Intermediate General and Applied Science

Physics Module: Lab Manual

Developed by Christine Miller © 2018

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KEEP CALM
AND
WEAR YOUR
LAB COAT

Getting to Know Your Lab Manual

Each lab is designed to include a pre-lab reading and assignment, 3 activities, and then a post-lab assignment. The pre-lab reading needs to be completed **before** you come to lab. The pre-lab assignment is due at the beginning of the lab and includes questions and activities based on the pre-lab reading. The three lab activities are designed to fit into a two-hour lab. The post-lab assignments are typically due within the week after the lab has been completed. However, due dates are ultimately set by your instructor.

Being familiar with the symbols in your lab manual will help you know what you are supposed to do during specific lab activities. There are symbols in this manual that indicate which type of activity is required. Below is a table summarizing these symbols:

Symbol	You should:
MARK: ______ **10**	This is a page that will be handed in for marks. It is either a pre- or post- lab assignment, and your instructor will let you know when it is due.
?	A simple question mark in any of the text of your lab manual means that you are supposed to be thinking about the question being asked, but that you don't need to record an answer.
	This icon means that there is a question in your lab manual that you need to answer in writing in the space provided.
	This icon means that before proceeding, you need to check in with your instructor.

Lab 1: Safety and Rube Goldberg Machines

Pre-Lab Reading

Safety: Student Copy

Safety in the lab is a serious thing. Some of the equipment and chemicals we use can be harmful if safety rules are not followed. Here are some guidelines to help you and others stay safe in the lab:

Plan Ahead	•Read your lab ahead of time. •Ask any questions before you start.
Stay Organized	•Keep your lab bench clear of unneccesary items. •Know ahead of time where safety equiment is in the lab.
Protect yourself	•Know where all safety equipment is in the lab. •Wear a lab coat at all times, and safety goggles as required. •If you get a chemical on your skin, rinse it immediately with lots of water. •Do not eat or drink in the lab.
Report Accidents	•Let your teacher know right away if you spill something, break something, or get hurt.
Use Equipment Properly	•Be careful of cords, and unplug them properly. •Handle hot items with the approriate tools. •If you're not sure how to use/store something, just ask your instructor.
Clean Up Afterwards	•Put everything away. •Clean your glassware and leave it to dry. •Wipe down your work area. •Wash your hands.

In a physics lab, we sometimes use materials or tools that could be harmful if not handled carefully. In this course we will be using electricity and simple machines. Please make sure you do all your lab readings in advance so you are aware of the materials/tools we are using and the associated safety precautions.

I have read, and agree to the lab safety rules as listed on this page:

Signature: ___________________________

Print Name: ____________________ Date: ____________

Safety: Instructor Copy

Safety in the lab is a serious thing. Some of the equipment and chemicals we use can be harmful if safety rules are not followed. Here are some guidelines to help you and others stay safe in the lab:

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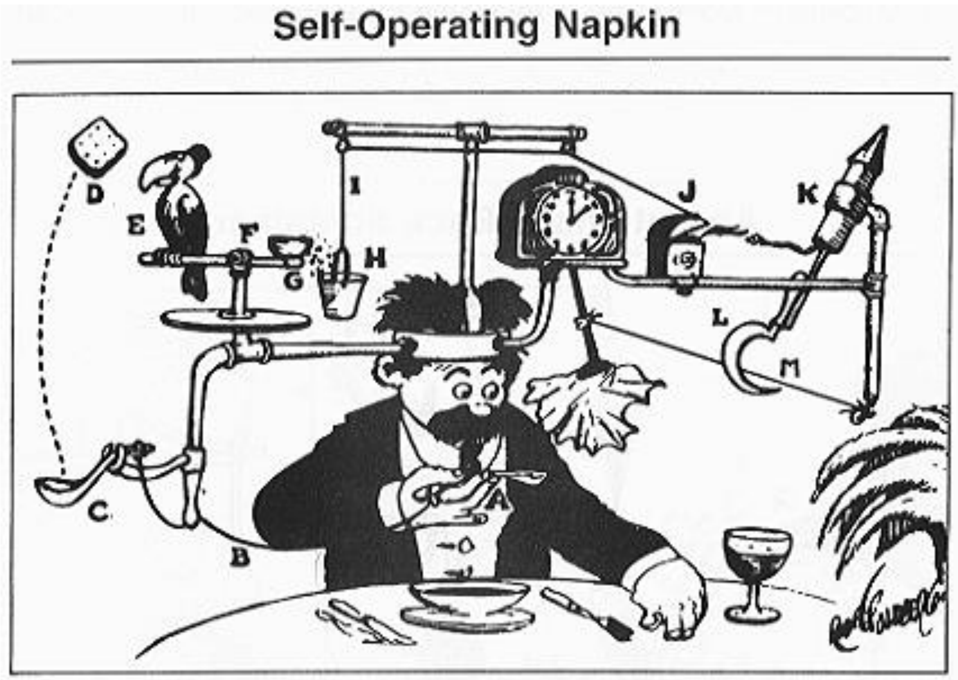
Print Name: _____________________ Date: ____________

