EXERTING FORCES LAB

Purpose:
What are the strengths/amounts and effects of various types of forces?

Materials

Station 1: Ball and Water Ball Bucket Water	Station 2: Paper Clips and Magnets Clear plastic cup Paper clips Strong magnet	Station 3: Balloons, fabric and fur Balloons PVC rods Scrap of wool, fur, or an old sock
Station 4: Dropping Paper A flat piece of paper A sheet of paper folded so that it is 1/4 its original size A crumpled piece of paper	Station 5: Ramp and Block Wooden blocks or slotted masses board for ramp with two different surface books or blocks to support ramp	Station 6: Rubber-band stretch A rubber band 3 rubber bands knotted in a line 3 rubber bands hooked or knotted together A horizontal support on which to hang the rubber bands 5-7 Film canisters with screw-in hooks, weighted to ~ 20 g each Ruler
Station 7: Scales Bathroom scales	Station 8: Book or hanging object A book placed on a table A picture hanging on the wall	Station 9: Tow truck Truck or car with a string tied to it

Pre-lab Discussion:

1. What do you think is a force?

2. How do you know when you exert a force?

3. Make a list of the different forces you exerted in the last five minutes.

4. How strong a force do you think you can exert?

5. What are some things that can happen to an object when a force acts on it?

Directions:

After answering the questions above, go around each station and at each station create a chart that includes the following:

1. A picture or diagram showing each situation.
2. Are there any forces exerted?
3. What/who is applying the force?
4. What object is receiving/feeling the effect of the force?
5. What effect is the force having on the object?
6. What would you call the force being demonstrated at this station?

At each station, besides the questions above, also answer the questions written below:

<u>Station 1: Ball and Water</u>

1. Place the ball in the bucket of water. What happens to the ball?

2. Are there any forces acting on the ball?

3. Now push the ball all the way under the water and hold it there. What forces do you think act on the ball now?

4. Do you feel any forces acting on your hand as you hold the ball under the water?

<u>Station 2: Paper clips and magnet</u>

1. How can you use the paperclips and magnet to demonstrate forces?

2. What force(s) are involved?

3. How can you figure out the strengths of these forces?

<u>Station 3: Balloons, fabric and fur</u>

1. Inflate the balloons. Hold both balloons up with one hand and observe their behavior. Then rub the balloons with the different materials provided. Describe what happens. What do you think is going on?

2. What is the direction of the forces on the balloons?

Station 4: Dropping Paper

1. Compare how fast the three papers fall to the ground: (be sure to drop the papers from the same height each time!). The three papers are: a sheet of paper held horizontally, a sheet of paper folded to 1/4 its size (held flat), and a piece of paper crumpled into a ball. How do the falling rates compare?

2. Are there any forces involved?

Station 5: Ramp and Blocks

1. Set up a ramp with the board and the books or blocks. Test how far a wooden block or slotted mass will slide on the ramp and floor before stopping. Change the angle of the ramp. What do you observe?

2. Repeat the experiment, changing the ramp surface and record your observations. What forces are involved in the motion of the block?

3. What changes the motion of the blocks/slotted masses?

4. What is the direction of the forces acting on the block/slotted mass?

Station 6: Rubber band stretch

1. Suspend the rubber band from a horizontal support. Predict what will happen if one weighted film canister were hung from the rubber band. How about two? Three? Try it and record your observations.

2. Predict what will happen if you tried the same canisters with two configurations of knotted rubber bands: (1) three rubber bands knotted to each other lengthwise and (2) three tied together so they are side-by-side. Explain your reasoning. Try it and record your observations.

3. What do you think causes the differences between the single rubber band and the two configurations of knotted rubber bands?

4. Is there a practical application for this activity?

Station 7: Bathroom scales

1. Hold up the bathroom scales and use your hands to squeeze on it. What readings do you get?

2. Is it close to your weight?

3. What forces are involved?

4. How does the scale work when a person stands on it?

Station 8: Book on a table or picture on the wall

1. What force(s), if any, act on the book? Explain your reasoning.

2. What force(s), if any, act on the picture hanging on the wall? Explain your reasoning.

Station 9: Tow truck

1. Tie the string to the front bumper of the car truck? Pull it with the string. What are all the forces involved?

Post-lab discussion:

1. At which one of the stations have you exerted a force?

2. Were there any stations where it wasn't you that exerted the force?

   a) If so what exerted the force?

   b) What object received the force that was exerted?

   c) What effect did the force have?

3. At any station, was there always motion when force was exerted?

4. Do you always have to touch an object in order to exert a force?

5. Are there any factors that a person could control to change the amount of force?

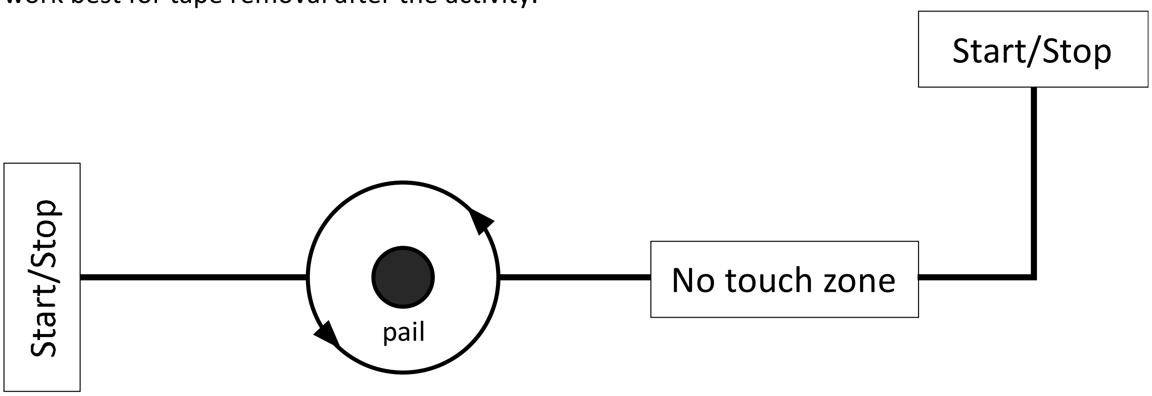
6. Summarize what you learned about forces from this activity.

7. Do you know the names of any of the exerted forces? List them.

Broom Ball – The Game Lab

Purpose:
What is a force and what does it do?

