IPC/Algebra I

Integrated Instructional Unit:

Motion and Force

Student Materials

Texas Instruments

Region IV Education Service Center
Houston, Texas

IPC/Algebra I

Acknowledgements

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1.1 Activity #1 – Motion in One-Dimension

One student volunteer (the walker) will perform this experiment. You will need to record the experimental data, sketch the graphs and answer the questions below:

Situation #1- Walker starts at 0 on the masking tape and moves at a constant rate of 2m/s

Complete the following table:

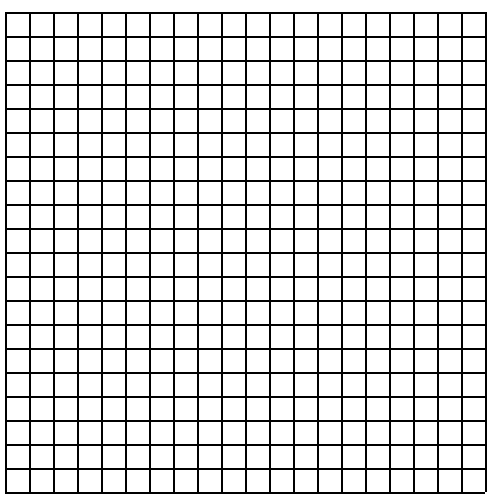
time(in seconds)	distance walked(in meters)
0	
1	
2	
3	
4	
5	
n	
20	

a) How far will the walker have traveled in 10 seconds?

b) How far will the walker have traveled in 1 minute?

c) How long would it have taken the walker to walk 1 kilometer?

Sketch a graph of the situation below:



Situation #2 – The walker starts at 0 and walks at a constant rate of 3 m/s

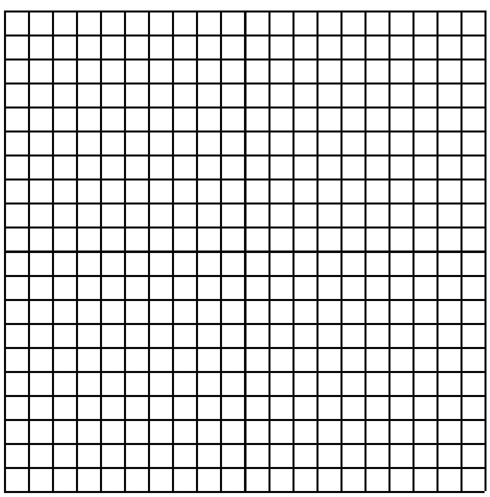
a) How do you think the table will differ from the table in situation #1?

b) How do you think the graph will differ from the graph in situation #1?

Complete the following table

time(in seconds)	distance walked(in meters)

Sketch the graph for this situation below:



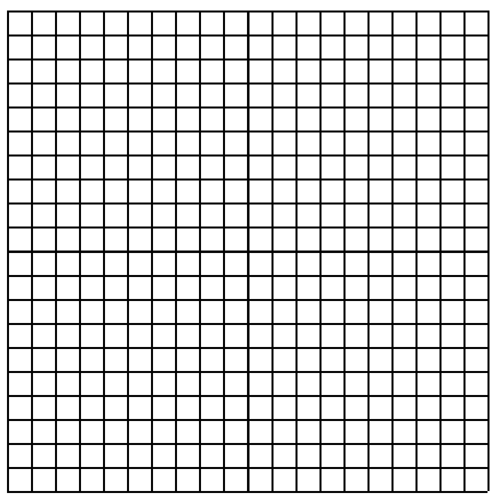
Situation #3 - The walker starts at 1 meter and walks at a constant rate of 3 m/s.

Complete the following table:

time(in seconds)	distance walked (in meters)	distance from the beginning of the tape (in meters)

Sketch two graphs on the same axes below:

1) distance traveled versus time
2) distance from the end of the tape versus time



a) How are the two graphs similar?

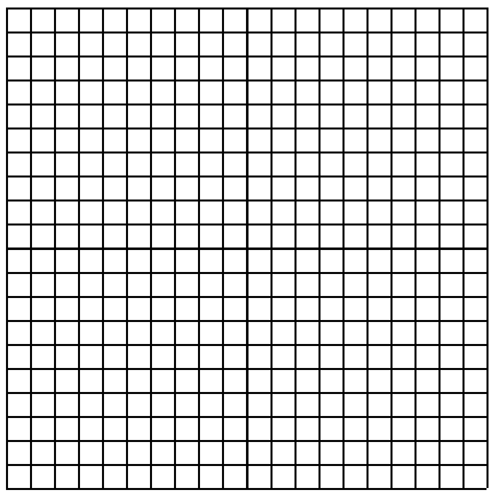
b) How are the two graphs different?

1. 2 Activity #2 – Investigating motion with the CBR

Part I - Situation 1
A walker will be asked to walk on the number line, starting at 1 meter, and moving away from the detector at a rate of ½ m/s. On the graph below sketch what you believe would be an appropriate graph of the walker's distance from a motion detector placed at "0" on the masking tape.

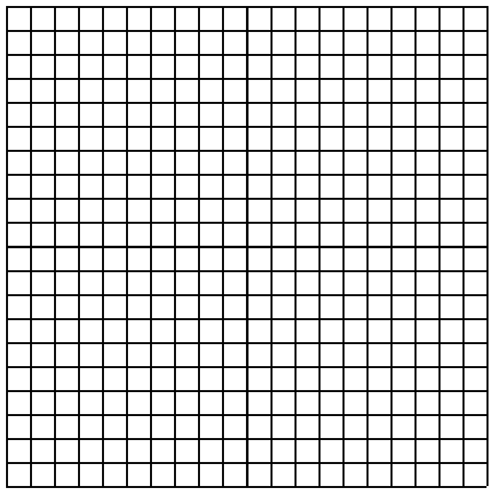
a) Does your graph appear to be different from the graph the calculator displayed for the walker? Why might your graph appear to be different?

b) The walker was supposed to walk at a constant rate of ½ m/sec.; does the graph show a constant rate of change? How?



Part 1 - Situation 2

This time the walker walks towards the motion detector, starting at 3 meters, and moving at a rate of ½ m/s. Sketch your prediction of what this graph of distance from the motion detector versus time should look like:



a) How does the graph show that the walker walked towards the motion detector?

b) What is the real world meaning of a zero distance? Where would this show up on the graph?

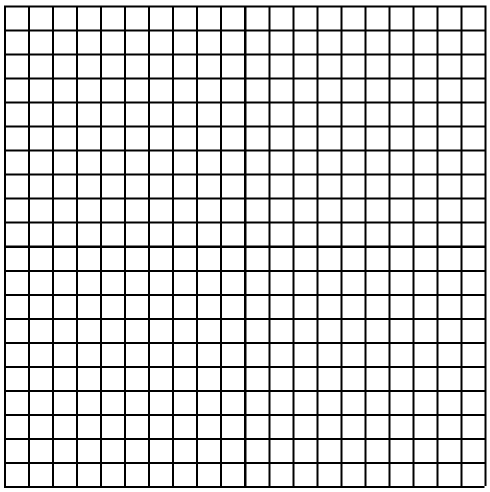
c) What would be the meaning of a “negative” distance? Where would this show up on the graph?

Part II – Situation 1

For each of the following situations complete the following tasks (if possible)

a) Complete the experiment with the CBR
b) Sketch the graph of distance from the CBR versus time on the graph provided
c) Complete the given table by choosing two pairs of points and calculate the average velocity for each pair of points.

1. Walk away from the CBR at a constant rate faster than 0.5 m/s.



time(seconds)	distance (meters)	velocity (m/s)

2. Walk in front of the CBR so that the graph of distance versus time is a line with a slope between zero and 0.5 m/s.

time(seconds)	distance (meters)	velocity (m/s)

3. Create with the CBR a graph with a negative rate of change.

time(seconds)	distance (meters)	velocity (m/s)

4. Create with the CBR the graph of a horizontal line.

time(seconds)	distance (meters)	velocity (m/s)

5. Create with the CBR the graph of a vertical line.

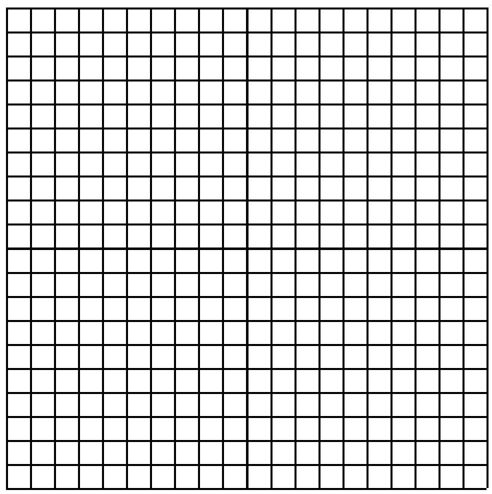
time(seconds)	distance (meters)	velocity (m/s)

Part II – Situation 2

For each of the following situations complete the following tasks (if possible)

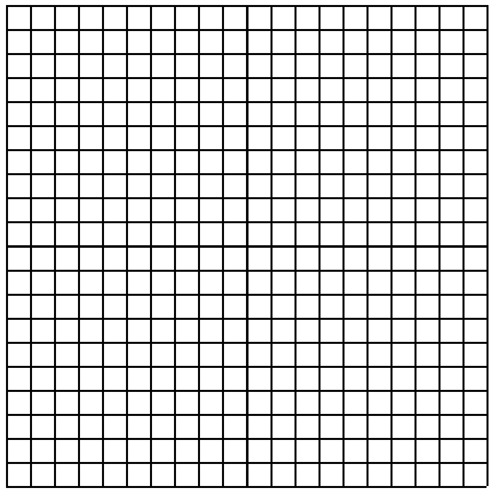
a) Complete the experiment with the CBR
b) Sketch the graph of distance from the CBR versus time on the graph provided
c) Complete the given table by choosing two pairs of points and calculate the average velocity for each pair of points.