Rube Goldberg Machines

Rube Goldberg was an inventor and an award-winning cartoonist who lived from 1883–1970. Within one of his more famous cartoons, he included a character who would build elaborate machines to accomplish very simple tasks in the most convoluted, inefficient, and hilarious way possible. These inventions are often referred to as Rube Goldberg Machines. Often times, the concept of Rube Goldberg has grown to include processes that have become more complicated or confusing (often in reference to bureaucracy).

The picture below shows one of Rube Goldberg's cartoons showing an invention called "The Self-Operating Napkin":



Rube Goldberg's "Self-Operating Napkin" (cropped), by Rube Goldberg, 1931, [public domain], via Wikimedia Commons [Originally published in Collier's, September 26, 1931]

Today, there are competitions held around the world for both children and adults who enjoy creating the types of elaborate inventions depicted in Goldberg's artwork.

To see examples, visit the following videos on YouTube:

- "Six Simple Machine Project Using All Six Machines – Rube Goldberg," posted by Tim Luft, 2012, at https://bit.ly/2RZyrps
- "Rube Goldberg easy examples," posted by Kelly Dunn, 2017, at https://bit.ly/2N0Y3lb"Honda – The Cog," posted by Honda Suisse, 2013, at https://bit.ly/2iyfwRG.

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Pre-Lab Assignment

Name: _____________

1. Why is it important to wear close-toed shoes in the lab? (1)

2. What should you do if you break something in the lab? (1)

3. Why is it important to read through your lab ahead of time? (1)

4. Who was Rube Goldberg and when did he live? (2)

5. What were some of the items used in the three Rube Goldberg Machine videos you watched? (5)

Activity 1: Safety in the Lab

Look at the lab room around you.

What are some types of safety equipment you can see?

What are some types of safety equipment you don't see, but could still access?

Do you see any hazards in the lab?

What are some ways you can minimize these hazard risks?

Activity 2: Using gravity

Many Rube Goldberg Machines use the forces of potential and kinetic energy. Potential energy is stored energy due to an object's position (a child at the top of a slide, for example). Kinetic energy is the energy associated with the movement of an object (a child traveling down the slide).

When the child sits at the top of the slide, they have a high potential energy. As they start to slide down, the amount of potential energy drops, as this energy is converted to kinetic energy. When the child reaches the bottom of the slide, all potential energy has been converted to kinetic energy.

Rube Goldberg machines often contain large amounts of potential energy as they are being set up, and then once the machine is activated or put into motion, all of this potential energy is converted to kinetic energy.

Watch the video, "The Dresser – Rube Goldberg Machine for Getting Dressed | Joseph's Machines," found at: https://bit.ly/2E7V2wm.

In this video what were some of the ways of storing potential energy?

What were some of the ways in which potential energy was released?

What are some examples of kinetic energy you saw in the video?

Activity 3: Rube Goldberg Machines

You and your partner now get to design, build, and test a Rube Goldberg Machine!

Your goal is to roll a marble off of the edge of a table, but your machine must be activated from 4 feet away from the marble. You and your partner get 1 bag of materials to use, and 45 minutes to plan, build, and test your machine. Near the end of class, we will have each pair demonstrate their machine for the rest of the group. Have fun!

Make a simple diagram of your machine here.

Post-Lab Assignment

Name: _____________

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1. What were some of the types of potential energy you used in your Rube Goldberg Machine design? (2)

