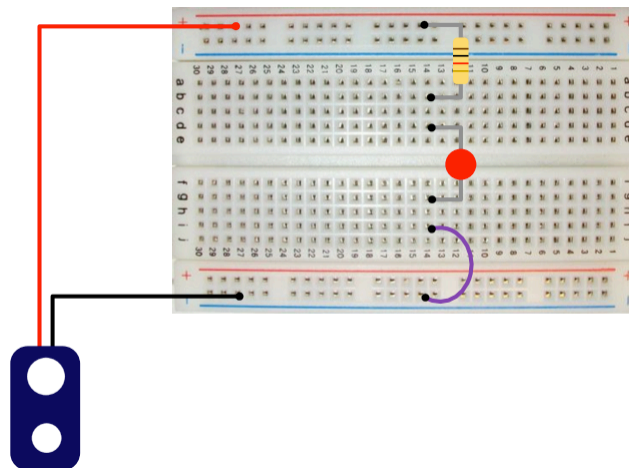
A worksheet is provided at the end of this document that needs to be passed in by the end of the lab session. Most times you are asked to observe something in this document, a corresponding question is asked in the worksheet.

1. Examine the battery – notice the voltage rating and the polarity designations of the terminals.
2. Examine the LED – notice the flat side or edge at the bottom of the diode; notice the difference in length of the legs.
3. Examine the resistor – identify the specific colors of the color bands. The color bands identify the resistance in Ohms.
4. *Simple Electric Circuit.* Electric circuits are normally represented by schematic diagrams that specify the topology of the electrical devices. Topology is a term that refers to the nature of how devices are interconnected (in this case to form electric circuits). The following is a series (topology) circuit consisting of an interconnection of four, two-terminal electrical devices forming a closed path.



Wire up (construct) the circuit represented in the schematic diagram above using the white breadboard and wires provided. It is a good idea to strategically use coloured wires. This assists with troubleshooting if things do not operate as expected.

Connect the red lead on the battery to the top horizontal rail of the bread board as shown in the figure below. The holes along the top horizontal rail are all connected underneath by a common wire, i.e., the tie-in points along the top horizontal rail are all at the same voltage.



Connect the black lead on the battery to the bottom horizontal rail of the bread board. The holes along the bottom horizontal rail are all connected underneath by a common wire, i.e., the tie-in points along the bottom horizontal rail are all at the same voltage. Connect the resistor and LED as shown. Connect a purple wire to implement the operation of a switch.

What are your observations? Reverse the connection of the diode in the circuit so the flat side is now on the opposite side. What are your observations?

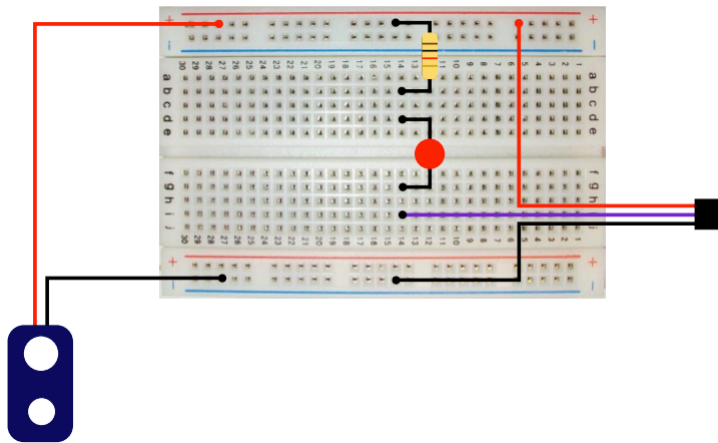
Disconnect one end of the purple wire and then reconnect. What are your observations?

Reverse the connection of the resistor. What are your observations? Note: the operation of a resistor does not depend on its orientation in a circuit. The operation of a LED does depend on its orientation.

A diode looks like a *wire* when current flows through it. The purpose of the resistor is to limit the current that flows through the diode. When the diode is on then Ohm's law says, $i_{diode} = V/R$, otherwise when the diode is *off* the diode current is zero, i.e., $i_{diode} = 0$.

5. **Hall Switch Circuit.** Examine the Hall switch. It is a 3-terminal element. The red lead is the voltage supply wire. The black lead is the ground wire. The purple wire is connected to one side of an internal electronic switch and the other side of the internal electronic switch is connected to ground; i.e., the black lead.

Remove the purple wire from the breadboard. Connect the red lead of the Hall switch to the 9V power rail. Connect the black lead of the Hall switch to the ground rail. Connect the purple lead of the Hall switch to the bottom side of the LED. What are your observations?