1. Move away from the motion detector starting slowly but walking faster (speeding up) as the walk progresses



time(seconds)	distance (meters)	velocity (m/s)

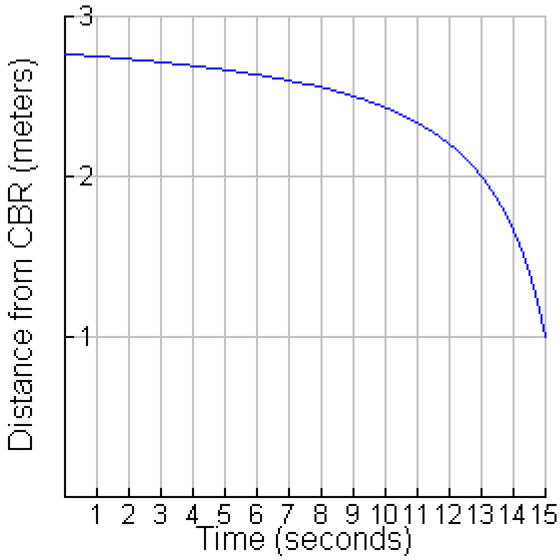
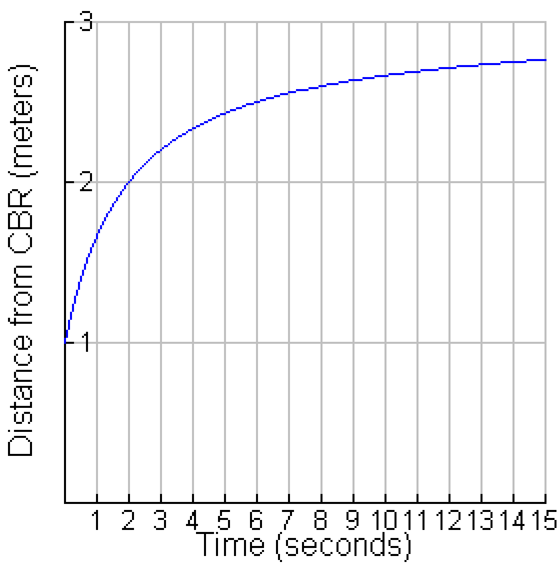
2. Move towards the motion detector starting quickly but slowing down as the walk progresses

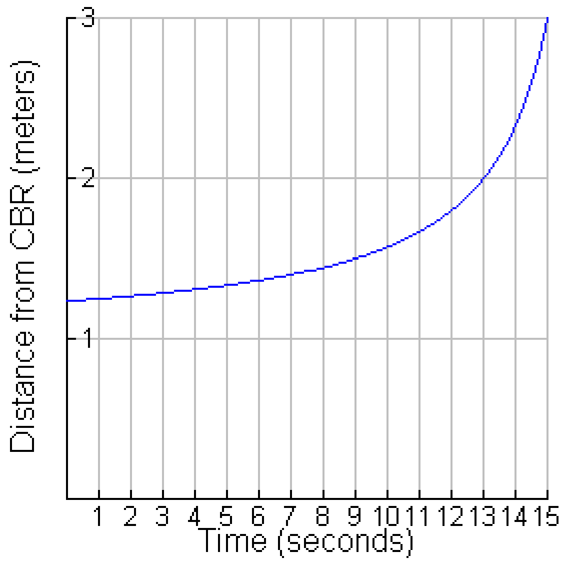


time(seconds)	distance (meters)	velocity (m/s)

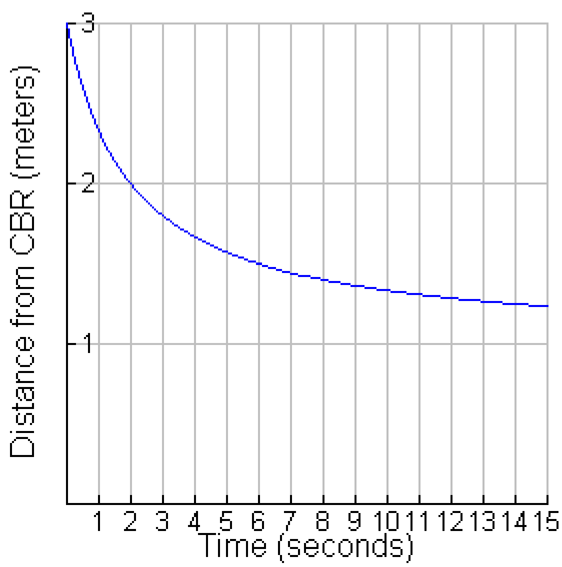
Activity#3- Interpreting Distance Time and Velocity Time Graphs

Part 1- Matching Distance Time Graphs
Using real time mode attempt to match the following graphs using the motion detector. Write a brief description of what you needed to do to match the graph.

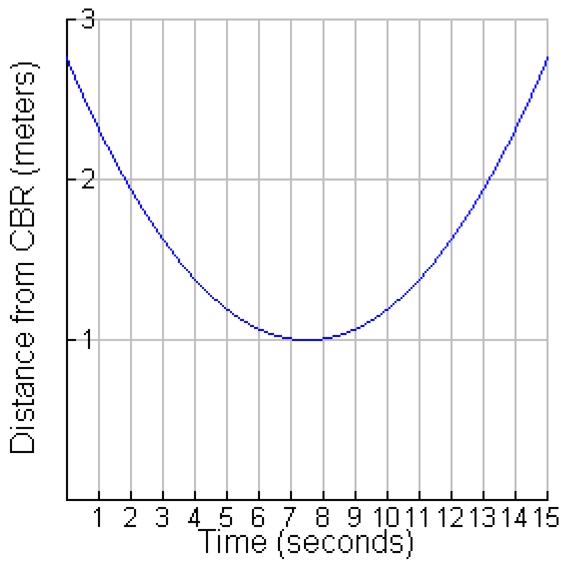
 1.	
 2.	


3
2
1
Distance from CBR (meters)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Time (seconds)

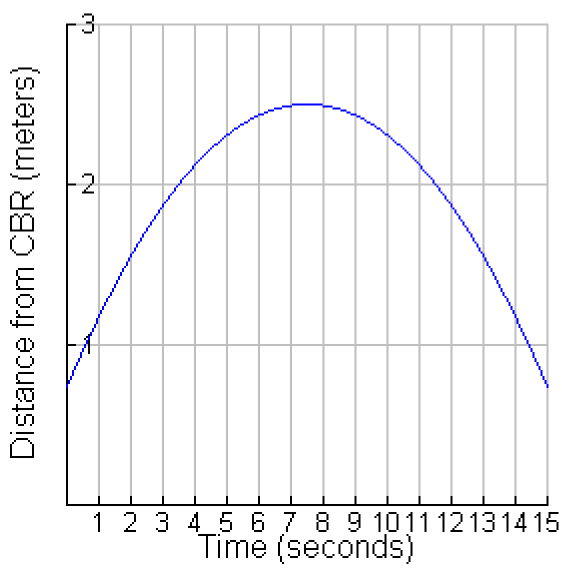
3.


3
2
1
Distance from CBR (meters)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Time (seconds)

4.



5.



6.

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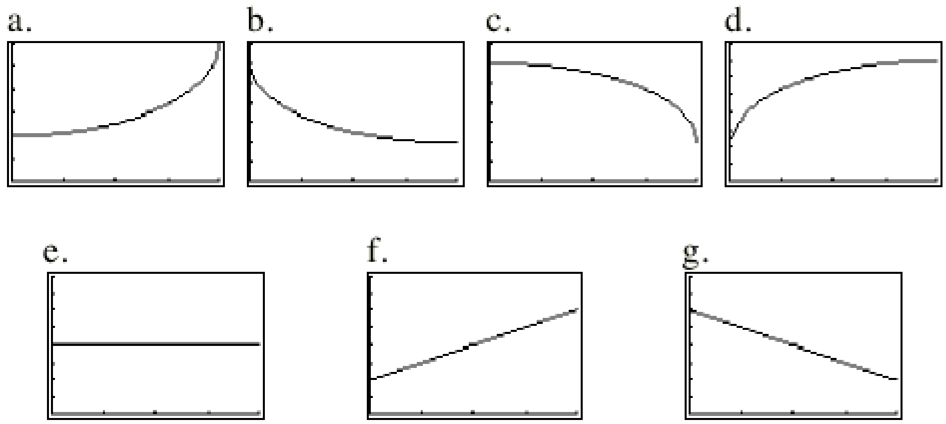
7.How did you know when to speed up?

8.How did you know when to slow down?

Now answer the following questions about these graphs:



Which graph(s) above show:
9.a constant rate?Why?

10.a walker speeding up?Why?

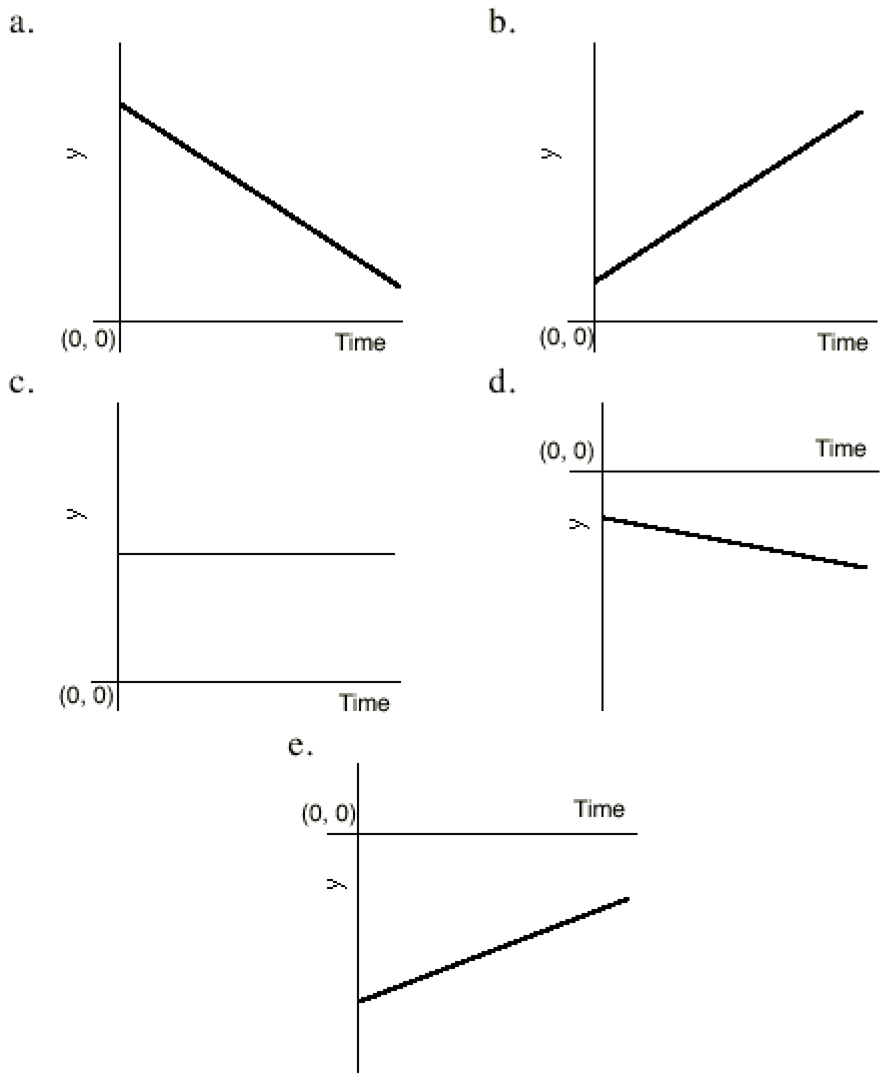
11.a walker slowing down?Why?