2. What were some of the ways you caused potential energy to be converted to kinetic energy? (2)

3. What were some problems that you encountered when designing, building and testing your machine? (2)

4. How did you overcome these problems? (2)

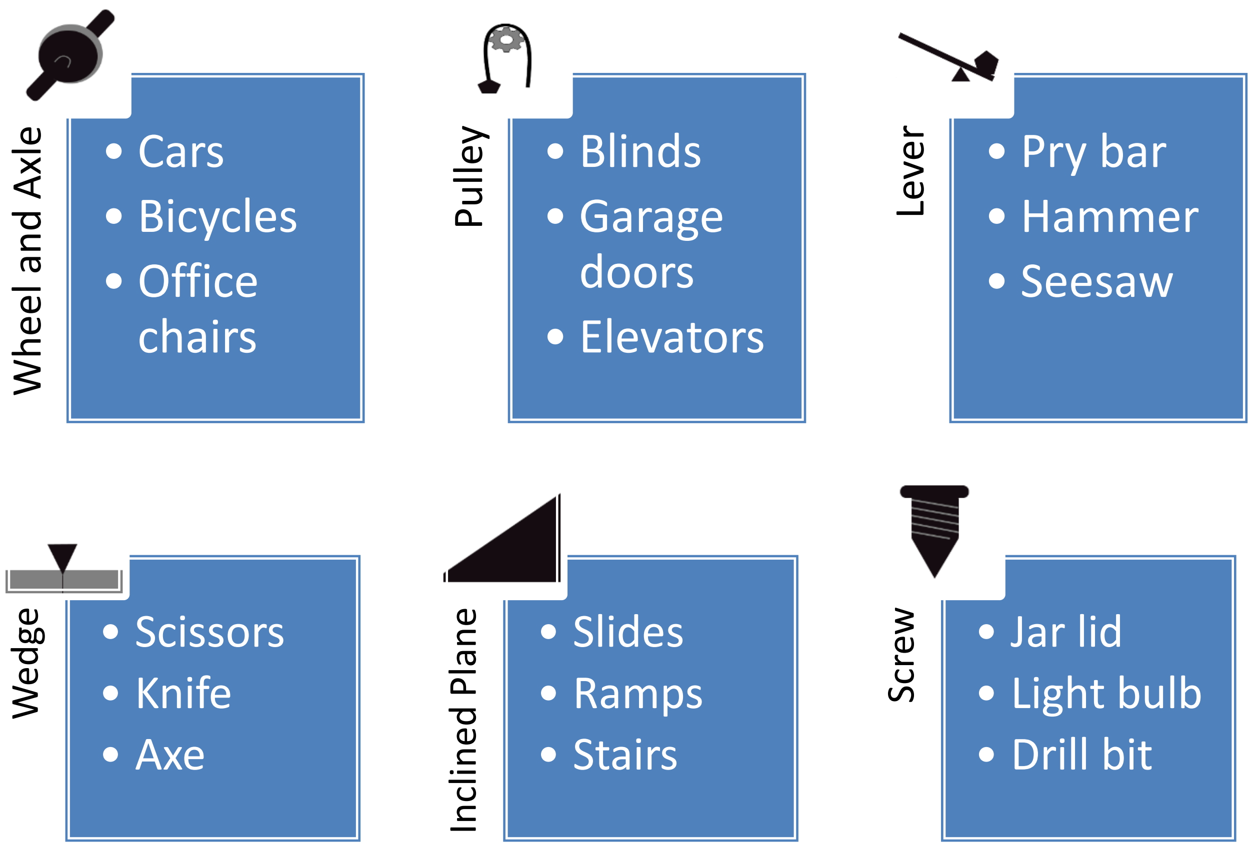
5. What types of materials would you have liked included in your bag of supplies? (2)

Lab 2: Simple Machines

Pre-Lab Reading

Simple Machines

Simple machines are built into our daily lives and we don't even notice that they are there helping us with **mechanical advantage**. These simple machines come in 6 categories: wheel and axles, pulleys, levers, wedges, inclined planes, and screws. See the table below for examples of where each of these simple machines show up where you might least expect them:



Simple machines create **mechanical advantage -** a measure of force amplification achieved by using a simple machine. In other words, mechanical advantage is the help you can get from using a machine to do something instead of just doing it using your own strength. A good example would be a wheel and axle. When you are at the grocery store you *could* carry all your groceries in a basket, but wouldn't it be easier to push them in a cart? This is because the wheel and axle of the cart provide a mechanical advantage and support some of the weight of your groceries.

The term "simple" might downplay the importance of these machines. Early civilizations used these tools to create amazing structures. The pyramids were built using wedges to cut huge stone blocks, levers and pulleys to lift the stones to the build site, and ramps to move the stones up the pyramid into place.

MARK:

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Pre-Lab Assignment

Name: ______________

1. Match the simple machine to its diagram: (3)

Pulley	Wheel and axle	Wedge	Inclined Plane	Lever	Screw

2. Which simple machines are present in the picture below? (3)

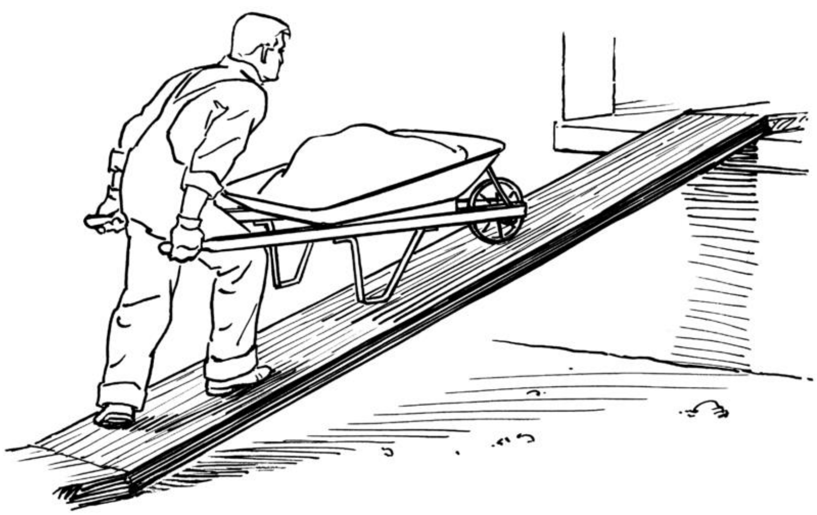


Image: [Inclined Plane (PSF),] by Pearson Scott Foresman [Public domain], via Wikimedia Commons

3. What are some simple machines you have used in your day so far? (2)

4. Describe mechanical advantage. (2)

Activity 1: Levers

You will need:

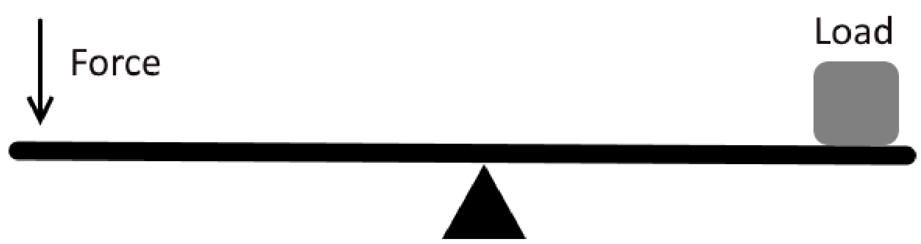
- A large tongue depressor
- A pencil with a hexagonal cross-section
- 20 pennies

A lever consists of two parts: a beam and a fulcrum. This setup is then used to create mechanical advantage when applying force to move a "load" (the term we use for the object we are trying to move.)

There are three types of levers, each defined by where the fulcrum, force, and load are positioned in the setup of the lever.

Class One Lever

The fulcrum is in the middle of the beam and the force and load are positioned on opposite sides of the fulcrum. Examples of Class One Levers include seesaws, crowbars, and scissors.

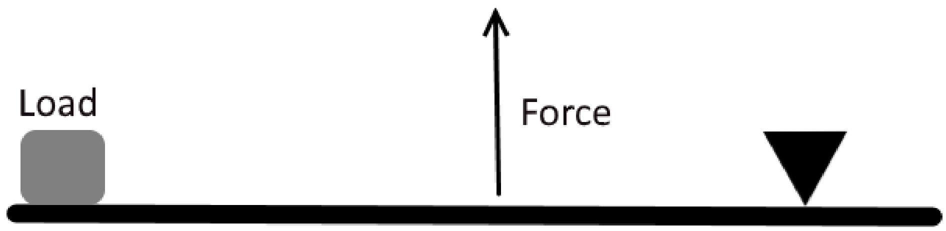


Class Two Lever

The load is in the middle of the beam, and force and fulcrum are on opposite sides of the load. Examples of Class Two Levers include wheelbarrows, nutcrackers, and bottle openers.

Class Three Lever

The force is in the middle of the beam, and the load and fulcrum are on opposite sides of the force. Examples include tweezers, hammers, and your jaw.



Each of the types of levers can be set up in different ways to manipulate mechanical advantage.

In this activity, you are going to use a class one lever and some pennies to try out different scenarios involving load and force.

You are going to use pennies for both the load and the force. The pennies you are trying to lift are the load and the pennies you use to balance your load are the force. Your beam will be your tongue depressor, and your fulcrum is a pencil.

First Set Up: Fulcrum in the middle

Your fulcrum should be placed in the exact center of your beam. Measure your tongue depressor and mark the exact middle, and place your fulcrum under this mark. Place 5 pennies on the end of your beam to represent your load (pennies at the 30 cm mark). Look at the diagram below if you are having trouble setting this up.

How much force (how many pennies) do you need to put on the opposite end of the beam (0 cm mark) to make it balance perfectly?

Second Set Up: Fulcrum close to force

Now remove the pennies, and slide your fulcrum 2 centimeters to the left. Place your 5 pennies at the end of the beam (right). How many pennies do you think it will take to balance this load now that the fulcrum has moved?

Now add enough pennies to make the two ends balance.

How many pennies did this take? Was your guess correct?

Third Set Up: Fulcrum close to load

Now remove the pennies, and slide our fulcrum 2 centimeters away from the left end. Place your 5 pennies at the end of the beam (30 cm mark). How many pennies do you think it will take to balance this load now that the fulcrum has moved again?

How many pennies did this take? Was your guess correct?

Is there a relationship between the distances of the load and force to the fulcrum and the force needed to make your apparatus balance? If so, can you describe this relationship?

