Name: ______________________ **Period:** ________ **Date:** ______________

Stations Labs – Exploring Newton's Laws

Newton's Laws of Motion

Newton's Laws of Motion are how we understand any object in motion. The three laws, which were first published in 1867 by **Sir Isaac Newton**, state:

1. An object at rest will remain at rest until acted upon by an unbalanced force, and an object in motion will remain in motion until acted upon by an unbalanced force.
2. The force needed to accelerate an object is directly proportional to the mass of the object. Accelerating objects of greater mass require a greater amount of force. Likewise, the acceleration of an object is directly proportional to the force being applied to the object. Increasing the rate of acceleration of an object requires a greater amount of force on the object. (Mathematical notation: **F=ma.)**
3. When one object exerts a force on a second object, the second object simultaneously exerts a force on the first object equal in magnitude and opposite in direction.

Predicting Newton's Laws

1. Lift your arm. Now, lift just your pinky finger. Which of Newton's Laws would explain why different force is required to lift your arm?
2. Which of Newton's Laws would explain why running on a soft surface will result in less impact forces on your legs than running on a hard concrete surface?

Instructions

There are 8 stations set up around the room for you and your group to complete. These stations are designed to explore Newton's Laws of Motion and the different types of forces involved in various physical activities.

When you get to each station, read the **Background** on your lab sheet. Then, review the procedures at the station. You will have approximately 15 minutes to complete each station.

Newton's Laws

Station 1: Lifting Force

Background

Gravity is a force that acts on all objects. In order to lift an object, a force has to be applied in the opposite direction of gravity. For example, a basketball player has to push off the ground with his or her feet to jump in the air.

When an object is at rest, it also experiences something called **static friction** that is the friction between two objects that are not moving.

Once an object starts moving, a **friction** force always acts in the opposite direction of motion. This type of friction can be **sliding** or **rolling friction.**

In this activity, you and your lab group will perform a series of tests to model the **lifting force** and **friction**.

Materials Needed

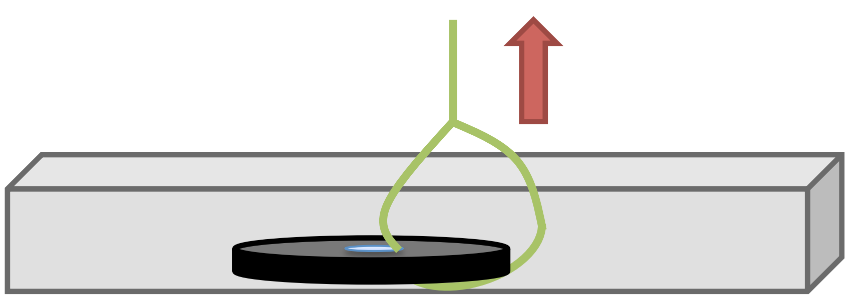
- Weight (at least 1kg)
- String
- Spring Scales
- Tray
- Ruler

Procedures

Lifting Force, Static Friction, Sliding Friction

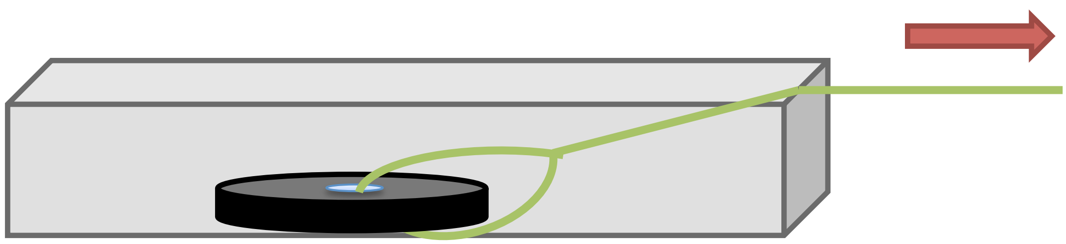
1. Find the force required to lift your object.
    a. Tie a string around one side of your object and attach it to your spring scale
    b. Place the object in the tray
    c. With the spring scale, lift one side of the object 10 cm off the tray
    d. Record the force on the spring scale
    e. Complete 3 trials and average your values

Trial	Force
1	
2	
3	
AVG.	