Materials:
Broom with flexible bristles and a plastic casing at the top of the bristle end.
Bowling ball and soccer ball or basket ball
Large pail containing sand
Course marked off with tape on the floor (see diagram below). Blue painters' masking tape or electrical tape work best for tape removal after the activity.



The rules of the game:
1. Broom Ball is played as a relay race.

2. There are two teams. Half of each team will be stationed at each end of the course.

3. The bowling ball should be at rest at one end of the course and the soccer ball will be at rest at the other end. Each student will run the course from whichever end he/she is one way using the bowling ball, and coming back using the soccer ball.

4. The ball may be manipulated only with the bristles of the broom. If any part of the broom other than the bristles touches the ball that is a penalty. If the ball touches any obstacle in the room, such as walls, pail, furniture, a student foot, etc. that is a penalty.

5. The clock starts when the first player takes off. Everybody should follow the course. You must go all the way around the large pail (360 degrees), through the no touch zone without touching the ball with the broom, around the corner and bring the ball to a complete stop in the starting box, before the next player takes off reversing the course.

6. After the last team member has completed the course the watch is stopped and a time penalty is added to the total time for each penalty while the ball was in play.

7. The team with the shortest time wins.

Post-lab discussion

1. What three things are the most difficult when it comes to handling the ball?

2. Was there a difference between handling the bowling ball and the soccer ball? Explain.

3. How can a player use the broom to overcome the difficulties mentioned in question 1? (What strategies would you recommend to a teammate?)

4. How does the ball move in the no-touch zone?

5. What causes the motion of the ball in the no-touch zone?

NORMAL OR ABNORMAL? – DEMONSTRATION LAB

Purpose:
How does the "support" or normal force act?

Materials:
A wood block
Soft and stiff springs
A sheet of foam board or piece of thin wood
Matter model (optional)
Demo – a large plastic mirror (without frame) and a pen laser

Directions:
1.
Imagine you are lifting a box as shown in the picture and then hold it stationary above your head.
Draw the forces acting on the box when you hold it above your head.

Receiver:

Force(s):

Agent(s):

Effect:

2. What do you think the strength of the force you exert is compared to the force of gravity on the object you are holding?

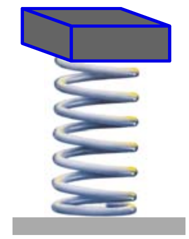
3. When you stand on the floor the force of gravity pulls down on you. When you are standing on a table, the force of gravity pulls down on you.
    a) How much force is your own body exerting on the floor?

    b) How much force is your own body exerting on the table you are standing on?

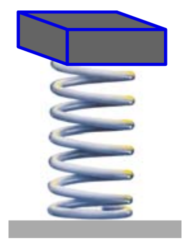
    c) If your body is exerting that much force on the table, why are you not falling through the table to the floor?

4. Examine the springs on your desk. Place the spring vertically on your desk and push down on it. What happens to the spring and what do you feel when you push down on the spring?

5. Next, imagine that you set a wood block on the spring.

What happens to the spring and what forces act on the spring?	Draw the forces acting on the spring . 

6. What forces act on the block? Draw the forces acting on the block on the figure provided.



7. Next, imagine that you placed the block on firmer material, like a piece of foam.
   a) What would happen to the foam and what forces act on it?

   b) What forces act on the block now?

8. Now imagine that the block sits on a much firmer surface, such as a table.
   a) What happens to the table and what force acts on it?

b) Does the table push back the same way the spring or the foam did?

c) What do you think would happen if a person stood on the table?

d) How much force do you think the table is exerting on the person to hold the person up?

9. Connections: Describe the relationship between what you learned in this lab and what you learned in the Exerting Forces and Broom Ball lab. Where do you see normal forces in the previous labs?

MEASURING THE FORCE OF GRAVITY LAB

Purpose:
What is the unit of force? What is the gravitational field strength?

Materials:
Spring scales (marked in newtons)
Plastic bag (to place objects in it)
Several masses (ideally, at least ten); make sure that all the masses fall within the range of the spring scales provided
Balance to measure mass
Paper cup and string tied to it

PART I: Measuring Forces

Directions:
1. Examine the spring scales, and describe how they function/operate.

2. What do the marked scales measure?

3. How can you make the scale read zero when no force acts on the spring?

4. How is the scale similar or different from a rubber band?

5. What forces act on an object hanging from the scale?

6. Estimate some "everyday" forces and measure them. Fill out the information in the table below:

TASK	ESTIMATE of FORCE NEEDED	ACTUAL FORCE MEASURED
Opening a drawer	N	N
Lifting a bag	N	N
Pulling a school bag along the floor	N	N
Stretching a rubber band by 3 cm	N	N
Pennies in the plastic bag	N	N
Your design:	N	N
Your design:	N	N

7. Estimate how much "stuff" will produce a gravitational force of one newton.

PART II: Measuring the Gravitational Strength

Prelab Discussion

8. What do you think would happen if you hold up a wooden block and let it go?

9. Why?

10. Where does the gravitational force come from?

11. What are various factors that affect this force?

12. How can we measure the factors that affect this force?

13. Which one of the factors listed can you measure easily? Why?

Directions:
Design an experiment by which you can study the effect of the mass on the gravitational force. Make sure you obtain at least seven data points. Your documentation should contain:

Experimental Question:

Hypothesis:

IV:

DV:

Constants of the experiment:

Materials List:

Procedure:

Data table:

MASS (specify unit)	Force of Gravity (N)

Graph with smooth line through data points. (plot force on the vertical axis)

Title ____

Analysis of data and conclusions

1. What conclusions can you draw from the graph?

2. Calculate the slope of the graph (rise/run) from the smooth line you drew. What value do you get for the slope of the graph?

3. What are the units for the calculated slope?

4. What do you think this slope represent? What would you call this slope?

5. Write a mathematical expression that describes the relationship between mass and gravitational force.

6. If you were to travel to the Moon, and redo this lab there, will the above mathematical expression hold (be valid) on the Moon? Explain your answer.

7. Add your conclusions from this activity to the “What is a force?” chart started in the Exerting Forces activity.

Measuring Elastic Strength Lab

Purpose:
How does one measure the strength of elastic force?