12.a walker standing still?Why?

Part 2- Matching Velocity Time Graphs

On each of the following graphs the horizontal axis represents time and the vertical axis represents the velocity.

Practice walking the following graphs using a motion detector and a graphing calculator. Describe the walk that you used to produce each graph.



Answer the following questions about your experiences with this experiment:

1. How did you know when to walk slowly?

2. How did you know when to walk quickly?

3. How did you know when to slow down?

4. How did you know when to speed up?

5. How did you know when to walk away from the motion detector?

6. How did you know when to walk toward the motion detector?

7. How did you know when to stop?

Practice Problems with Velocity

For the purpose of this exercise the point of origin is the point from which measurements are made.

1. Determine the average velocity of person who walks away from the motion detector 100 meters in 25 seconds. Convert this velocity to kilometers per hour.

2. Determine the average velocity of a person who drives away from their point of origin 240 kilometers in a total of 3 hours. Convert this velocity to meters per second.

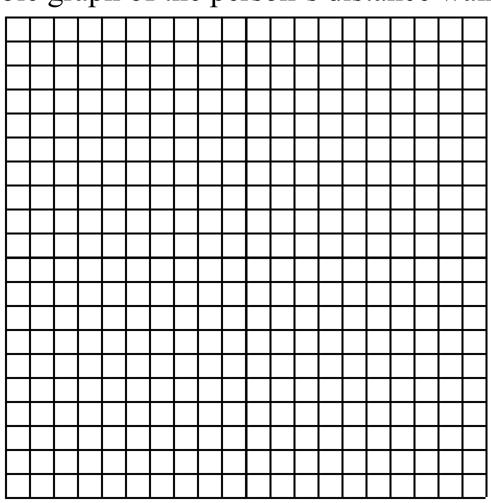
3. It is approximately 335 km west from Houston to San Antonio; determine the velocity a car must travel to make it there in 4 hours.

4. A person walks away from the point of origin at a rate of 4 m/s. How long it will it take them to travel 1 kilometer?

5. A person starts their walk 3 meters from the motion sensor and walks toward the sensor for 4 seconds before walking into the sensor. Determine the velocity for this situation.

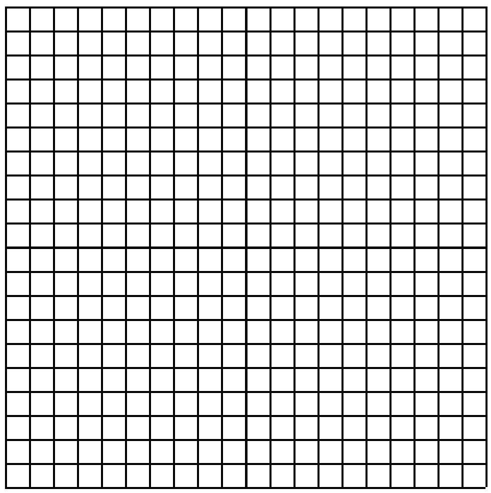
6. A person walks away from the point of origin for 3 seconds at a constant rate of 2 m/s and then continues in the same direction for 5 seconds at a rate of 4 m/s. What is the person's average velocity for the 8 second walk?

7. Over a 10 second period a person walks at an average rate of 4 m/s but is not walking at a constant rate over the entire 10-second period. Sketch a possible graph of the person's distance walked as a function of time.



1.3 Activity #4- Acceleration due to Gravity

Following your teacher's instructions perform the experiment with the motion detector and the racquetball. Sketch a rough graph of the time versus distance from the motion detector on the graph below:



- What part of the graph represents the ball dropping onto the motion detector?
- Why does the graph appear to start with a horizontal line before starting to curve?
- Why does the distance from the ball to the CBR never record zero on the graph?

Choose PLOT TOOLS from the next menu and then choose SELECT DOMAIN. Select the first part of the graph choosing the y-axis as the left bound and moving to the bottom of the first curve to represent the right bound. Sketch the new graph below:

- If you were to walk a graph with a similar curvature what would you need to do?

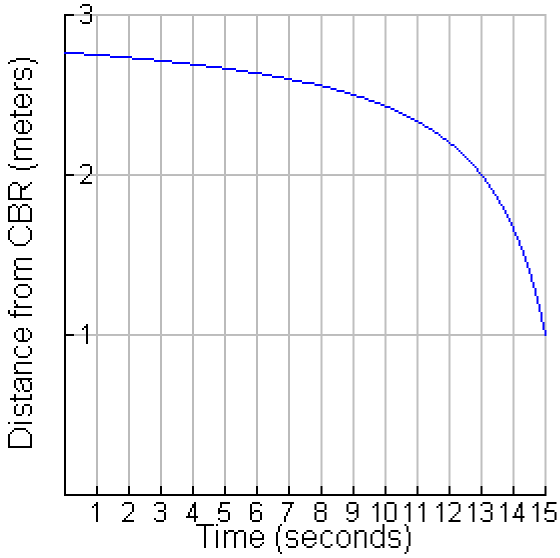
From the PLOT TOOLS menu select VEL-TIME. You may wish to increase the value for y-max to 1. Sketch your graph below:

Acceleration is the change in velocity with respect to time. It is often given by the formula: $a = \frac{\Delta v}{\Delta t}$. Choose two pairs of points and determine the average acceleration for those two pairs. Then sketch the graph of a line through the origin with an approximation of the average acceleration. What do you notice about this line?

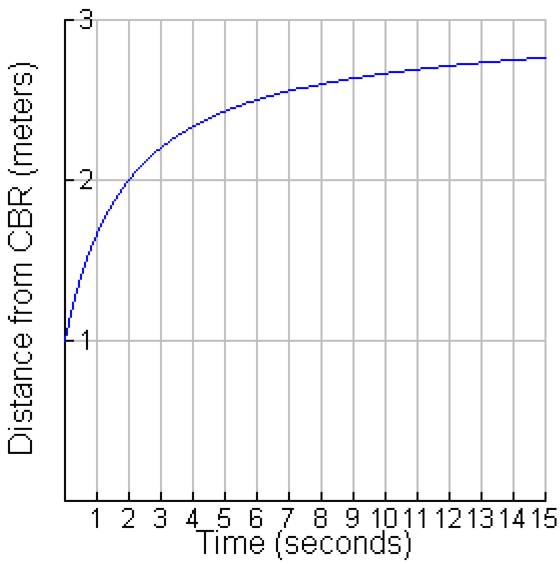
What is the real world significance of this average acceleration?

Activity #5 - Interpreting acceleration

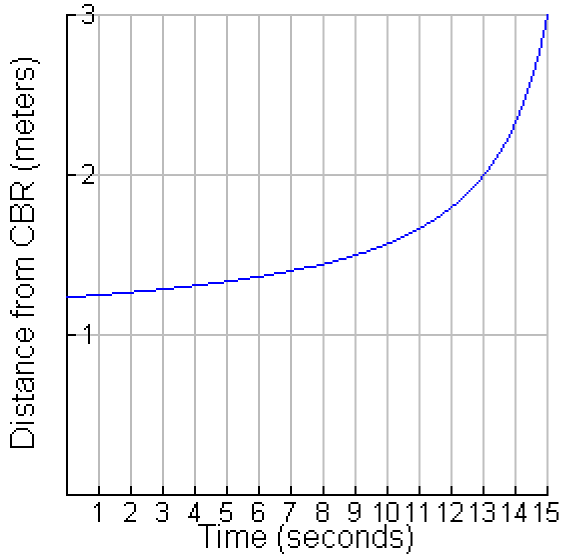
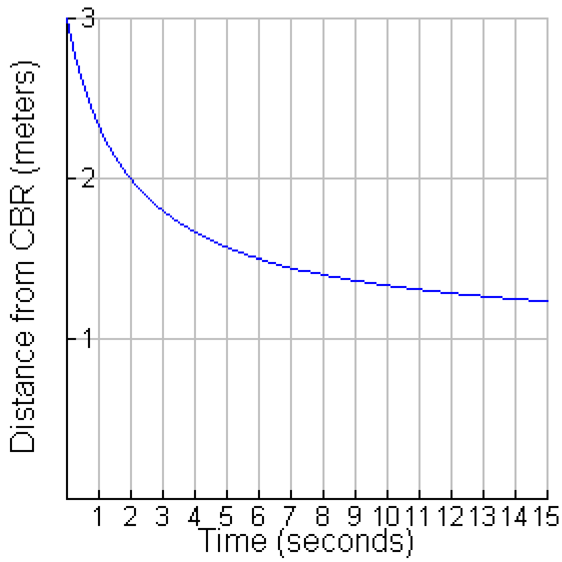
For each of the graphs below determine if acceleration is positive or negative.

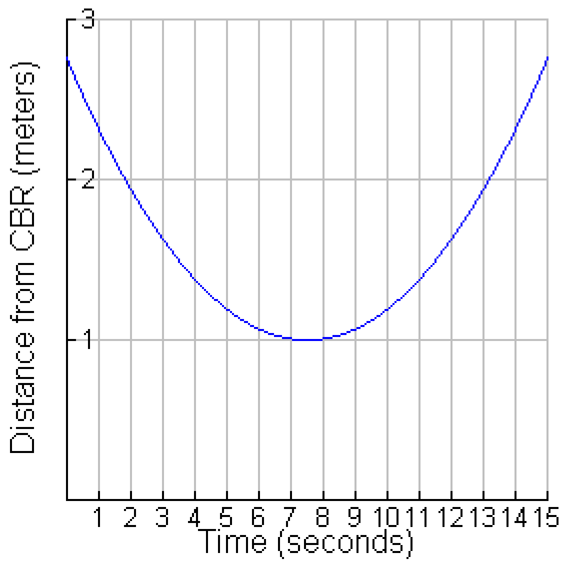
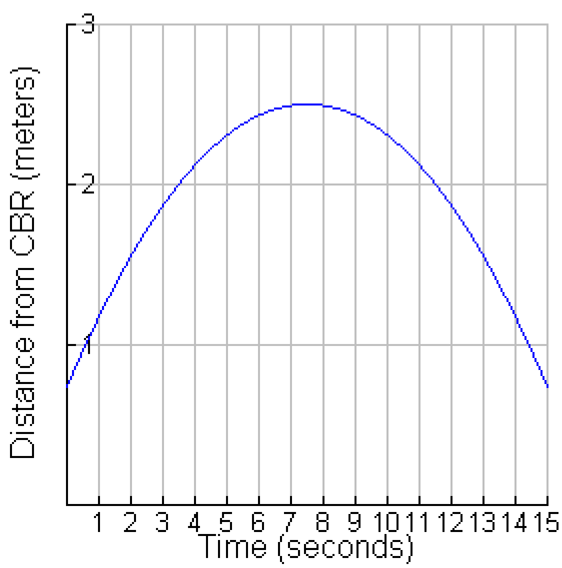


1.