Archimedes was a Greek mathematician, physicist, and engineer who was born in Syracuse in 287 BC. One of his more famous quotes is: "Give me a lever long enough and a fulcrum on which to place it, and I shall move the world." Why do you think Archimedes said this?

Take apart your lever and try to build a new one with which you can balance a load of 10 pennies with 1 penny of force.

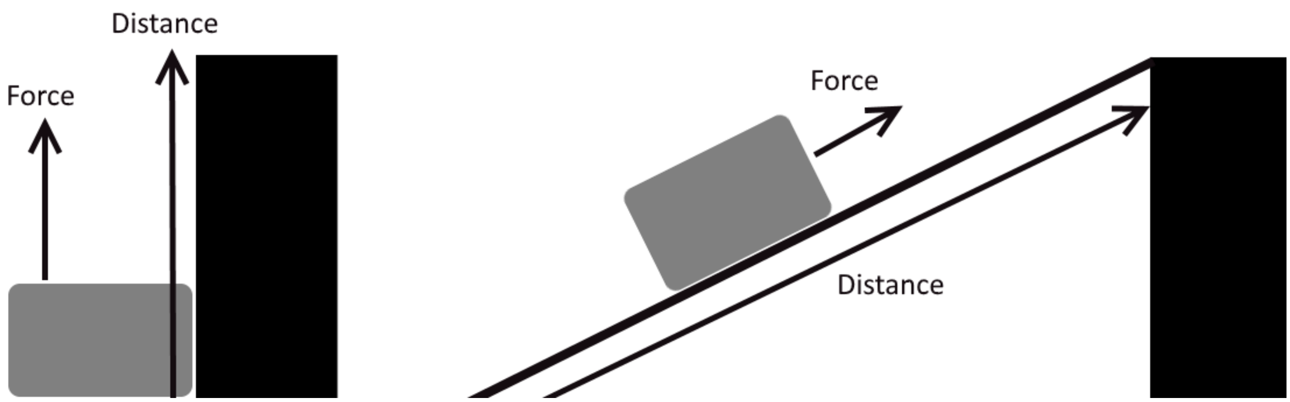
a. Where did you put the fulcrum to achieve this?
b. What length of the beam was on each side of the fulcrum?

Activity 2: Inclined Planes

You will need:

- A short board
- A long board
- 5 large books or textbooks (for elevating the end of your ramps
- A spring scale
- A wheeled weight (ie., a roller skate)

An inclined plane is a flat supporting surface on which one end is higher than the other. It is typically used for raising or lowering a load. When an object is moved up an inclined plane, less force is required than lifting it straight up, but at the cost of adding to the length of the distance moved.



Stairs are a good example of an inclined plane. Think about getting from the first floor of a building to the second floor. Could you generate enough force to jump 2 meters up to a second floor? Probably not. However, if you use stairs, you can break up the force needed to move up into smaller, more manageable amounts. Most people can't do a vertical jump of 2 meters, but most can take 10 steps of 20 cm each.

Inclined planes are often referred to as ramps. We see ramps in lots of places in our daily lives - to make buildings accessible to wheelchairs, to load cargo into moving vans, to park your vehicle in a multi-level parkade, etc.

A neat fact about the inclined plane is that two of the other types of simple machines are actually derived from it: wedges and screws are both just modifications of the inclined plane. A wedge is technically an inclined plane that moves when it is used and a screw is an inclined plane wrapped around a cylinder.

Stack your 5 textbooks.

How tall is your pile of textbooks, in centimeters?

Hang your wheeled weight from your spring scale, and hold it up so that the bottom of the weight is level with the top of the textbook pile, but not resting on it.

What is the measure of this force on your spring scale?

This is the amount of force needed to achieve this change in height by lifting the weight vertically.

Now rest one end of your short board on the pile of textbooks. You have created a ramp! Attach your weight to the spring scale and slowly pull the weight up the ramp.

What is the force measurement on your spring scale required to lift the weight? How does this compare to your first measurement?

Now replace the short board with the long board.

What effect do you think this will have on the force needed to pull the weight up the ramp?

Now pull your weight up the new, longer ramp.

What was the force required to do this? Was your prediction from above correct? Why or why not?

TALK IT OUT

- What do you think would happen if you made your pile of books taller?
- What about shorter?
- What if we joined two long boards together to make the ramp twice as long?
- What if we covered our ramp with a layer of ice?
- What if we covered our ramp with a layer of sandpaper?

Having discussed these, can you come up with a few statements about ramps and what sort of factors could affect their mechanical advantage?