Materials:
Springs/force probes, bungee cords and rubber bands
Support to attach rubber band or bungee cords, and ruler
Objects of different mass
Balance to measure masses
Ruler

Pre-lab discussion:
Look at the springs, bungee cords, and rubber bands provided. What quantities are measurable for these objects?

Directions:
Design an experiment to study how the force applied to a spring affects the amount it stretches. You should measure the amount the spring stretches by hanging it on a support, and measuring the increase in the length of the spring from its original length. Or you could measure the force applied using a force probe or a spring scale. You should obtain at least ten data points and take measurements for at least two different springs. Your documentation should contain:

Experimental Question:

Hypothesis:

IV:

DV:

Constants of the experiment:

Materials List:

Procedure:

Data table:

Graph with smooth line through data points. (hint: plot force on the vertical axis)

Title ____

Analysis of data and conclusions

1. What conclusions can you draw from the graph?

2. Calculate the slope of each graph (rise/run) from the smooth line you drew through the points. Include the units for the slope.

3. Are the slopes the same? Explain why they are or are not.

4. What is the physical significance of this slope? What would you call this slope?

5. Write a specific mathematical expression that describes the relationship between the “stretch length” and gravitational force.

Post-lab discussion:

6. What similarities and differences do you observe between this experiment and the one on measuring gravitational field strength?

7. What makes the elastic strength of the springs be different?

8. Did the force applied to the spring cause a change in position?

9. Would you say that the force applied to the spring caused motion?

10. Suppose that a mass of 6 kg hangs from a spring. Draw a picture and mark the force(s) that act on the 6 kg mass. What information must you specify to fully describe each force?

11. When the object is hanging from a spring, how is its weight related to the elastic force in the spring?

12. Connections: What are similar findings/conclusions between the Measuring the Gravitational Field Strength lab and this lab?

NEWTON'S FIRST LAW LAB

Purpose:
What is the relationship between mass and inertia? What does Newton's First Law say about inertia?

Materials:

Station 1:
An embroidery hoop is balanced on a flask and a nut is placed on the top of the hoop. Your task is to use one hand to quickly remove the hoop so that the nut drops into the flask.

After you have mastered the task write a paragraph to describe the successful technique and why it works.

Station 2:
Put a doll on the cart and slide the cart across the floor to collide with the wall. Make observations about the changes in motion of the doll and the forces acting on the doll.

Use a rubber band to attach the doll to the cart and repeat the collision. Make the same observations about the changes in motion of the doll.

Station 3:
A pair of mounds of modeling clay, one red and one blue, are attached to the ends of a hanger that was cut and bent such that the two ends are lower than the supporting point. Balance the hanger on your head such that you see the red ball of clay. Smoothly turn your head around 90° and then 180°. Can you see the blue ball of clay? Describe what happened and why it works.

Station 4:

Several objects are placed on a table cloth on a flat surface. Quickly remove the table cloth so the objects stay on the table. Describe your method and why it works.

Station 5:

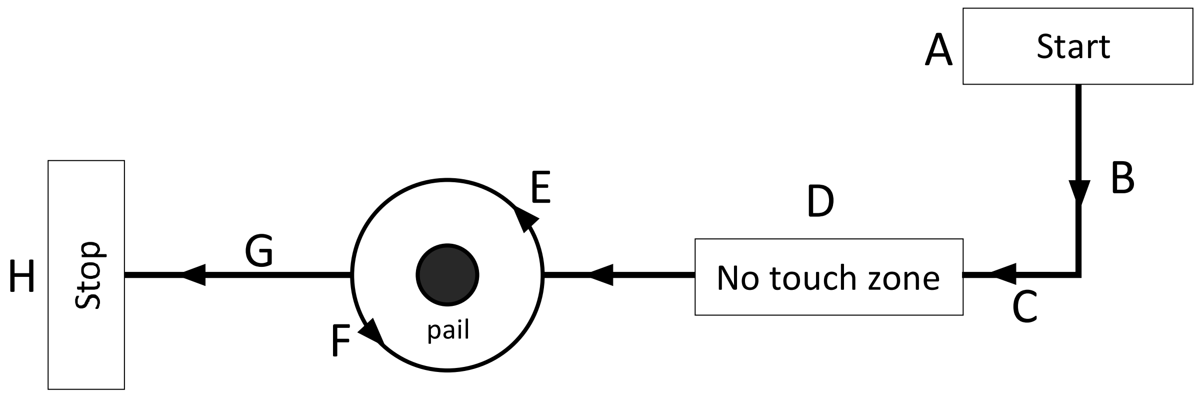
Balance a playing card or an index card on your thumb. Place a coin on the card over your thumb. With the other hand, determine a method of removing the card quickly so the coin remains on your thumb. Describe your method and why it works.

Station 6:

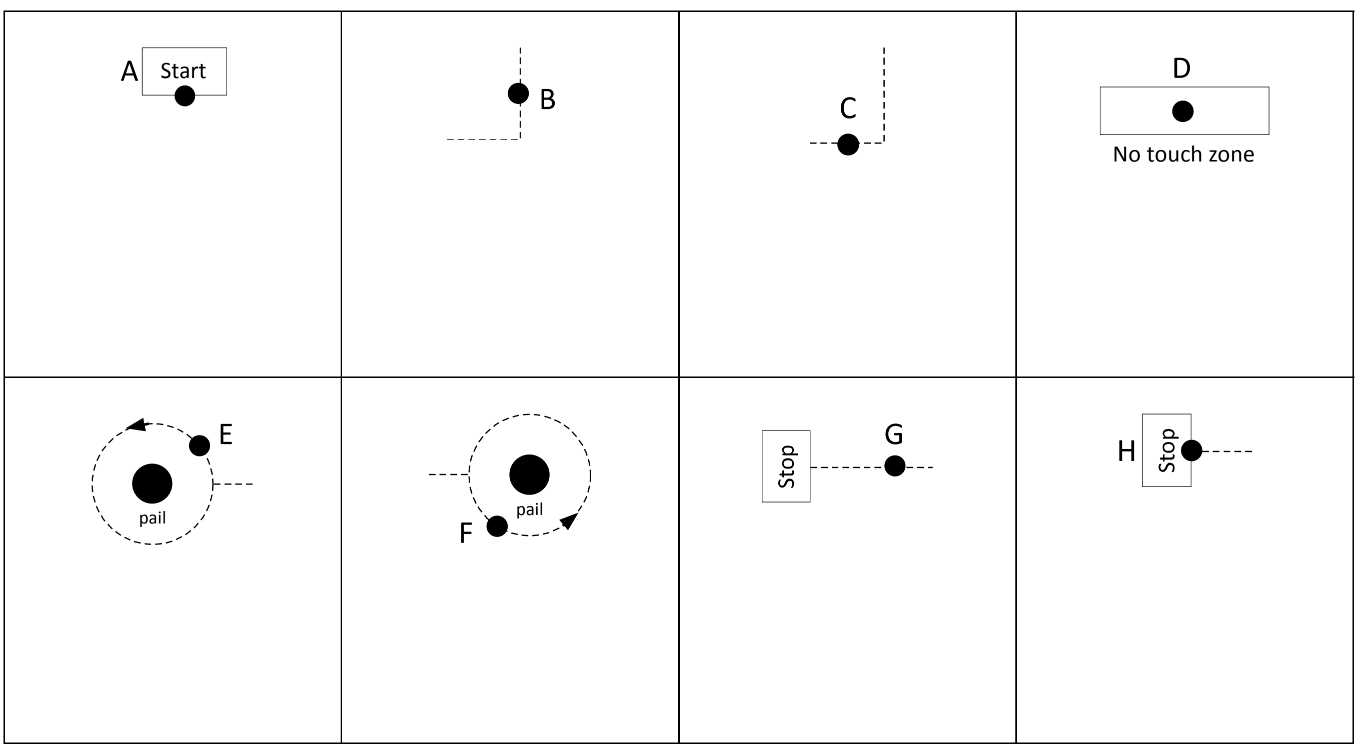
A boy stands in the center aisle of a bus moving down the highway at 55 mph. If the boy tosses a ball straight up toward the roof of the bus it falls back into his hands. Why?

Broom Ball Lab Revisited

Broom ball is the physics game you played at the beginning of this unit. The objective is to use a broom to cause a bowling ball to move along a specific course in the smallest amount of time without leaving the boundaries of the course. Consider the course shown below, where you start at A and stop at H.



Assignment:
For each of the lettered positions (A through H) on the diagram above, you will be asked to do the following:
1. Draw the force applied by the broom on the ball.
2. Draw the direction of the velocity of the ball at that position.
3. Describe the motion of the ball as one or more of the following: at rest, speeding up, slowing down, constant speed, changing directions.



After completing the table above, answer the following questions:

1. At which points is the direction of the force the same as the direction of motion (direction of the velocity)?

2. What is the effect of a force applied in the same direction as the direction of motion of the object?

3. Between what points did the direction of the force change? Did the direction of motion also change between those points? Is there a connection between these two changes?

4. At which points is the direction of the force different than the direction of motion (direction of the velocity)?

5. What is the effect of a force applied in a different direction than the direction of motion?

6. Was there a place where no force was applied by the broom? How did the ball move at that place? Explain your answer.

NEWTON'S THIRD LAW LAB

Purpose:
Is there a force law for two interacting objects?

Materials
A pair of spring scales (in newtons) or two bathroom scales

Directions:
1. You are driving down I-70 towards St Louis and an unlucky butterfly bumps into your windshield. The butterfly gets smashed but your windshield is fine. Which object experienced the strongest force during the impact, the butterfly or the windshield? Explain your answer.

2. There are two spring scales on your table. Imagine that you hook them together and pull on each scale. What do you predict your reading will be? Explain your prediction.

3. Try it and record the force read on each scale.

4. Student A holds one scale and student B pulls on the other scale. Predict how the force read by the scale held by student A compares to the force read by the scale held by student B. Explain your prediction.

5. Try it and record the force read on each scale.

6. What happens if the students reverse their roles? Predict how the force read by the scale held by student A compares to the force read by the scale held by student B. Explain your prediction.

7. Try it and record the force read on each scale.

8. What is the direction of the forces you applied? Draw a physical diagram for each spring, as well as a force diagram for each spring and indicate the direction of the applied forces.

9. Predict what would happen (what the scales will read) if you pushed two bathroom scales against one another as follows: (a) both students push, (b) the first student pushes only, and (c) the second student pushes only.

10. Hook your two spring scales together and make one read 3 N and the other one read 5 N. Were you successful?

NEWTON'S THIRD LAW WITH FORCE PROBES LAB

Purpose:
Is there a force law for two interacting objects?

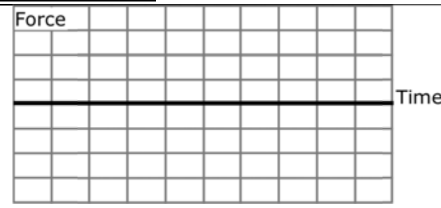
Materials:
Station A: Two force probes with rubber stoppers on each end
Station B: Two force probes with a rubber band connecting them
Station C: Two force probes with blocks being pushed - one small and one large
Station D: Two force probes with blocks being towed - one small and one large
Station E: Two carts with repelling magnetic bumpers on a track, with attached force probes

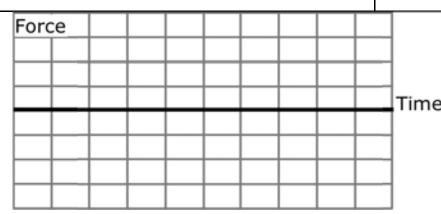
Note: You will have to set the logger pro settings to "reverse direction" for one of the force probes.

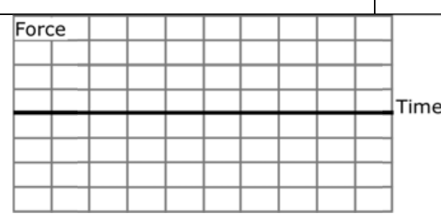
Directions for all stations:
You and your partner will each hold a force probe. First predict how the force student 1 exerts on student 2 will compare to the force student 2 exerts on student 1. Explain the reasoning behind each prediction. Then try the activity. After you have performed the experiment, sketch the graph of force vs. time shown on the computer. Plot the reading from force probe 1 in red, and force probe 2 in blue. Assume that the force experienced by student 1 is indicated in force probe 1. Your predictions can take the form of $F_{12} > F_{21}$, $F_{12} < F_{21}$, or $F_{12} = F_{21}$ if you wish, or some other form. Include a force diagram for each of the students in each situation. In the force diagram, represent only the interaction forces between the two force probes.