2.

Distance from CBR (meters) 3 2 1 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 Time (seconds) 3.	
Distance from CBR (meters) 3 2 1 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 Time (seconds) 4.	

3 2 1 Distance from CBR (meters) 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 Time (seconds) 5.	
3 2 1 Distance from CBR (meters) 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 Time (seconds) 6.	

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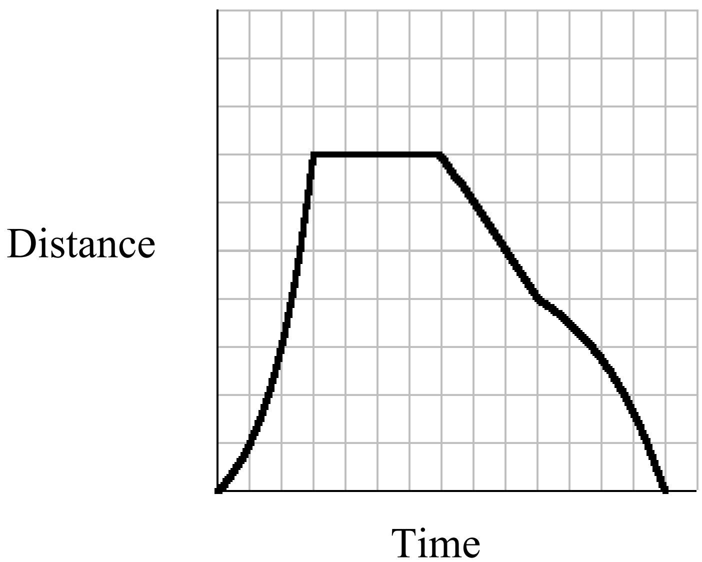
Performance Assessment

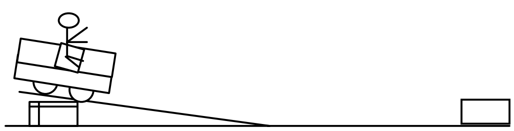
Create a story for the following distance time graph. Determine appropriate scale values and units of measure and mark those on the graph. In your story pay particular attention to position, velocity and acceleration describing how each of these change (or do not change) with respect to time.



Scoring Table:

Score	Axes	Story	Connection of story to graph	Position, Velocity, Acceleration
4	Both axes very well marked with correct units and easily understood scale	Story well written and easy to follow with few if any grammatical and/or spelling errors	Connection between story and graph is clear and easily understandable.	Position, velocity and acceleration are all correctly interpreted throughout the story.
3	Scale on one axis not easily understood or correct units not marked on axes	Story somewhat difficult to follow, possibly due to several grammatical and/or spelling errors	Story does not match graph in one or two instances	Two of : position, velocity and acceleration are correctly interpreted throughout the story OR all three are interpreted correctly for most of the story
2	Both axes lacking either scale or clearly labeled units	Story difficult to follow due to severe grammatical and spelling errors	Story does not match graph in several instances.	One of: position, velocity or acceleration are correctly interpreted throughout the story; or all three are correctly interpreted for some of the story or two of the three are correctly interpreted for most of the story.
1	No scale or labeling done on either axis	Story is not understandable	Story does not correctly interpret graph	Position, velocity and acceleration are not interpreted correctly in the story.

2.1 Inertia Lab

A. Place a car on the floor of your classroom. Observe the car for 10 seconds, and then record your observations.	
B. Using your prior experiences, what would need to happen in order for the car to move? Why?	
C. Using a low friction car, small action figure, book, ramp, and a block. Tape an index card or post-it note over the bed of the car so that the action figure is sitting on top of the car. Set up an observation as pictured:  Roll the car at least three times and record your observations.	
D. Restate your observation from part A, B, and C using the words force and motion.	
E. Using reference material available (i.e. textbook, dictionary, Internet), record Newton's First Law of Motion or the Law of Inertia. Compare this definition with your statement in Part D. How are they alike and/or different?	

2.2 Force, Mass, and Acceleration

What I **K**now	What I **W**ant to Know	What I **L**earned

2.2 Force, Mass, and Acceleration

In this lesson you will investigate Sir Isaac Newton's second law of motion by determining the relationship between the force on an object, its mass, and its acceleration. The data collected through our concrete investigations will be organized and analyzed in tabular, graphical, and symbolic representations.

Force can be defined as a push or pull upon an object, or any action that has the ability to change the motion of an object. Units of force are recorded in newtons (N) or pounds (lb). Scientists prefer to use the standard metric unit of measure, the Newton. One Newton is the amount of force required to give a 1 kilogram mass an acceleration of 1 meter per second per second, or 1 m/s/s, or 1 m/s^2. Using Newtons as the unit of measure (one Newton) is easier than saying one meter per second squared. The following unit equivalency can be stated:

$$1 \ Newton = 1 \ kg * \frac{m}{s^2}$$

Mass can be defined as the quantity of matter in a body regardless of its volume or of any forces acting on it. Inertia is the resistance of an object to a change in its motion. Kilogram (kg) is the unit of measure used to describe the quantity of mass. This quantity of "stuff" should not be confused with weight. Remember **weight** is the measure of the force of gravity acting on an object, which is also stated as the force of attraction between earth and the object.

PART A Just Hanging Around

Investigation:

Materials: Newton force spring scale or Dual-Range Force Sensor, hook or attachable mass (at least 3 of the same mass); graphing calculator
If using Dual-Range Force Sensor: S hook or large paper clip; DataMate program
See Appendix A for instructions of using the DUAL-RANGE FORCE Sensor
Alternative material - Create the mass by uniformly filling film canisters with small ball bearings to represent attachable mass units. You might use a triple beam balance to determine the mass of the canister. Attach a plastic cup to the force sensor to hold the canisters as they are added.

Procedure:
The following investigation is to determine the relationship between the force (F) on an object and it's mass (m).

1. Predict the relationship between the force (F) on an object and it's mass (m).

2. Which variable would you identify as the independent variable in this investigation?

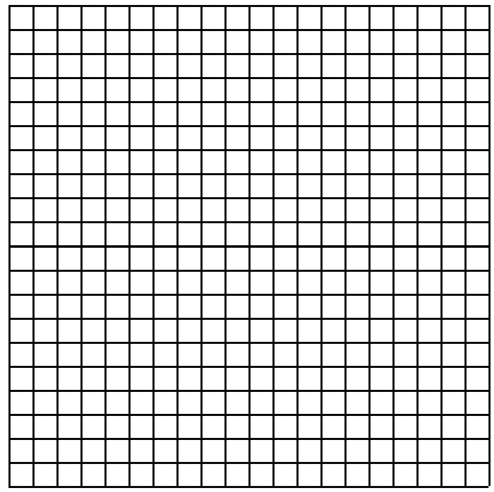
3. Zero the force spring scale or run the DataMate program that is located in APPS on your graphing calculator to zero the DUAL-RANGE FORCE Sensor and collect data. Attach S hook (or plastic cup) on the DUAL-RANGE Force Sensor before zeroing the sensor.
Determine the relationship between the force (*F*) on an object and it's mass (*m*).
    a. Increment the mass in multiples. For example, if you use an object that has a mass of .295 kg for term (1) and then determine the force on that mass; then term (2) would determine the force on two .295 mass objects, etc.
    b. Describe your thinking process as you relate the force (*F*) on the object to the mass (*m*) of that object.
    c. Express the force on the object, *F*, in terms of the mass, *m*, of the object.
    d. Using your line of thinking, predict the force on an object that has a mass of 1.77 kilograms.

REMEMBER the unit of measure!

	Process	

4. Graph the data.
    a. Enter your data into the list feature of your graphing calculator if you used a spring force. If you use DataMate, the data is stored in List 1 and List 2.
    b. Set an appropriate window and plot the data.
    c. Enter your function in the y= feature, and graph the relationship over the collected data.
    d. Record your window settings and sketch your graph below.

WINDOW
Xmin=
Xmax=
Xscl=
Ymin=
Ymax=
Yscl=
Xres=



5. Describe the relationship verbally. Write the relationship as a function *f* in terms of the mass, *m*.

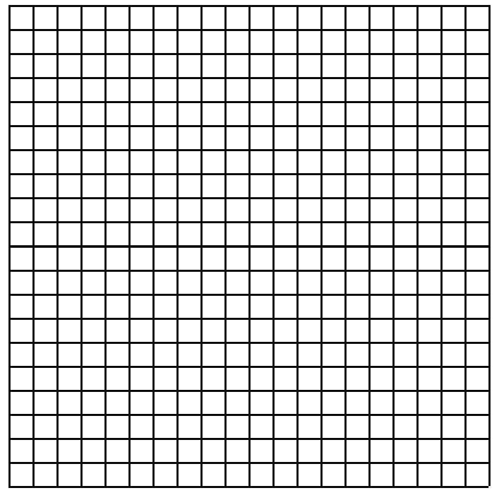
6. Is the relationship proportional? If the relationship is proportional, state two methods of determining why the relationship is proportional.

7. Does the relationship represent a direct variation? If so, explain why.

8. If the vertical force of an object hanging from the force sensor is 23.128 N, what is the mass of the object? Use at least two different methods to determine your answer.

9. If an object has a mass of 0.7375 kg and is hanging from the spring scale or force sensor, what is the vertical force? Use at least three different methods to determine your answer.

10. Predict the relationship between force, mass, and acceleration if we had NOT reset our spring scale or DUAL-RANGE FORCE Sensor to zero before collecting our data. Sketch your first investigation and your prediction of the new investigation below.



11. Repeat the investigation without zeroing the sensor or spring scale.

12. Is the "non-zeroed" relationship proportional? Explain your thinking.

13. Is the "non-zeroed" relationship varying directly? Explain your thinking.

14. There is something about 9.8. Do you remember another common relationship we use on earth that involves 9.8?

15. Why is $9.8\ \frac{m}{\sec^2}$ positive?

16. Write the algebraic relationship between force, mass, and acceleration.

17. Update KWL organization chart. Add additional information necessary to provide a quick summary of important concepts contained in this lesson.

PART B *Zoom, Zoom, Zoom*

In Part A of this lesson we discovered $F = ma$ where F represents the force being applied to an object, m the mass of that object, and a the acceleration of that object as a result of the force applied to the object's mass. We varied the *mass*, our independent variable, and collected the *Force*, our dependent variable, acting on the *mass.* For each data point (*mass, Force)* the ratio of the dependent variable quantity, *Force,* to the independent variable quantity, *mass,* was constant (9.8 *N/kg* in our Part A investigation).