Activity 3: Compound Machines

You will need:

- 12 craft sticks
- 2 tongue depressors
- 2 drinking straws
- 1 small wooden dowel
- 1 rubber band
- 1 glue gun
- 6 grapes


Image: Flyfishing,

Compound machines are a combination of two or more simple machines. A good example of a compound machine is a fishing rod: the rod itself is a lever that lets you cast your line further than you would be able to throw it normally. Then the reel is a wheel and axle that lets you easily pull in your catch.

A can opener is also a compound machine combining three different simple machines: the two arms that you squeeze to clamp onto the can are levers, the handle you turn is a wheel and axle, and the blade that cuts into the can is a wedge.

In this part of the lab, your challenge is to build a catapult that will throw a grape as far as possible.

Working in pairs, you and your partner will receive the supplies list above and use your knowledge of simple machines and mechanical advantage to build a catapult. This lab will end in a grape-catapulting competition. Each pair will shoot their catapult three times and will calculate their average distance thrown. The pair that built the catapult with the highest average distance is the winner!

Plan your catapult here:

Throw 1: ________________

Throw 2: ________________

Throw 3: ________________

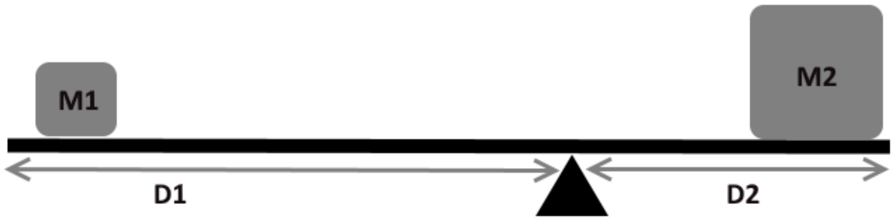
Average: _______________

MARK:
____
10

Post-Lab Assignment

Name: ______________

1. Archimedes determined the “Law of the Lever” in which balance occurs when the mass x distance on one side of the fulcrum is even to the mass x distance on the other side of the fulcrum. This principle applies only to class one levers.



$$M1 \times D1 = M2 \times D2$$

Using your data from Activity 1, was Archimedes correct? (6)

Show your work below:

First Setup: M1: D1: M1 x D1: M2: D2: M2 X D2	Second Setup: M1: D1: M1 x D1: M2: D2: M2 X D2	Third Setup: M1: D1: M1 x D1: M2: D2: M2 X D2

2. To calculate the mechanical advantage of a ramp, you divide the length of the ramp by the height it raises the object. Using your measurements from Activity 2, calculate the mechanical advantage provided from your short board and long board ramps. (4)

Show your work below:

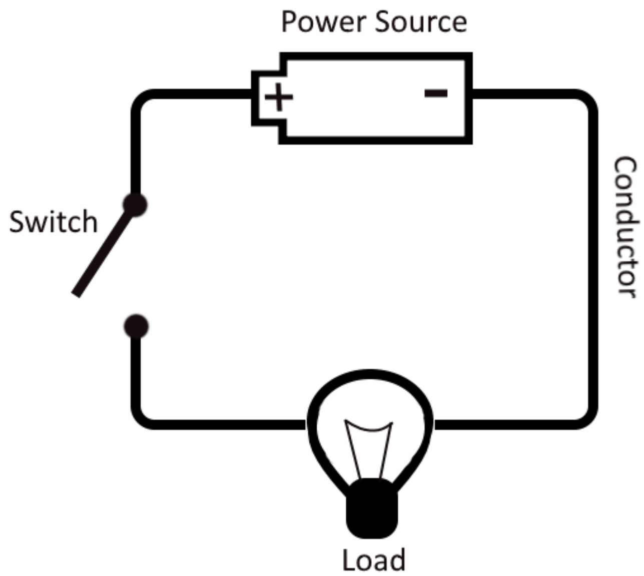
Short ramp:	Long ramp:

Lab 3: Circuits

Pre-Lab Reading

An electrical circuit is a line through which an electrical current flows. A circuit typically contains:

- conductors (usually wire)
- a switch
- a load (something that uses electricity)
- a power source

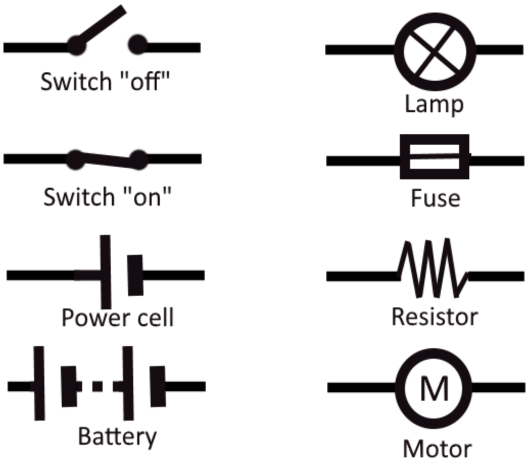


We can map out circuits using symbols.