Station A: Rubber stopper on the end of each force probe

<table>
<tr><td rowspan="2">Student 1 pushes the stopper while student 2 passively holds the force probe
Prediction:

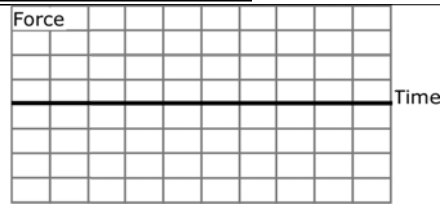
Result:</td><td colspan="2">
</td></tr>
<tr><td>Force Diagram for object 1:</td><td>Force Diagram for object 2:</td></tr>
<tr><td rowspan="2">Student 2 pushes the stopper while student 1 passively holds the force probe
Prediction:

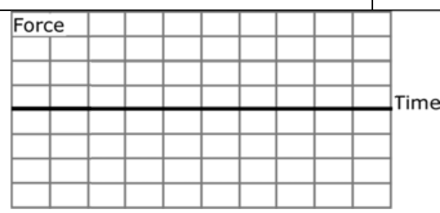
Result:</td><td colspan="2">
</td></tr>
<tr><td>Force Diagram for object 1:</td><td>Force Diagram for object 2:</td></tr>
<tr><td rowspan="2">Both students push on each other
Prediction:

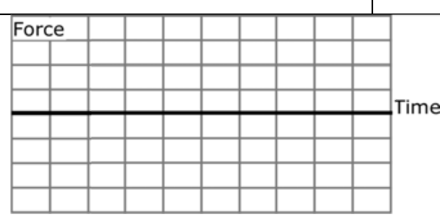
Result:</td><td colspan="2">
</td></tr>
<tr><td>Force Diagram for object 1:</td><td>Force Diagram for object 2:</td></tr>
</table>

<u>Station B: Rubber band connecting the hook of each force probe</u>

<table>
<tr><td rowspan="2">Student 1 pulls on the rubber band; student 2 passively holds his/her force probe
Prediction:

Result:</td><td colspan="2">
</td></tr>
<tr><td>Force Diagram for object 1:</td><td>Force Diagram for object 2:</td></tr>
<tr><td rowspan="2">Student 2 pulls on the rubber band; student 1 passively holds his/her force probe
Prediction:

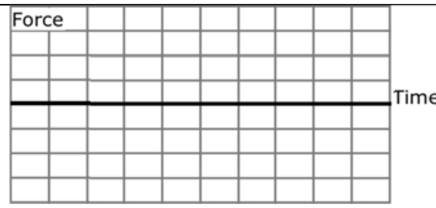
Result:</td><td colspan="2">
</td></tr>
<tr><td>Force Diagram for object 1:</td><td>Force Diagram for object 2:</td></tr>
<tr><td rowspan="2">Both students pull on each other
Prediction:

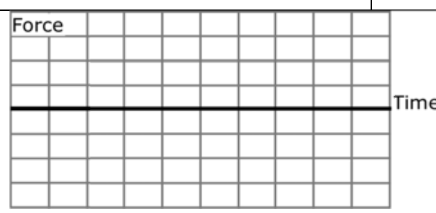
Result:</td><td colspan="2">
</td></tr>
<tr><td>Force Diagram for object 1:</td><td>Force Diagram for object 2:</td></tr>
</table>

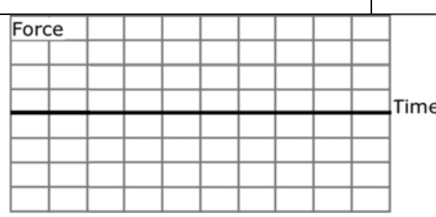
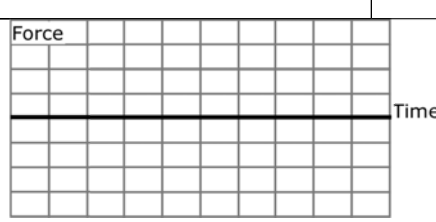
Station C: Cars Pushing each other

You and your partner will each hold a force probe. One of the cars should be imagined to be in neutral with its engine off. The other car has its engine on and pushes on the first one. Your hand will be like the engine, pushing the car. The cars are simulated by wooden blocks.

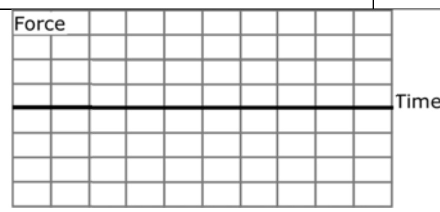
<table>
<tr><td rowspan="2">Large car pushes small car at constant speed on a level road
Prediction:

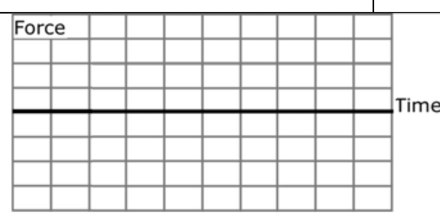
Result:</td><td colspan="2">
Force Diagrams:</td></tr>
<tr><td>Large car</td><td>Small Car</td></tr>
<tr><td rowspan="2">Small car pushes large car at constant speed on a level road
Prediction:

Result:</td><td colspan="2">
Force Diagrams:</td></tr>
<tr><td>Large car</td><td>Small Car</td></tr>
<tr><td rowspan="2">Small car pushes large car while speeding up
Prediction:

Result:</td><td colspan="2">
Force Diagrams:</td></tr>
<tr><td>Large car</td><td>Small Car</td></tr>
<tr><td>Small car pushes large car up a hill at constant speed (make a ramp)
Prediction:</td><td colspan="2">
Force Diagrams:</td></tr>
</table>

<table>
<tr><td>Result:</td><td>Large car</td><td>Small Car</td></tr>
<tr><td rowspan="2">Large car pushes the small car up a hill at constant speed
Prediction:

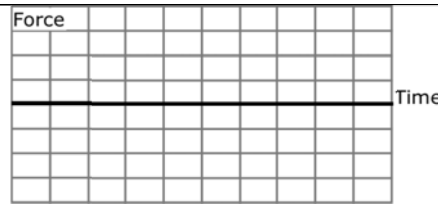
Result:</td><td colspan="2">
Force Diagrams:</td></tr>
<tr><td>Large car</td><td>Small Car</td></tr>
<tr><td rowspan="2">Large car pushes small car down the hill at constant speed
Prediction:

Result:</td><td colspan="2">
Force Diagrams:</td></tr>
<tr><td>Large car</td><td>Small Car</td></tr>
</table>

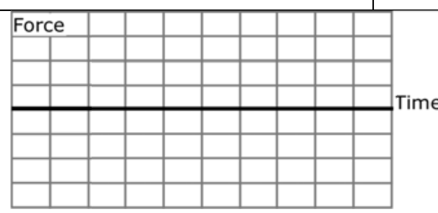
Station D: Cars Towing each other

You and your partner will each hold a force probe. One of the cars should be imagined to be in neutral with its engine off. The other car has its engine on and pulls on the other one. Your hand will be like the engine, pulling the car. The cars are simulated by wooden blocks.