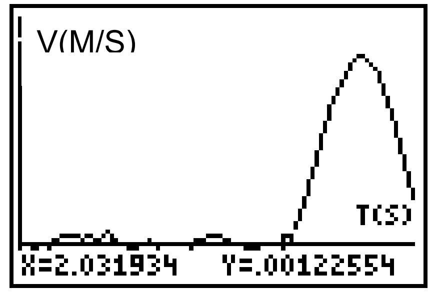
In Part A of this lesson we also made connections between $F = ma$ and direct variation. Direct variation is defined as:

> **Direct variation**
> A relationship between variables in which the variables have a constant ratio k, $k \neq 0$. If x and y are the variables, then $\frac{y}{x} = k$, *or* $y = kx$. The number k is called the constant of variation or the constant of proportionality.

Since we know that *Force = (mass)(acceleration),* rewrite the equation $F = ma$ to model the direct variation relationship both "in words" and using symbols.

Acceleration is equal to the ratio of force over mass. A push or a pull upon an object is referred to as force and has the ability to change the motion of that object. Applying force creates changes in motion and causes acceleration. Acceleration is also defined as the rate of change in velocity with respect to time. What is velocity? The velocity of an object in motion tells how fast the object is moving (speed) and in what direction the object is moving. A positive velocity denotes the object is moving away or going up (as time increases speed increases) and a negative velocity denotes the object is moving toward or down (as time increases speed decreases).

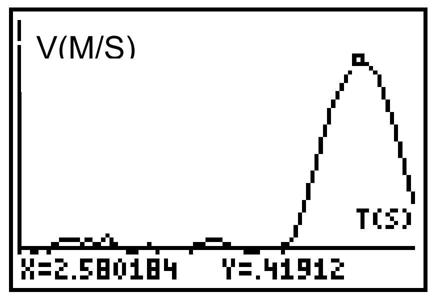
The velocity vs. time graph of a car collected by a motion detector or CBR is pictured to the right. To calculate the acceleration of this car we must first determine the time where the minimum velocity is zero, the time just before the car began to roll. According to this graph, the car began rolling about 2.031934 seconds. The motion detector began collecting data at time = 0 seconds, but the car was not released for about 2 seconds. The velocity vs. time graph between time = 0 and about 2 seconds could be interpreted as the velocity of the student's hand holding the car before the car was released.



At about 2 seconds the velocity of the car was about 0 meters/second. (2.032 sec, 0.001 m/s)

The car's speed increased as time increased then began to slow down as time continued.

Now that we have located the time that the car began to move (2.032 seconds) we must determine the time at which the car reached its maximum velocity. At about 2.580 seconds the car reached a maximum velocity of 0.419 meters per second. Using this data we can calculate the rate of change in the car's velocity with respect to time.



$$acceleration = \frac{\triangle\ velocity}{\triangle\ time} = \frac{\max\ velocity - \min velocity}{time_{\max velocity} - time_{\min velocity}}$$

$$acceleration \approx \frac{0.419\, m/\sec - 0\ m/\sec}{2.580 \sec - 2.032\ \sec} = \frac{0.419\ m/\sec}{0.548 \sec}$$

$$acceleration \approx 0.765\ meters\ \ per\ \text{second}\ \ per\ \text{second}$$

$$acceleration \approx 0.765\ \frac{m}{\sec^2}$$

In Part B of this lesson you will investigate the second part of Sir Isacc Newton's second law of motion by determining the relationship between the acceleration of a car and the mass of the car when the force acting on the car is kept constant.

PART B-1 Investigation: ***Zoom, Zoom, Zoom***
Qualitative investigation:

Materials: A low friction car (need to be able to tie a string in one end), uniform paper clips, kite string, clamp pulley
Check to make sure clamp pulley is large enough for your table

Using the materials listed above determine the relationship between the acceleration (*a*) of a low friction car and the mass (*m*) of the car.

1. Set up an investigation.
2. Record your observations
3. Formalize your conjecture

PART B-2 Investigation: ***Zoom, Zoom, Zoom***
Quantify your conjecture.

Materials: A low friction car (need to be able to tie a string in one end), uniform paper clips, kite string, clamp pulley, CBR , graphing calculator, triple beam balance to determine mass

Procedure:
The following investigation is to determine the relationship between the acceleration (*a*) of a low friction car and the mass (*m*) of the car.

1. Set up the investigation:
    a. Use a triple beam balance or other device to determine groups of paper clips that have the same mass. String like groups together.
    b. Position a clamp pulley to the end of the table.

    Repeat c and d below until the force attached in c barely moves the car in d.

    c. Tie enough kite string to the car such that the string passes over the clamp pulley and hangs off the table but does not touch the floor before the car would reach the end of the table. Tie a large loop in the other end of the string. Hang group(s) of paper clips to the loop in the string such that the car barely rolls.

    d. Load the low friction car with enough paper clips such that the mass of the car moves VERY slowly. Determine the mass of the car in kilograms and record in the table below.
    e. For each term, use the CBR or motion detector to collect velocity vs. time graphs and determine the acceleration of the car for at least three trials. Average the calculated accelerations for each term and record in the table.
    f. Continue to decrease the mass of the low friction car by removing one set of paper clips.

2. BEFORE you begin - Which variable would you identify as the independent variable in this investigation? Why?

3. PREDICT: In this investigation as the mass of the car decreases the acceleration will ________________. Why?

4. Determine the relationship between the acceleration of the car (*a*) and the mass of the car (*m*) when the force acting on the car is held constant.
   - Record the car's mass and acceleration in the table.
   - For each term in the table, record the time where the car's velocity is approximately zero and the time and velocity of the car when it reaches it's maximum velocity. Determine the acceleration of the car. Repeat this at least three times and calculate the average of the three runs. Record the acceleration for the mass of the car in the data table.
   - Enter the data in the list feature of your graphing calculator, determine an appropriate window to view the data, and graph.
   - Record your window and sketch of your graph.
   - Describe the relationship algebraically.

Part B-2: Zoom, Zoom, Zoom

m		

WINDOW
Xmin=
Xmax=
Xscl=
Ymin=
Ymax=
Yscl=
Xres=

Term 1 ____ sets of paper clips; mass of car = ______

Minimum	Maximum
Time:	Time:
Velocity:	Velocity:

$acceleration = \frac{\Delta v}{\Delta t} =$ ________

Minimum	Maximum
Time:	Time:
Velocity:	Velocity:

$acceleration = \frac{\Delta v}{\Delta t} =$ ________

Minimum	Maximum
Time:	Time:
Velocity:	Velocity:

$acceleration = \frac{\Delta v}{\Delta t} =$ ________

Average acceleration of the three trials.

Term 2
____ sets of paper clips; mass of car = ______

Minimum	Maximum
Time:	Time:
Velocity:	Velocity:

$acceleration = \frac{\Delta v}{\Delta t} =$ ________

Minimum	Maximum
Time:	Time:
Velocity:	Velocity:

$acceleration = \frac{\Delta v}{\Delta t} =$ ________

Minimum	Maximum
Time:	Time:
Velocity:	Velocity:

$acceleration = \frac{\Delta v}{\Delta t} =$ ________

Average acceleration of the three trials.

Term 3 ____ sets of paper clips; mass of car = ______

Minimum Time: Velocity: Maximum Time: Velocity: $acceleration = \frac{\Delta v}{\Delta t} =$ ________	Minimum Time: Velocity: Maximum Time: Velocity: $acceleration = \frac{\Delta v}{\Delta t} =$ ________
Minimum Time: Velocity: Maximum Time: Velocity: $acceleration = \frac{\Delta v}{\Delta t} =$ ________	Average acceleration of the three trials.

Term 4
____ sets of paper clips; mass of car = ______

Minimum Time: Velocity: Maximum Time: Velocity: $acceleration = \frac{\Delta v}{\Delta t} =$ ________	Minimum Time: Velocity: Maximum Time: Velocity: $acceleration = \frac{\Delta v}{\Delta t} =$ ________
Minimum Time: Velocity: Maximum Time: Velocity: $acceleration = \frac{\Delta v}{\Delta t} =$ ________	Average acceleration of the three trials.

Term 5 ____ sets of paper clips; mass of car = ______

Minimum	Maximum
Time:	Time:
Velocity:	Velocity:

$$acceleration = \frac{\Delta v}{\Delta t} = \_\_\_\_\_\_$$

Minimum	Maximum
Time:	Time:
Velocity:	Velocity:

$$acceleration = \frac{\Delta v}{\Delta t} = \_\_\_\_\_\_$$

Minimum	Maximum
Time:	Time:
Velocity:	Velocity:

$$acceleration = \frac{\Delta v}{\Delta t} = \_\_\_\_\_\_$$

Average acceleration of the three trials.

Term 6
____ sets of paper clips; mass of car = ______

Minimum	Maximum
Time:	Time:
Velocity:	Velocity:

$$acceleration = \frac{\Delta v}{\Delta t} = \_\_\_\_\_\_$$

Minimum	Maximum
Time:	Time:
Velocity:	Velocity:

$$acceleration = \frac{\Delta v}{\Delta t} = \_\_\_\_\_\_$$

Minimum	Maximum
Time:	Time:
Velocity:	Velocity:

$$acceleration = \frac{\Delta v}{\Delta t} = \_\_\_\_\_\_$$

Average acceleration of the three trials.

5. If you remove 5 more sets of paper clips what is the mass of the car?

6. Use at least two different methods to determine the acceleration of the car with the mass you found in question 5. Use the CBR or motion detector to verify your answer.

7. In Algebra I, we learn that an inverse variation is a relationship between variables in which the variables have a constant product *k*, $k \neq 0$. If *x* and *y* are the variables, then $xy = k, \ or \ y = \frac{k}{x}, x \neq 0$. The number *k* is called the constant of variation.

   Does this investigation represent an inverse variation? Describe the variables in the context of the investigation.

8. Applying force creates changes in motion and causes acceleration. What force(s) cause the car to accelerate in this investigation?

9. Multiply the mass you placed on the end of the string by 9.8 $\frac{m}{\sec^2}$ (acceleration due to gravity).

10. Compare the quantity from calculating the mean *(mass)(acceleration)* to your answer in question 9. Describe as many reasons as you can why the empirical results (the investigation results) differ from the theoretical results.

11. Record key terms you have identified (What you Know) and what you have learned or remembered (What you Learned) in your KWL chart.