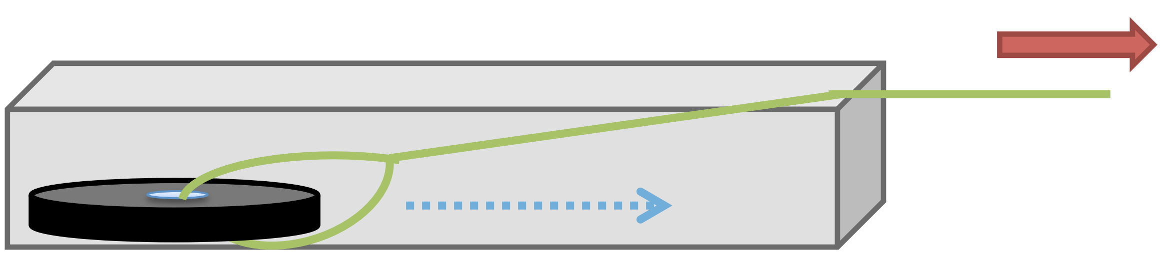
2. Find the **static friction** between your object and the surface it is on.
    - *Static friction is friction between two objects that are not moving relative to each other.*
    a. Tie a string around the object. Place the object in the middle of the tray and run the string to the outside of the tray
    b. Have one person hold the tray in place on the table
    c. With the spring scale attached to the string outside of the tray, slowly pull on the object, parallel and level with the top of the tray
    d. Record the largest force on the scale BEFORE the object starts moving
    e. Complete 3 trials and average your values

Trial	Force
1	
2	
3	
AVG.	



3. Find the **sliding friction** between your object and the surface it is on.
    - *Sliding friction is friction between two objects that are sliding past one another at a constant speed.*
    a. Tie a string around the object. Place the object at the end of the tray and run the string to the outside of the tray
    b. Have one person hold the tray in place on the table
    c. With the spring scale attached to the string outside of the tray, slowly pull on the object, parallel and level with the top of the tray
    d. Record the largest force needed to keep the object sliding at a slow, CONSTANT speed
    e. Complete 3 trials and average your values

Trial	Force
1	
2	
3	
AVG.	



Station 2: Resistance and Drag

Background

Resistance (or drag) is a **friction** force usually caused by wind or water. Like all friction, it acts opposite the direction of motion. In this activity, you will compare the difference in resistance between air and water.

Materials Needed

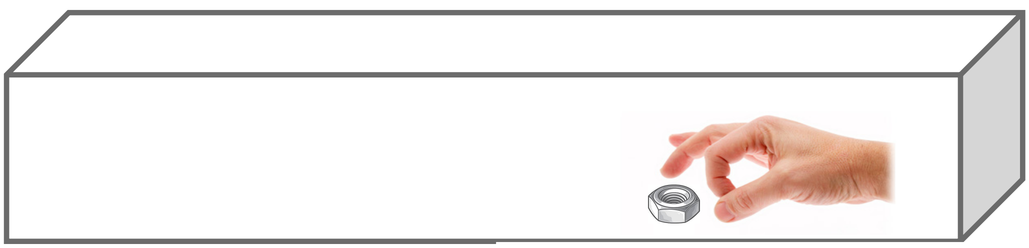
Tray
Tray with water
Hex nut

Procedures

Before you begin: go to this link: http://www.physics4kids.com/files/motion_friction.html
Read “Friction and Gases” and “Friction and Liquids”

Drag/Resistance

1. Place a hex nut toward the end of the empty tray.
2. With your middle finger, flick the hex nut ONLY ONCE toward the other end of the tray. If done correctly, the hex nut should slide along the bottom of the tray.
3. In the diagram below, make a mark that shows how far the hex nut traveled.



http://www.fotosearch.com/clip-art/hex-

4. Repeat Steps 1 and 2 in a tray with water. Try to apply the same amount of force on the hex nut as the first time you flicked it with an empty tray.
5. In the diagram below, make a mark that shows how far the hex nut traveled along the bottom of your tray full of water.

http://www.fotosearch.com/clip-art/hex-

Station 2: Drag/Resistance - Analysis Question

1. Which scenario, out of the water or under water, had a greater **drag/resistance** between the hex nut and the tray? Explain why you think this happened?