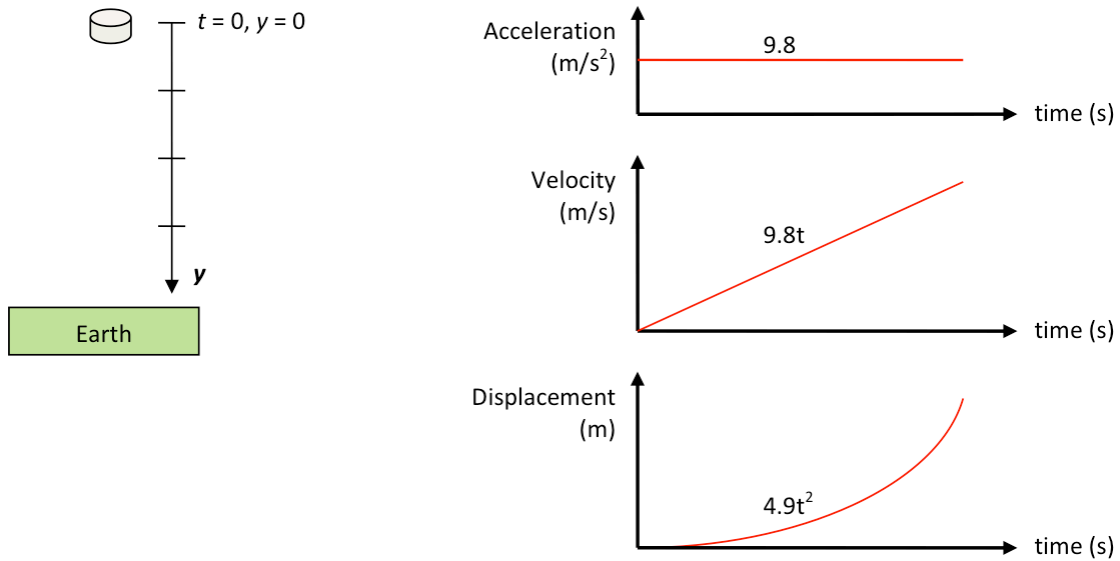


Bring a magnet in proximity to the Hall switch and investigate the effect of changing the orientation of the magnet relative to the flat surface of the Hall switch. What are your observations? The Hall switch behaves like the mechanical (purple wire) switch in the previous circuit, except that the switch is now activated without physical contact by the presence of a magnetic field (with a certain orientation).

These forms of non-contact switches find application in: security alarms, automobile ignition systems, limit switches, and proximity sensors.

6. **Magnet Drop Experiment.** Observe whether or not the magnet is attracted to the copper tube, that is, determine if the magnet sticks to the copper tube. Make sure there is a piece of foam on the bottom of the tube apparatus that will cushion a magnet exiting a tube. Drop the magnet into the copper tube and measure the time it takes for the magnet to fall through. This can be achieved by using the hall switches embedded into the tube apparatus and a timing device. Most groups will have a member with a digital watch or a smartphone capable of timing the magnet as it drops, if not let a TA know. By connecting a 5 volt power supply to the banana plugs on the tube apparatus the LEDs will light when the magnet passes each sensor. Let the magnet drop and measure how long it takes to reach the end of the tube. The magnet may get stuck; this is alright, simply tap the copper tube and the magnet will be dislodged. If this happens, repeat the measurement. A table has been provided in the worksheet where you can record your measurements.

7. **Relating to Projectile Motion in a Gravity Field.** In a gravity field, near the earth's surface, the trajectory (i.e., acceleration, velocity, and displacement) of a free falling object starting from rest is show shown in the diagrams below.



Drop the magnet through the plastic tube and note how much faster it exits the tube. Time how long it takes for the magnet to exit the plastic tube and record this on the worksheet.

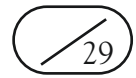
Name(s):

ID(s):

Lab Group:
Lab Day:
Date:

Lab 1 Worksheet: Motion of a Magnet:

For Marker's
use only



1. What is the voltage rating of the battery?
_____ (___/1)

2. With the following table determine the value of the resistor. Note, resistance units are in Ohms (Ω).

Black	Brown	Red	Orange	Yellow	Green	Blue	Violet	Grey	White
0	1	2	3	4	5	6	7	8	9

The resistor has four colour bands on it. Start reading from the side opposite the gold or silver band. The first two bands represent integer values, while the third represents a multiplier (power of ten). The last band represents tolerance, where gold is $\pm 5\%$ and silver is $\pm 10\%$. For example, a colour scheme of *orange violet orange gold* represents:

Orange = 3, Violet = 7, Orange = 3.

$37 \times 10^3 = 37000 \Omega$ or $37 \text{ k}\Omega$. Adding the tolerance results in $37 \text{ k}\Omega \pm 5\%$.

What is the value of the resistor you have? (include tolerance)

_____ (___/2)

3. How does changing the orientation of the LED affect its state? What is the orientation of the flat edge when the LED is on? (Note, the LED has two states: on and off. Mention the direction of the flat edge as it relates to the red lead of the battery).

_____ (___/2)

4. How does changing the orientation of resistor affect the state of the LED?

_____ (___/2)

5. What happens when you disconnect the purple wire?

_____ (___/2)

6. What happened to the LED when you connected the Hall switch before exposing it to the magnet?

_____ (___/2)

7. When you bring the magnet near the hall sensor what happens? Be sure to mention what happens when you change the orientation of the magnet.

_____ (___/2)

8. Did the magnet stick to the copper tube? (Circle One: Yes No) (___/1)
9. Magnet drop results – copper tube (Take at least **three** measurements) (___/5)

Distance	Time	Comment

10. Is the magnet accelerating? (Circle One: YES NO) (___/1)
 Hint: Measure the time between LEDs lighting as the magnet falls. If the time between LEDs lighting is constant, the magnet is not accelerating.
11. What is the velocity of the magnet as it travels through the copper tube? Calculate the velocity below, $v = d/t$ where v is velocity, d is distance, and t is time. (___/4)

$$v = \frac{d}{t} =$$

12. The time for the magnet to fall through the plastic tube was _____ seconds. (___/1)
13. Write a brief reason why you think the magnet takes longer to fall through the copper tube than the plastic tube. Remember that the magnet did not stick to the copper tube. (___/4)