PART C Force: Another look

Newton's Second Law of Motion – Part 1	Direct variation
The acceleration of an object is directly proportional to the force acting on it. Acceleration (m/sec^2) → $a = \frac{F}{m}$ ← Force (N) The two variables are acceleration and force. The constant is *m,* mass.	A relationship between variables in which the variables have a constant ratio k, $k \neq 0$. If x and y are the variables, then $\frac{y}{x} = k$, *or* $y = kx$. The number k is called the constant of variation or the constant of proportionality.

Newton's Second Law of Motion – Part 2	Inverse variation
The acceleration of an object is inversely proportional to its mass. Acceleration (m/sec^2) → $a = \frac{F}{m}$ ← Mass (kg) **or** $m\,a = F$ The two variables are acceleration and mass. The constant is *F,* force.	A relationship between variables in which the variables have a constant product k, $k \neq 0$. If x and y are the variables, then $x\,y = k$, *or* $y = \frac{k}{x}$, $x \neq 0$. The number k is called the constant of variation.

REFLECT:

1. If the mass is held constant and you change the force, what do you expect will happen to the acceleration?

2. If the force is held constant and you change the mass, what do you expect will happen to the acceleration?

In the investigation *Zoom, Zoom, Zoom,* the acceleration of the car is inversely proportional to its mass. The constant of variation, the *force* in this investigation, is numerically close to the product of the *mass* of the paper clips providing the force to move the car and the acceleration of the paper clips due to gravity. The calculations were not exact because we did not consider another force that can alter the acceleration of the car. That force is friction. The *American Heritage Dictionary of the English Language* defines friction as "the rubbing of one object or surface against another." Physicists define friction as any force that is caused by motion and acts to slow down and finally stop an object in motion. The friction produced by wheels or ball bearings is called rolling friction. A force is not required to keep an object in motion; in fact, it is force, friction, which brings an object to rest.

> If you remove the wheels from the car in *Zoom, Zoom, Zoom*, how would it affect the car's acceleration? *Wheels were invented to make the task of moving an object easier. If we remove the wheels then sliding friction would decrease the car's acceleration. Ask students to investigate by repeating one term of Zoom, Zoom, Zoom and comparing the acceleration.*

Weight is not the same thing as mass. The weight of an object is defined as the magnitude of the gravitational force acting on it. Weight, F_w, is equal to an object's mass, *m,* times the acceleration of gravity, *g*. Since different planets have different gravitational forces, weight changes from one planet to another. Mass; however, remains the same. Weight depends upon mass and the acceleration of gravity.

Weight

$$F_w = m\,g$$

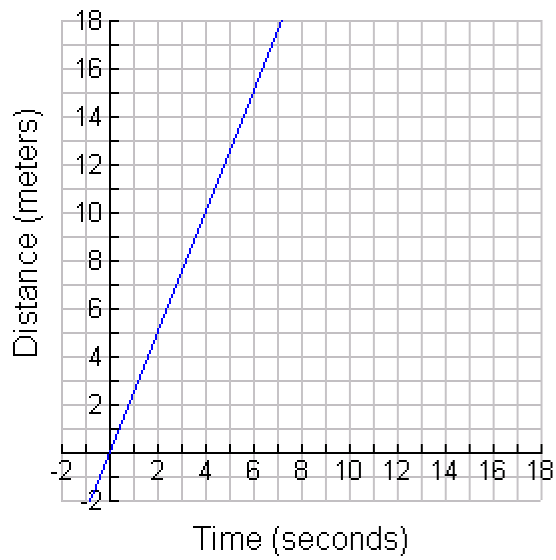
Weight force (N) = mass (kg) × Acceleration of gravity (m/sec^2)

> The acceleration of an object due to gravity is directly proportional to its ______*weight*____. The acceleration of an object due to gravity is inversely proportional to its _____*mass*_____.

Check for understanding:

1. In the formula *d=vt*, d represents distance in meters, *v* represents velocity (rate in meters/second), and *t* represents time in seconds. Use the word *directly* or *inversely* to complete each statement. Write an equation for each.
   a. The time it takes a walker to walk 50 meters is ______________ proportional to the velocity of the walker.
   b. If the walker travels at a constant rate of 0.5 meters per second, the distance you travel is ____________ proportional to the time you travel.

2. How far will the walker have traveled in 20 seconds? Explain your thinking.



3. For each of the tables of x and y values, determine if the values indicate a direct variation, an inverse variation, or neither. Explain how you made your decision. If the values represent a direct or inverse variation, write an equation.

a.

L1	L2	L3 3
3	16	
4	12	
5	9.6	
6	8	
8	6	
10	4.8	
16	3	
L3(1)=		

b.

L1	L2	L3 3
4	17	
5	21	
6	25	
7	29	
8	33	
9	37	
10	41	
L3(1)=		

c.

L1	L2	L3 3
4	.25	
5	.2	
6	.16667	
7	.14286	
8	.125	
9	.11111	
10	.1	
L3(1)=		

d.

L1	L2	L3 3
2	4.6	
3	6.9	
4	9.2	
5	11.5	
6	13.8	
7	16.1	
8	18.4	
L3(1)=		

4. Ohm's law describes the mathematical relationship present in most circuits.
R represents the resistance, measured in ohms*,*
E represents the voltage, measured in volts,
and *i* represents the amount of current, measured in amperes (amp).

$$i = \frac{E}{R}$$

Use the word *directly* or *inversely* to complete each statement.

a. If the voltage, E, is held constant, then the current, i, is ______________________ *proportional* to the resistance, R.

b. The current, i, is ________________ proportional to the voltage, E.

2.2 Force, Mass, and Acceleration

SAMPLE ASSESSMENT

1. A toddler pedaling a tricycle applies a net force of 150 N to the pedals. We will assume that 100% of this force is transferred to forward motion. The grandmother of this toddler notices that the toddler on the tricycle is accelerating at a rate of 5 m/sec^2. What is the combined mass of the tricycle and the toddler? Use **two different** methods to solve the problem.

2. What is the force on a 2000 kg crate that is falling freely at $9.8\ \frac{m}{\sec^2}$?

   Use **two different** methods to solve the problem.

3. How much force is needed to accelerate a 88 kg skier $1\frac{m}{\sec^2}$?

4. Does the data in the table below represent a proportional relationship? Explain your thinking.

L1	L2	L3 3
1	2.7	
2	5.4	
3	8.1	
4	10.8	
5	13.5	
6	16.2	
------	------	

L3(1)=

5. The data table below contains data collected by a group of 9th grade students. The mass of an object is recorded in L1. The force acting on the object is recorded in L2. Write a function that would describe the relationship between the mass and the force acting on the mass. Explain your thinking.

L1	L2	L3
.1475	.826	------
.4425	2.478	
.885	4.956	
1.3275	7.434	
------	------	

L2(1)=.826

6. If the mass of the object in question 5 is 1.77 kg, what is the quantity of the force acting upon the mass? Use two different methods to solve the problem.

7. Write two scenarios involving force, mass, and acceleration where the unknown is the mass. One scenario must contain the phrase "inversely proportional" and the other "directly proportional." Write an equation for both scenarios.

8. For each of the tables of x and y values, determine if the values indicate a direct variation, an inverse variation, or neither. Explain how you made your decision. If the values represent a direct or inverse variation, write an equation.

a.

L1	L2	L3
2	51	
3	34	
4	25.5	
5	20.4	
6	17	
8	12.75	

L3(1)=

b.

L1	L2	L3
2	8.4	
3	12.6	
4	16.8	
5	21	
6	25.2	
8	33.6	

L3(1)=

c.

L1	L2	L3
2	1.4	
3	1.6	
4	1.8	
5	2	
6	2.2	
8	2.6	

L3(1)=

d.

L1	L2	L3
2	4.8	
3	7.2	
4	9.6	
5	12	
6	14.4	
8	19.2	

L3(1)=

2.3 Newton's Third Law of Motion

A force is a push or pull upon an object from its interaction with another object. Forces result from interactions. Some forces result when objects come into contact with each other, while other forces, like gravity, are the result of action-at-a-distance interactions.

According to Newton, whenever objects A and B interact with each other, they exert forces upon each other. When you stand on a scale, your feet exert a downward force on the scale and the scale exerts an upward force on your feet. There are two forces resulting from this interaction – a force on the scale and a force on your feet. These two forces are called *action* and *reaction* forces and are the subject of Newton's third law of motion.

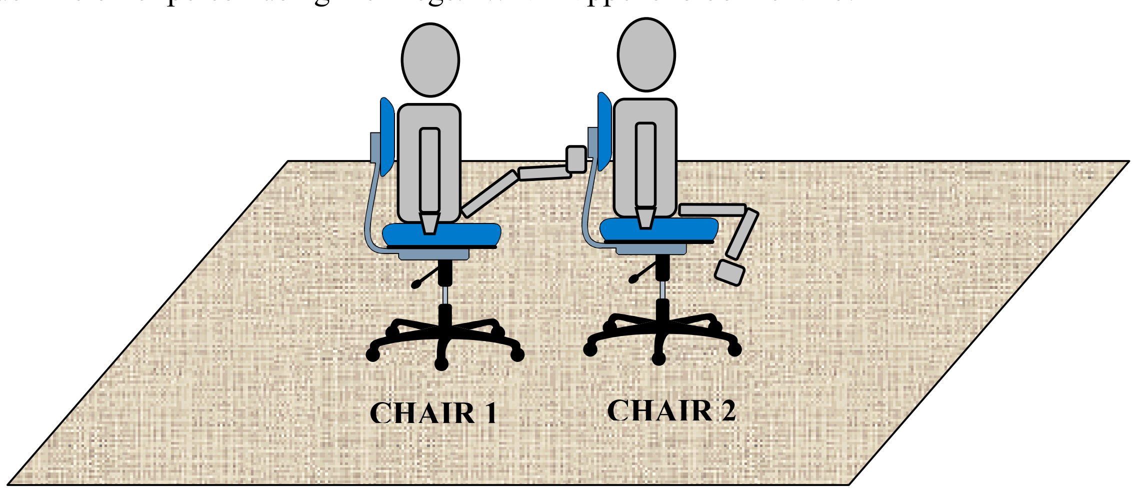
Newton's third law is:

"For every action, there is an equal and opposite reaction."