Station 3: Balance

Background

Newton's 1st Law of Motion states that an object at rest will remain at rest unless acted upon by an unbalanced force, and an object in motion will remain in motion unless acted upon by an unbalanced force. We use muscles in our body to help us move and balance. **Newton's 3rd** Law says that when one object exerts a force on a second object, the second object simultaneously exerts a force on the first object equal in magnitude and opposite in direction. In this activity, you will see how muscles help you balance and how this is a representation of **Newton's 1st Law** and **Newton's 3rd Law.**

Materials Needed

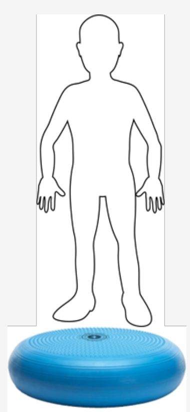
Stability Cushion

Procedures

TASKS
1. With your partner next to you to provide support, **stand** on the stability cushion with **both feet** and **try to maintain your balance for at least 30 seconds**. **If you ever feel like you are going to fall, simply step off the stability cushion.**
2. While balancing, have your partner GENTLY and SLOWLY push you *backward*.
3. While balancing, have your partner GENTLY and SLOWLY pull you *forward*.
4. While balancing, have your partner GENTLY and SLOWLY sway you from *side to side.*

Station 3: Balancing - Analysis Questions

1. Draw and label all forces acting on a person trying to maintain his or her balance on a stability cushion. (Hint: think of where you start and direction of the forces needed to move the body.)



2. If your partner pulls you toward your left, in which direction are you pushing on the stability cushion to maintain your balance?

3. How does Newton's 3rd Law apply to maintaining your balance on a stability cushion?

Station 4: Tension

Background

Exercise bands, or resistance bands, use the force of **tension**, which is the force exerted when an object is stretched apart. In this activity, you and your group members will manipulate three different exercise bands of varying resistance to explain **Newton's 2nd Law of Motion**: The change in motion of an object is directly proportional to its mass and the force applied to it.

Materials Needed

Set of Exercise/Resistance Bands (Yellow, Red, Blue)
Meter Stick
Spring Scale

Procedures

	Task
1	Using the spring scale, record the mass of each of your exercise bands in the table below.
2	For each of the exercise bands, tie the ends together in a knot to create a loop.
3	At the knot, pin the exercise band firmly against your table with the palm of your hand. Attach the hook of your spring scale at the other end of the exercise band. Be sure not to tear or punch a hole in the exercise band.
4	Lay the meter stick on the table, parallel to the length of your exercise band. By pulling on the spring scale, measure how much force it takes to stretch each exercise band 5cm, 10cm, 15cm, and 20cm. Be sure to pull in a direction parallel to the table (keep it flat).

Analysis & Interpretation

Table 1: Force Required to Stretch Exercise/Resistance Bands

Exercise Band	Mass (g)	5cm (N)	10cm (N)	15cm (N)	20cm (N)
Yellow					
Red					
Blue					

Graph 1: Force (N) vs. Length of Stretch (cm)
Use your data in Table 1 to create a graph that outlines the amount of force needed to stretch each exercise band a certain distance. Be sure to label the x and y axis and identify your three different data sets (yellow, red, blue bands).

Station 3: Resistance Bands - Analysis Questions

1. Rank the different exercise bands from least resistance to most resistance. Use your data to draw your conclusions.

2. What is the relationship, if any, between the mass of the exercise band and the amount of force needed to stretch the exercise band?

3. What is the relationship, if any, between the amounts of force needed to stretch the exercise band and the length of the stretch?

4. Does your data in Table 1 and Graph 1 support Newton's 2nd Law of Motion? Remember to use your data to justify your answer.

Station 5: Compression

Background

During a muscle contraction, muscle fibers pull on one another, and this is called a **compression** force. In this activity, you and your group members will perform two exercises and use a spring scale to calculate the amount of force generated by the quadriceps and hamstrings in your legs.

Materials Needed

Scale
String

Procedures

Task	Response
Quadriceps 1. Have your group member sit up at the edge of a lab stool with his/her feet hanging freely without touching the ground, creating a 90° angle at the knee. 2. Place the string around the person's shin and move behind your partner. Hold the scale attached to the string under the chair or table and be sure the string is parallel to the ground. 3. Ask your partner to pull forward against the string for 3 seconds, and then relax. Be sure to hold the scale in place and make sure your partner's leg does not lift off the table or chair. Remind your partner to focus on using ONLY the quadriceps to pull against the string. 4. Record the highest value obtained on the scale. Repeat the same test two more times and find the average of your values.	
Hamstrings 1. Have your group member remain in the same position on the table/chair. Move in front of him/her and hold the scale attached to the string tightly with the string parallel to the ground. 2. With the spring scale attached, tell your partner to pull backward against the string for 3 seconds, and then relax. Be sure to hold the scale in place and make sure your partner's leg does not lift off the table or chair. Remind your partner to focus on using ONLY the hamstrings to pull against the string. 3. Record the highest value obtained on the scale. Repeat the same test two more times and find the average of your values.	
Analysis Question: Which muscle (quadriceps or hamstring) generated the greatest amount of force? Why? (Hint: Newton's 2nd Law.)	