In a circuit, there is an uninterrupted flow of electrons. The rate of flow of these electrons is called **current**. The electrons must have something to flow through, called a conductor; we use wiring as a conductor. In order for these electrons to flow through the conductor, there needs to be a force applied; we call this force **voltage**. Voltage is supplied by the energy source — typically through a battery, an electrical outlet, or a power cell.

AA, AAA, C, and D batteries all have a voltage of about 1.5 V. E batteries are 9 V and a car battery has a voltage of about 13 V. The electrical outlets in your home are probably 120 V, and the residential power lines supplying your home with energy carry a voltage somewhere between 12,000 V and 19,000 V. High voltage power lines used for long distance transmission can carry anywhere between 155,000 and 800,000 V. A bolt of lightning can carry as much as 1 billion volts.

The electrons flowing through a circuit can convert their energy to other types, depending on the device attached to the circuit. A doorbell converts electrical energy to sound energy. A blender converts electrical energy to kinetic energy. A toaster converts electrical energy to heat energy. These are all types of energy conversions.



Different devices, loads, power sources, etc., have different symbols. Look at the figure to the left for some of the symbols we can use in a circuit diagram.

In order for an appliance to work, it needs to have an uninterrupted flow of electrons cycling through the circuit. A switch turns a circuit off by disrupting the path electrons take around the circuit. The figure of the circuit above has a switch in the “off” position - electrons don’t have a circular path to flow through, therefore there is no current. An “on” position switch will complete a circuit, creating a circular path for electrons and allowing for a current.

A single circuit can have several loads, either in series (all in a row) or in parallel (on separate branches of the circuit). Loads in series would all work on the same switch, but loads in a parallel circuit could have separate on/off switches.

In this lab, we will build an electrical circuit containing a motor, a type of load that converts electrical energy into kinetic energy. We will then control the direction of that kinetic energy to navigate a path with our motor; this is similar to driving a car.

Later in the lab, we will look at coding, or how blocks of instructions to a device can be used to accomplish a task. When coding, humans use a language that both people and computers can understand. This coding, or language, can take many forms. Binary is a type of coding using sequences of zeros and ones to store data or instructions. The word “electricity” converted into binary code becomes: 01100101 01101100 01100101 01100011 01110100 01110010 01101001 01100011 01101001 01110100 01111001. Java and JavaScript are examples of coding languages often used to build websites, while CSS (another coding language) adds colour and styling to these pages.

MARK:

____

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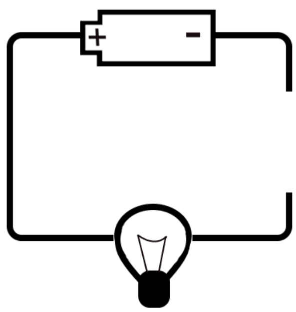
Pre-Lab Assignment