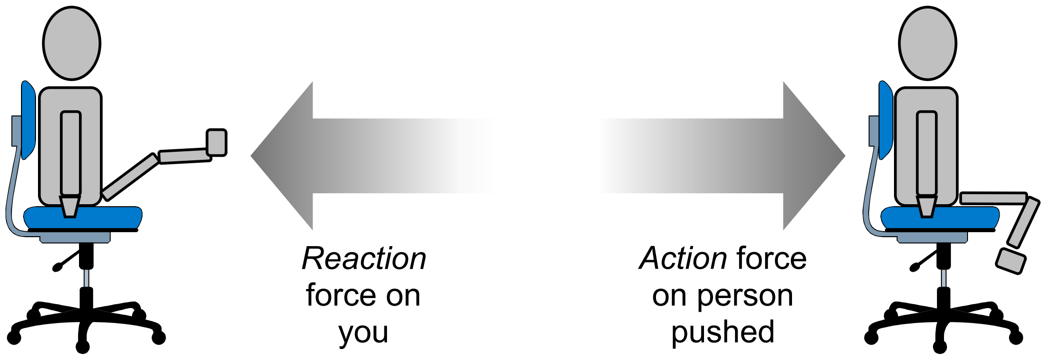
The statement means that in every interaction, there is a pair of forces acting on the two interacting objects. The size of the force on the first object equals the size of the force on the second object. The direction of the force on the first object is opposite the direction of the force on the second object. Forces always come in pairs – equal and opposite action-reaction force pairs. The action/reaction forces act on separate objects, *not* the same object.

Try this:

Two people sit on rolling chairs as shown in the picture below. Have one person gently push the other person using their legs. What happens to both chairs?



Why did both chairs move? When one person pushes the other, action and reaction forces are created.



When the person on the left pushes the chair and person on the right, he applies the action force to the chair on the right, creating acceleration of the chair. The reaction is the chair pushing back against his feet.

There are lots of action-reaction force pairs evident in nature. Have you ever blown up a balloon and then let it go and watched it fly around the room? The escaping air from the balloon pushes in one direction, and the balloon pushes back in the opposite direction. The escaping air pushes with a much larger force than the balloon, so the balloon accelerates.

If you are standing on a boat and step off the boat onto the dock, if you aren't careful, you could end up in the water. When you step off of the boat, you create action-reaction forces. You push the boat, and the boat pushes back on you, but if you push the boat too far, you may end up taking an unexpected swim!

Try this!

Set up two ramps facing each other so that when cars are rolled down the ramps, the cars will collide head-on. Both ramps need to be the same length, the items used to raise the ramps should be the same, and the cars should be identical. Put tape at the front of each car so that when they collide, they stick together. Leave enough space in between the ramps so that the cars are traveling horizontally when they collide.

Part A:
Place two low-friction cars at the tops of both ramps. Without any extra nudge, release the cars at the same time and let the cars roll down the ramps. Observe what happens as they collide and stick to each other. Record your observations below, including observations on the velocity of each car.

Part B:
Increase the mass of one of the cars and try the experiment again. Record your observations below.

Part C:
This time, keep the mass of the cars the same, but make one of the ramps higher. By raising the ramp, what variable in the experiment are you changing? Repeat the experiment and record your observations below.

WHAT HAPPENED?

Every object has mass. And if that object is moving, it has velocity. When that mass is in motion, we say it has *momentum.* The amount of momentum an object has is dependent on two variables: how much *stuff* is moving and how *fast* the stuff is moving. In other words, momentum depends upon the variables mass and velocity.

The momentum of an object is equal to the mass of the object times the speed or velocity of the object. We use the letter *p* to stand for momentum.

$$\text{Momentum} = \text{Mass} \cdot \text{Velocity}$$

$$\text{kg} \cdot \text{m/s} = (\text{kg})(\text{m/s})$$

$$p = mv$$

Exploring Momentum

Investigation 1:

What happens to an object's momentum if the mass of the object is increased while the velocity is kept constant?

Suggested Materials:

- Low-friction car
- Blocks to elevate ramp
- Index card
- Centimeter ruler
- Ringstand
- Balance
- Ramp
- Centimeter grid paper
- Scissors
- Photogate
- Tape
- CBL2 with link cord
- TI graphing calculator with Datagate program
- Objects (weights) to increase the mass of the car in equal increments
- Block (approx. 150 g) to run low-friction car into
- Equal-sized blocks used to raise ramp

Investigation 1

- ❑ Working in a group of three to four students, set up an experiment in which a low-friction car will roll down a ramp and collide with a stationary block.
- ❑ On each roll of the car, determine the car's velocity after exiting the ramp.
- ❑ Increase the mass of the car in equal intervals each subsequent roll.
- ❑ Create a data table to display for each roll the mass (kg), velocity (m/s), and momentum (kg-m/s) of the car, and the distance (cm) the block moved on each collision.
- ❑ Create a graph of momentum vs. mass, determining the appropriate independent and dependent variable.
- ❑ Answer the questions that follow. Attach a copy of your data table and graph to the following sheet.

EXPLORING MOMENTUM

Investigation 2:
What happens to an object's momentum if the velocity of the object changes while the mass stays the same?

Suggested Materials:

- Low-friction car
- Blocks to elevate ramp
- Index card
- Centimeter ruler
- Ringstand
- Balance
- Ramp
- Centimeter grid paper
- Scissors
- Photogate
- Tape
- CBL2 with link cord
- TI graphing calculator with Datagate program
- Objects (weights) to increase the mass of the car in equal increments
- Block (approx. 150 g) to run low-friction car into
- Equal-sized blocks used to raise ramp

Investigation 2

- ❑ Working in a group of three to four students, set up an experiment in which a low-friction car will roll down a ramp and collide with a stationary block.
- ❑ On each roll of the car, determine the car's velocity after exiting the ramp.
- ❑ Increase the velocity of the car by raising the ramp's height in equal intervals each subsequent roll.
- ❑ Create a data table to display for each roll the mass (kg), velocity (m/s), and momentum (kg-m/s) of the car, and the distance (cm) the block moved on each collision.
- ❑ Create a graph of momentum vs. velocity, determining the appropriate independent and dependent variable.
- ❑ Answer the questions that follow. Attach a copy of your data table and graph to the following sheet.

Investigation 1

1. Sketch the experiment set-up and explain the procedures you used for collecting the data.

2. List at least three different ways you can describe the relationship based on your graph or data.

3. Write an algebraic function to represent the graph and data and explain how you arrived at this function.

.

4. Describe what happened to the block that the car was colliding with and explain why this happened.

5. Complete the following statement:

   As the mass of the car ______________________________, *the momentum of the car* ______________________________.

6. If the mass of an object doubles and the velocity remains the same, what happens to the momentum of the object?

7. If the mass of an object is decreased by a factor of 1/3, and the velocity stays the same, what would happen to the momentum?

Investigation 2

1. Explain the procedures you used for collecting the data.

2. List at least three different ways you can describe the relationship based on your graph or data.

3. Write an algebraic function to represent the graph and data and explain how you arrived at this function.

4. Describe what happened to the block that the car was colliding with and explain why this happened.

5. If the velocity of an object quadruples and the mass remains the same, what happens to the momentum of the object?

6. If the velocity of an object dropped from 10 m/s to 5 m/s and the mass remained the same, how would the momentum of the object change?

7. Which variable, mass or velocity, is more important in determining a moving object's momentum? Explain your reasoning.

8. Complete the following statement:

As the velocity of the car ________________________________*, the momentum of the car* ________________________________.

MOMENTUM ASSESSMENT

1. A truck has a momentum of 15,000 kg-m/s. What would be the truck's new momentum if:
   a. its velocity was doubled and the mass stayed the same?

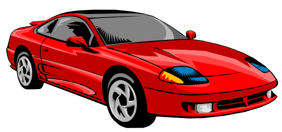
   b. its velocity was tripled and the mass stayed the same?

   c. its mass was doubled (by adding more people and a greater load) and its velocity stayed the same?

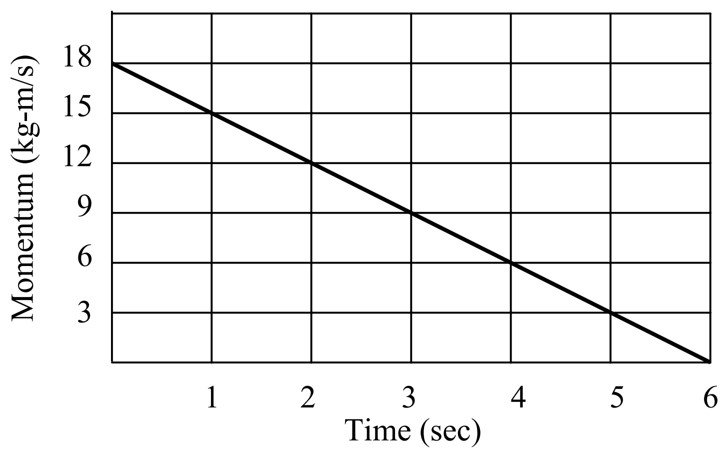
   d. both its velocity and mass were doubled?

2. A 250-lb (113 kg) fullback is running down the football field at speed of 11 m/sec. Which value is the independent variable? Which is the dependent? What is the football player's momentum?

3. What is the momentum of a 1425 kg Corvette stopped at a red light?



4. The velocity of a moving 40 kg cart is shown on the graph below.



a. What is the cart's momentum at time zero? Show how you determined this.

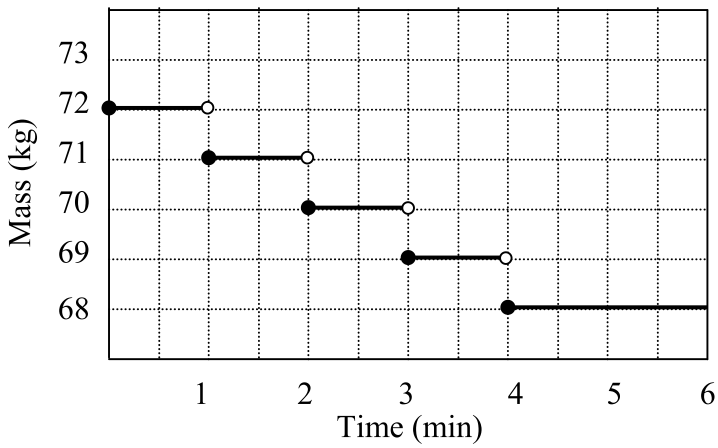
b. What is the cart's momentum at 4 seconds? Show how you determined this.

c. When will the cart have no momentum? Why?

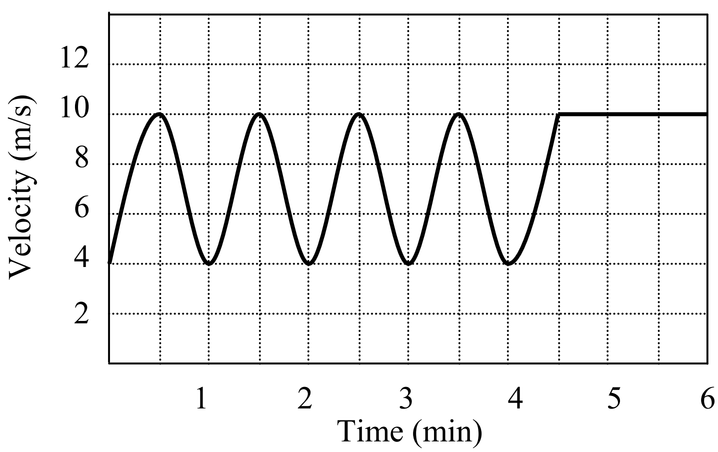
d. When would the cart be most difficult to stop?