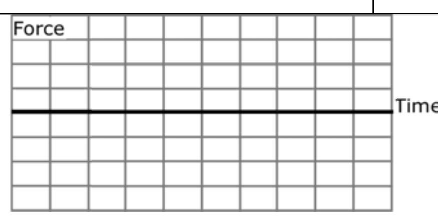
<table>
<tr><td rowspan="2">Large car tows small car at constant speed on a level road
Prediction:

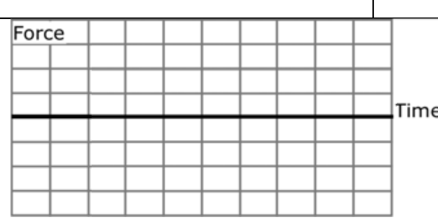
Result:</td><td colspan="2">

Force Diagrams:</td></tr>
<tr><td>Large car</td><td>Small Car</td></tr>
<tr><td rowspan="2">Large car tows small car while speeding up
Prediction:

Result:</td><td colspan="2">

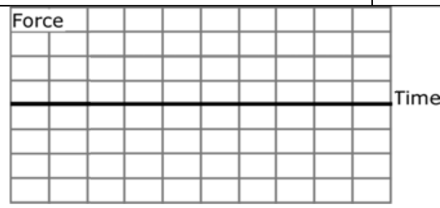
Force Diagrams:</td></tr>
<tr><td>Large car</td><td>Small Car</td></tr>
<tr><td rowspan="2">Small car tows large car while speeding up
Prediction:

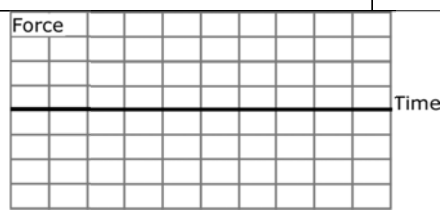
Result:</td><td colspan="2">

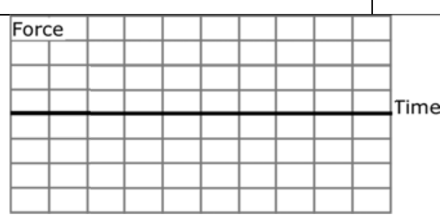
Force Diagrams:</td></tr>
<tr><td>Large car</td><td>Small Car</td></tr>
<tr><td>Small car pulls large car up a hill at constant speed (make a ramp)
Prediction:</td><td colspan="2">

Force Diagrams:</td></tr>
</table>

<table>
<tr><td>Result:</td><td>Large car</td><td>Small Car</td></tr>
<tr><td rowspan="2">Large car tows small car up a hill at constant speed
Prediction:

Result:</td><td colspan="2">
Force Diagrams:</td></tr>
<tr><td>Large car</td><td>Small Car</td></tr>
<tr><td rowspan="2">Small car tows large car down the hill at constant speed
Prediction:

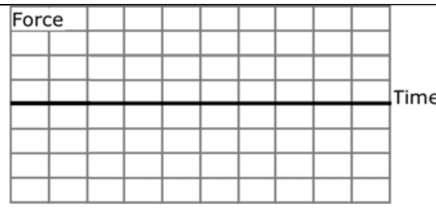
Result:</td><td colspan="2">
Force Diagrams:</td></tr>
<tr><td>Large car</td><td>Small Car</td></tr>
<tr><td rowspan="2">Large car tows small car down the hill at constant speed
Prediction:

Result:</td><td colspan="2">
Force Diagrams:</td></tr>
<tr><td>Large car</td><td>Small Car</td></tr>
</table>

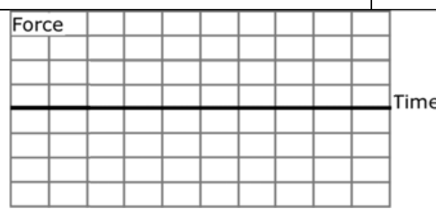
Station E: Carts colliding

Two carts, of equal or different masses, will collide as described below. The magnetic bumpers will extend the time of collision. Be sure to keep the cars on the track.

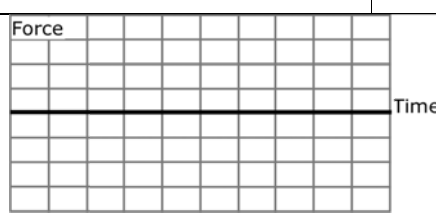
<table>
<tr><td rowspan="2">Cart 1 collides with an identical cart which is initially at rest
Prediction:

Result:</td><td colspan="2">

Force Diagrams:</td></tr>
<tr><td></td><td></td></tr>
<tr><td rowspan="2">Two identical carts with equal speeds have a head-on collision.
Prediction:

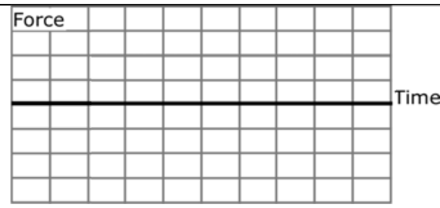
Result:</td><td colspan="2">

Force Diagrams:</td></tr>
<tr><td></td><td></td></tr>
<tr><td rowspan="2">Slow cart collides with fast cart.
Prediction:

Result:</td><td colspan="2">

Force Diagrams:</td></tr>
<tr><td></td><td></td></tr>
</table>

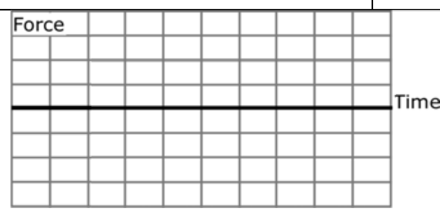
Large-mass cart collides with a small-mass cart which is initially at rest
Prediction:



Force Diagrams:

Result:

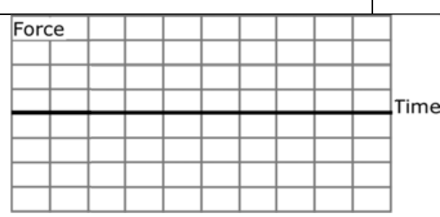
Large-mass cart collides with small-mass cart that is initially at rest.
Prediction:



Force Diagrams:

Result:

Large-mass cart collides with small-mass cart, both of which are moving toward each other with equal speeds.
Prediction:



Force Diagrams:

Result:

What common conclusion can you draw from all of these situations?