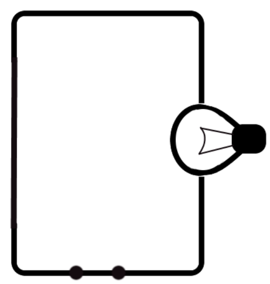
Name: ______________

1. Define current: (1)

2. Define voltage: (1)

3. For each circuit below, why won't they work, and how could you fix them? (2)





4. Match the symbol to its name: (4)

Lamp

Resistor

Battery

Switch

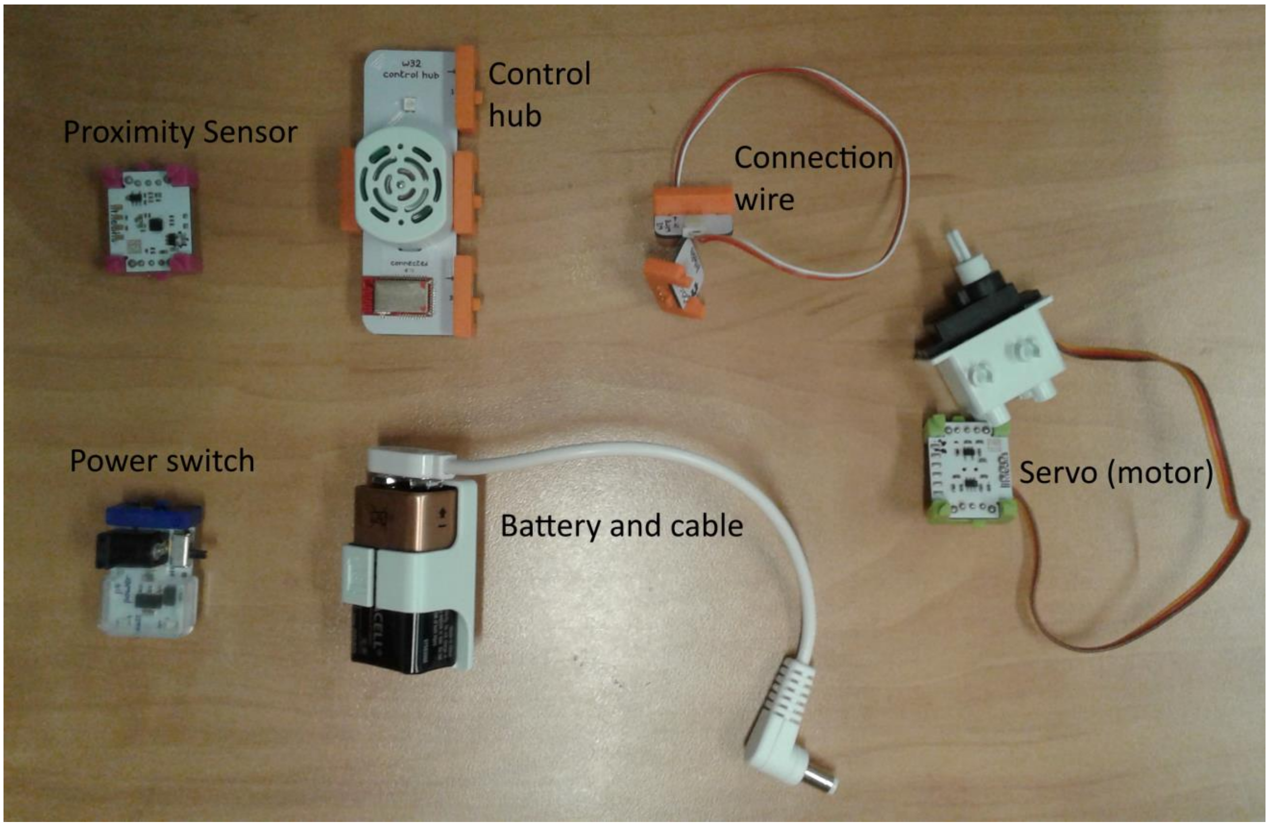
5. Name two electrical devices you use at home and what form of energy they convert electrical energy to (Do not use the examples from the pre-lab reading): (2)

Activity 1: Building

You will be assembling a Star Wars © droid™ using the littleBits™ inventor kit. You will be working in groups of 3 to do this activity.

First, you need to identify and locate the 6 bits in your droid inventor kit:

- Power switch
- Proximity sensor
- Connection wire
- Control hub
- Servo (motor)
- Battery and cable



Follow the instructions on the littleBits website at: https://bit.ly/2Ub9sFO to build your droid. You can also use the app from the App store at https://apple.co/2WBzZZF or Google Play at https://bit.ly/2WFhfIu.

When you have completed missions 1-4, what components are in your circuit?

Draw a diagram of how your components are connected.

Does this look like the circuit diagrams we've done in class? Why or why not?

Do you think this is a series or a parallel circuit? Why?

Activity 2: Driving

Once each group is done building their droid, teams can start building a maze through which the opposite team will have to navigate their droid.

You will build your droid maze on a 1-metre x 1.5-metre flat surface. You will get 5 metres of masking tape to use as a track. The droids will have to follow the masking tape wherever it leads.

Draw a diagram of the track you built for the other team to navigate:

Once teams have built their track, they will have a chance to race against one another using the littleBits app to control their droid.

Which team won? Why?

Now switch tracks, so that your own droid is on the track your own team made. Have one team member control the droid, but turn their back on the track. It is the rest of the team's job to give instructions to the driver, who cannot see the track.

Did your droid make it through your own track? Was this difficult or not difficult? Why?

Activity 3: Coding

Coding is very similar to giving someone instructions. Using the diagram you made of your track above and the symbols ↓↑← →, write a series of instructions a computer could follow to navigate your droid through the track.

My instructions to navigate the track:

Compare your sequence to what your group members came up with.

Are the sequences the same? Where are the differences? Is there a “right” answer? Why or why not?

MARK:
______
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Post-Lab Assignment

Name: _____________

1. Draw a circuit containing a battery, a switch, a motor, and a lamp, all in series: (2)

2. What components of a circuit are in a flashlight? Draw a circuit diagram of how you think a flashlight may be set up. (2)

3. Describe the process from Activity 2 that your team used to have the droid navigate the maze you made when the driver was not allowed to look at the droid or the maze. (2)

4. How did this process compare to the coding instructions you came up with in Activity 3? What was the same? What was different? (2)

5. Try out the coding activity from the Google Doodles Archive at https://www.google.com/doodles/celebrating-50-years-of-kids-coding
(Click on the bunny picture with the play arrow on top to start the game). Play to at least level 6.
What was similar between this coding activity and your droid instructions? What was different? (2)

References

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