TRIAL	Force (N) exerted by Quadriceps
1	
2	
3	
AVG.	

TRIAL	Force (N) exerted by Hamstrings
1	
2	
3	
AVG.	

Station 6: Force as Pressure

Background

In this activity, you and your partners will assemble a Cartesian Diver, in which you will manipulate the pressure inside of a bottle and examine the effects on its contents.

Materials Needed

Clear 2-Liter Bottle With Cap
Eyedropper With Rubber Bulb
Water

Procedures

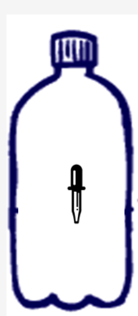
	Task	Response
1	Place the eyedropper into the bottle. The eyedropper should barely float and the water in the bottle should be overflowing. Seal the bottle tightly with the cap.	
2	With both hands, squeeze the sides of the bottle and hold, applying an increasing amount of force. Describe what happens to the eyedropper.	*Observations:*
3	Repeat step 2, but this time pay attention to what happens to the **contents (inside) of the eyedropper**. Record your observations.	
4	Practice applying varying amounts of pressure to get the eyedropper to remain stationary in the middle of the bottle.	

Station 6: Pressure - Analysis Questions

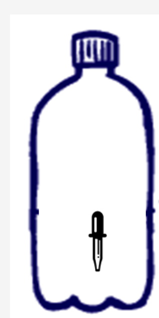
1. What is the relationship, if any, between the amount of force you used to squeeze the bottle and the motion of the eyedropper?

2. Draw the forces acting on the bottle as the eyedropper is stationary in the middle of the bottle, as the eyedropper is sinking to the bottom of the bottle, and as the eyedropper is rising to the top of the bottle:

Rising



Stationary



Sinking

Station 7: Inertia

Background

Newton's 1st Law says that an object at rest will remain at rest, unless a force causes it to move. This is also called the **Law of Inertia**. **Inertia** is the resistance to a change in motion. In this activity, you will see how the inertia affects objects that are stacked on top of each other.

Materials Needed

Glass of water
Index card
coin

Procedures

	Task
1	Watch the video at this link: http://www.exploratorium.edu/snacks/whack_a_stack/
2	Place the index card on top of the cup of water. Then, place the penny at the center of the card.
3	Quickly flick the card so it moves horizontally away from the cup. Watch what happens to the coin.

Station 7: Inertia - Analysis Questions

1. Why do you think the penny didn't move with the card? (Hint: Think about inertia and what you saw with the blocks in the video.)

2. What do you think had more inertia: the card or the coin? Explain your reasoning.

3. How could you repeat this experiment to make the coin move **with** the card? Try out your hypotheses and see if you can make it work.

Station 8: Mass and Force

Background

Newton's 2nd Law shows us the relationship between force, mass, and acceleration. It says that the change in motion of an object is directly proportional to its mass and the force applied to it. In this activity, you will examine how the mass of an object determines the force of impact.

Materials Needed

Box
Flour
Marbles (two sizes)
Ruler

Procedures

	Task
1	Read this link: https://www.exploratorium.edu/exploring/space/space5.html
2	Measure the mass of each marble using the digital scale.
3	Drop the smaller marble from a height of 30 cm. Measure the diameter and depth of the impact crater.
4	Drop the larger marble from a height of 30 cm. Measure the diameter and depth of the impact crater.
5	Shake the box gently until the flour is level again. (No craters.)

Marble	Mass (g)	Height of Drop (cm)	Diameter of crater (cm)	Depth of crater (cm)
Smaller				
Larger				

Station 8: Mass and Force - Analysis Questions

1. Which marble do you think hit the flour with a greater force? Why?

2. Predict: How massive was the asteroids that caused craters on Earth and the Moon?