WHAT DOES IT TAKE TO MOVE? – LAB

Purpose:
What is the connection between force and motion–related factors such as time, displacement, velocity and acceleration?

Materials:
Cart and spring scale on low-friction floor
Or large spring scale and a skateboard
Or car, spring scale and track

Directions:
Use the spring scale and the cart provided. First predict the motion then try it out.

1. What forces act on a cart that is sitting motionless on a surface?

2. Draw a force diagram for the cart.

3. If you want to make the car(t) move, what must you do?

4. Suppose you were to attach a spring scale to the cart and pull on it to make it move. What do you think the spring scale will read?

5. Will the reading change once the cart is moving?

6. Now try it. As the cart just begins to move, note what the spring scale does, and describe it. Draw a force diagram for the cart.

7. Predict: Using the spring, can you start the cart in motion and keep it moving with zero net force? Explain your reasoning.

8. Now try it. Describe what happens. Draw a force diagram and a motion diagram for the cart.

9. What conclusion can you draw about the connection between force and velocity?

10. Predict: Using the spring, you start the cart in motion and keep it moving by applying a constant force of 2 N. Describe the motion of the cart and explain your reasoning.

11. Now try it. What happened? How did the cart move?

12. Draw a force diagram and a motion diagram for the cart.

13. What conclusion can you draw regarding force and acceleration?

14. For an object to move at a steady speed, what force must be exerted on it?

15. What if it were still moving at a steady speed but twice as fast?

16. If an object is accelerating, what can one conclude about the force on the object?

17. What have you learned about how force is related to the motion factors of speed and acceleration?

18. Predict: you have a cart that is moving at a steady speed. If you want to increase the speed of that cart, you must apply a force F. Now if you have a cart with twice the mass moving at the same steady speed and want to increase its speed by the same amount, would you apply the same, more or less amount of force?

19. Is there a relationship between the force required to change the speed of the object and the mass of the object? If yes, what is the relationship?

20. What are the factors that affect the motion of an object and how are they related to each other?

21. Connections: In Newton's Third Law lab, you saw that two objects colliding have the same force acting on each other during collision. However, when a small car collides with a big car, the small car has more damage than the big car. How can you explain this effect using knowledge from all previous labs?

22. Fill out the table below:

Situation	**1**	**2**	**3**	**4**
Description of motion	Starting to move to the left	Constant velocity to the left	Speeding up while already moving to the left	Slowing down while moving to the left
Force Measured				
Force Diagram				
Net Force				
Motion Diagram				

NEWTON'S SECOND LAW: SIMULATION LAB

Purpose:
What is the connection between force and motion?

Materials:
Computer with internet connection or the Phet simulation already installed on it.

Directions:
Go to the PHET simulations website at: http://phet.colorado.edu/en/simulations/category/physics and select "Forces in 1 Dimension" simulation. Once the simulation window is opened, look at the right side panel and close the "Free Body Diagram" window. Then click/select the "barriers" button and click on the Friction "off" button. Select the textbook and then click the "More controls" button. Several new controls will show up. Change the coefficient of static and kinetic friction to 0 (zero).

1. In the left side window for "Applied Force" enter 10 (you are then applying a constant 10 N force to the textbook). Click the "go" button and look at the motion of the textbook. Draw a force diagram for the textbook, during its motion.

2. How would you describe the motion of the textbook (uniform, uniform accelerated)? Explain your answer.

3. Complete the following statement based on your observations:

   "When a horizontal force to the right is applied to the textbook, the textbook moves with constant___________________________________"

4. Now click on the "Graph applied force" button, reset everything and rerun the simulation. If necessary, zoom in using the "zoom in" button (the magnifying glass with a plus sign). Also, you can turn off showing friction and total force.How is the applied force during the motion of the textbook before hitting the wall?

5. Next, click on the “Graph velocity”, clear everything and rerun the simulation. How does the graph look like? What happens to the velocity of the textbook? What type of motion does this graph represent?

6. Next, click on the “Graph Acceleration”, clear everything and rerun the simulation. How does the graph look like? What type of motion does this graph represent?

7. What can you conclude?

   “When a horizontal force to the right is applied to the textbook, the textbook moves with constant___________________________________”

Next, you will try to find a relationship between the force applied to the textbook and the acceleration of the textbook. Keep open the windows that allow you to graph Force and Acceleration.

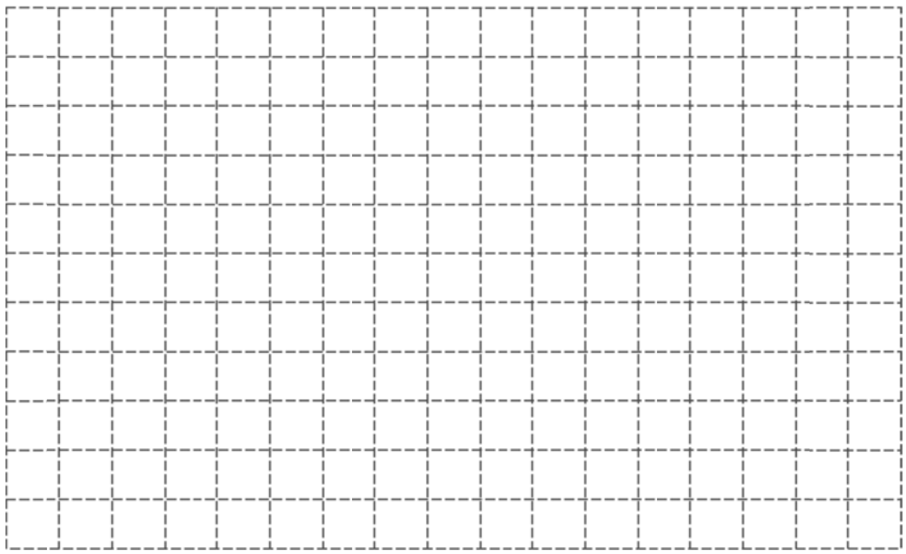
8. Change the mass of the textbook (in the right side panel) to 2.5 kg. Start with a 10 N force applied to the textbook and keep changing the force, running the simulation for each value of the force; read the acceleration for each applied force. Then change the mass to 4.8 kg and repeat. Fill out the table below:

Mass	Force	Acceleration
2.5 kg	10 N	
2.5 kg		
2.5 kg		
2.5 kg		
2.5 kg		
2.5 kg		
4.8 kg		
4.8 kg		
4.8 kg		
4.8 kg		

4.8 kg		
4.8 kg		

9. Graph the Force applied versus the acceleration separately for each textbook on the graph provided below:

Title ____



10. How are the two graphs similar?

11. How are the two graphs different?

12. Why do you think the two graphs have different slopes?

13. Calculate the slope of each graph. What are the units for the slope?

14. What do you think that the slope represents? Compare the slope for the two graphs with the mass of the textbook.

15. What is the mathematical relationship that you can write between the applied force and the acceleration of the textbook?

16. Do you think that this relationship will also work if we turn on the force of friction?

Make sure all the graph windows are closed. Turn on friction and then click on the “Restore Defaults” button at the bottom of your right side window. Select “Textbook” and change its mass to 2.5 kg.

17. Apply a force of 1 N and click run. What happens? Explain why.

18. Draw a force diagram for the textbook in this case and record the value of the applied force and friction force in this case on your diagram. What can you tell me about the applied force and friction force?

19. Now apply a force of 2 N and click run. What happens?

20. Draw a force diagram for the textbook in this case and record the value of the applied force and friction force in this case on your diagram. What can you tell me about the applied force and friction force?

21. Keep increasing the applied force by 1 N until the textbook starts moving. What is the smallest value for the applied force that still balances out the force of friction?

22. Now increase the applied force to 10 N. What happens?

23. Draw a force diagram for the textbook in this case and record the value of the applied force and friction force in this case on your diagram. What can you tell me about the applied force and friction force in this case?

24. How would you describe the motion of the textbook in this case?

25. Do you find anything strange about the value of the friction force as compared to the one found when the textbook was not moving? What do you think is going on?

26. Open the windows that allow you to graph Force and Acceleration and rerun the simulation. Do the graphs displayed support your statement for question 24? Explain.

27. The simulation window also reports a "**Total Force**". What do you think that this **Total Force** (also named **Net Force**) represents?

28. What is the **Net Force** acting on the textbook in this case?

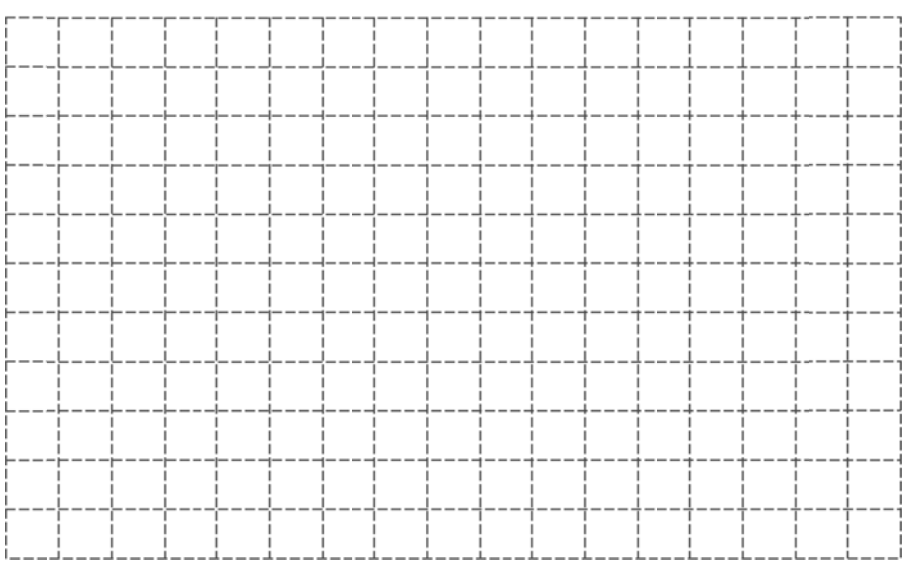
Next, you will try to find a relationship between the **Net Force** on the textbook and the acceleration of the textbook. Keep open the windows that allow you to graph Force and Acceleration.

29. Start with a 10 N force applied to the textbook and keep changing the force, running the simulation for each value of the force; read the acceleration for each applied force. Then change the mass of the textbook to 4.8 kg and repeat starting with a higher value of the applied force if necessary. Fill out the table below:

Mass	Applied Force	Friction Force	Total (Net) Force	Acceleration
2.5 kg	10 N			
2.5 kg				
2.5 kg				
2.5 kg				
2.5 kg				
2.5 kg				
4.8 kg				
4.8 kg				
4.8 kg				
4.8 kg				
4.8 kg				
4.8 kg				

30. Graph the **Net Force** versus the acceleration separately for each textbook on the graph provided below:

Title ____



31. Calculate the slope of each graph. What are the units for the slope?

32. What do you think that the slope represents? Compare the slope for the two graphs with the mass of the textbook.

33. What is the mathematical relationship that you can write between the **Net Force** and the acceleration of the textbook?

34. How would you read this mathematical relationship in words?

35. How is this relationship the same or different from the one you found previously in the simulation with the textbook and no friction?

36. From your graphs for the two different experiments, read the value of the applied force (in the experiment without friction) and the net force (in the experiment with friction) on the 2.8 kg for the same acceleration of 5 m/s^2. Are they the same or different? Explain.

37. Look at the graph you made for the simulation with friction. Compare the force applied to the 2.5 kg textbook and 4.8 kg textbook for the same acceleration. Complete the following statement:

    For two objects to have the same accelerations, the ___________ object must have a _______________ force applied to it."