.

5. A paper girl is delivering her papers while riding her bicycle. She has to slow down when she throws each paper. Her mass vs. time graph and velocity vs. time graph are both shown below.



a. What will her momentum be at 1½ minutes?



b. When will her momentum be 272 kg-m/s?

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EXPLORING NEWTON'S THIRD LAW AND MOMENTUM

Recall the difference between speed and velocity. Since velocity includes direction, and momentum is the product of mass and velocity, momentum can be a positive or a negative value.

Example:
A toy car with a mass of 4 kg is moving towards a motion detector. The motion detector determines the car to have a constant speed of 4 m/s. What is the car's momentum?

Now think back to the experiment you did with the two rolling chairs. When you push the second chair with your feet, the second chair moves in one direction and you and your chair move in the opposite direction. Since both objects have mass and velocity, both objects have momentum. The momentum of you and the first chair are connected to the momentum of the second chair. If the second chair takes away momentum to the right, you must take away an equal amount of momentum to the left. This rule is an example of the *law of conservation of momentum.* As long as the interacting objects are not influenced by outside forces (like friction), the total amount of momentum cannot change.

Before you push the second chair with your feet, your speed (and the other chair's) is zero. Since momentum is mass times velocity, the total momentum is also zero. The law of conservation of momentum says after you push the chair with your feet the total momentum still has to be zero.

This means that:

$$p_{Chair\,1} + p_{Chair\,2} = 0$$
$$p_{Chair\,1} = -p_{Chair\,2}$$
$$\left|p_{Chair\,1}\right| = \left|-p_{Chair\,2}\right|$$

If we ignore the sign (+ or -) of the momentums (and the velocities), then

$$p_{Chair\,1} = p_{Chair\,2}$$
$$m_{Chair\,1} \cdot v_{Chair\,1} = m_{Chair\,2} \cdot v_{Chair\,2}$$

Example:
Sheila and Jon are doing the chair experiment described earlier in this unit. Sheila is going to push Jon. The combined mass of Sheila and her chair is 77 kg, while the combined mass of Jon and his chair is 125 kg. Sheila pushes Jon and he moves at a velocity of 4 m/s. At what speed will Sheila move backwards?

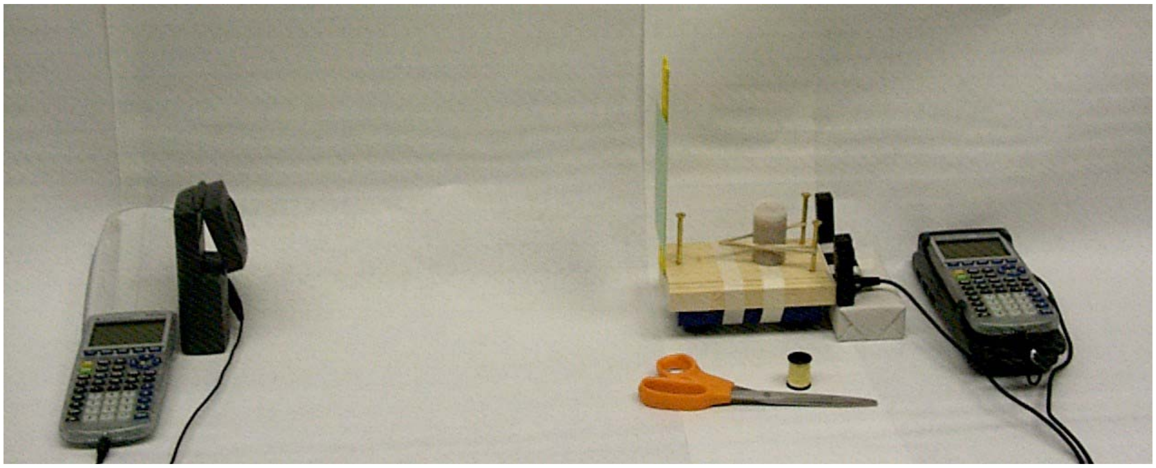
TESTING THE LAW OF CONSERVATION OF MOMENTUM

Objective:
In this lab experiment, students will work in groups of four to test the Law of Conservation of Momentum.

Materials:
- Low-friction car
- 1 Newton Car
- Plastic film canister with assorted materials for filling canister (e.g. washers, nuts, pennies, ball bearings) or some form of mass
- Cotton thread
- 4 rubber bands
- Scissors
- Meter stick
- Metric balance
- Photo gate
- Datagate program
- CBR
- CLB2
- 2 TI-83+ Graphing Calculators
- 2 link cords
- 6-inch ruler
- 12-inch ruler
- Index card
- Tape
- Safety glasses for each student

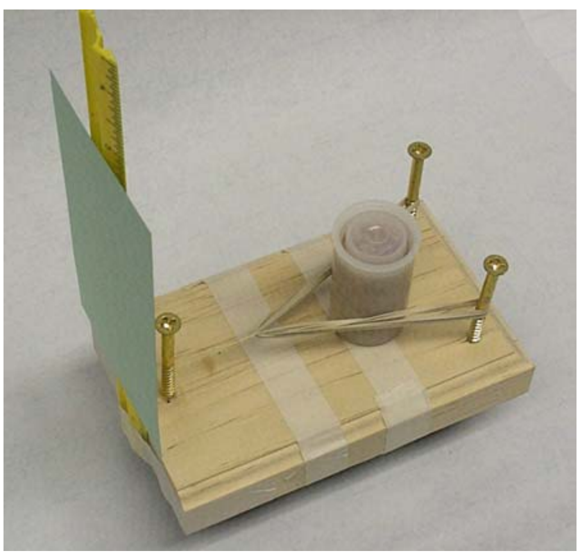
Job Responsibilities:
- **Group Leader:** You are responsible for leading the group. You must make sure everything is in place and ready before running the experiment. You will also serve as recorder.
- **CBR Operator:** You are responsible for setting up the CBR and TI-83+ calculator and using these during the experiment.
- **CBL Operator:** You are responsible for setting up the photo gate, CBL2, and TI-83+ graphing calculator, and running these during the experiment.
- **Newton Car Operator:** You are responsible for setting up the Newton Car during the experiment and for cutting the string and launching the mass.

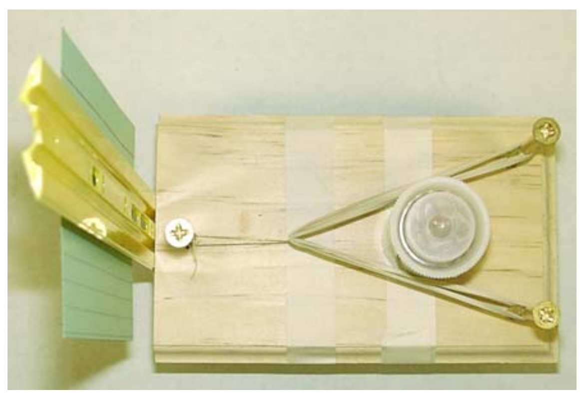
NEWTON CAR SET-UP GUIDE



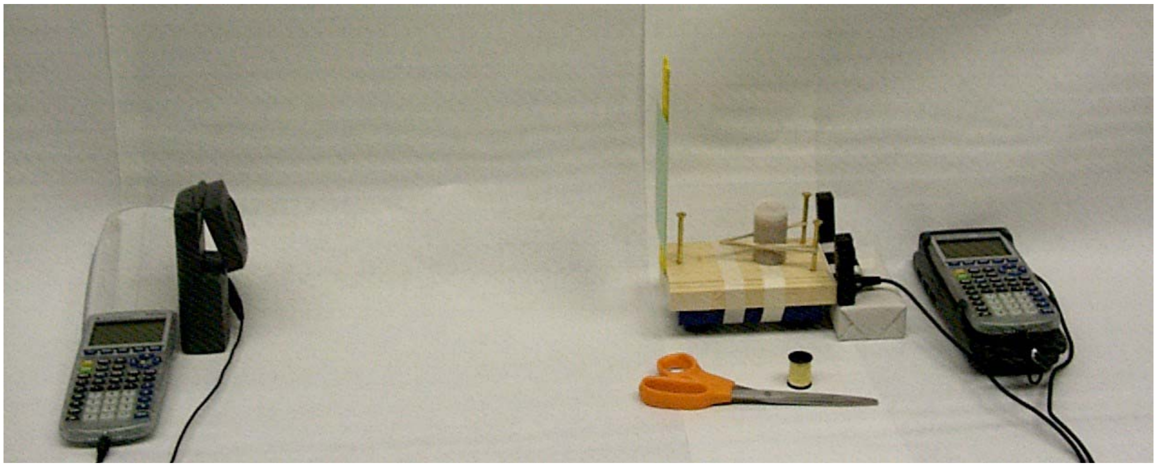
Put on your eye protection!

Set up your Newton Car as shown in the picture. Use two of the rubber bands and/or tape to secure the Newton Car to the low-friction car. Be sure the ejector mass (film canister, or whatever mass you are using) will slide smoothly off the car when it is ejected. Use at least two rubber bands for the slingshot. Slip the rubber bands through the string loop. You may need to double the loop of thread to keep the rubber bands in place.



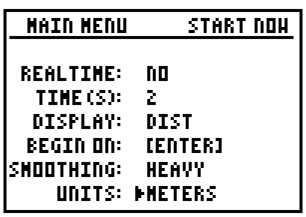


CBR/TI-83 SET-UP GUIDE



Put on your eye protection!

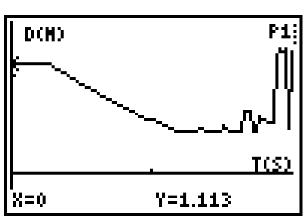
Attach the CBR and graphing calculator with a link cord. Start the CBL/CBR application under the blue APPS button, and run the RANGER program. On the main menu, choose SETUP/SAMPLE, and set to the following:



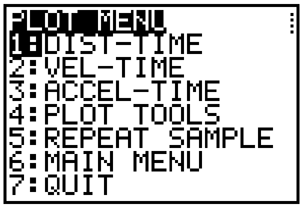
When all of your settings are the same as on the left, arrow up to START NOW and press the enter key.

Once the Newton Car is set up and in place, run a check of the CBR. The CBR should be placed about 1 meter from the Newton Car's starting point. With the Newton Car stationary, collect data. You should have a completely horizontal distance-time graph. Make sure the distance the CBR determined to the Newton Car is accurate. If the distance is incorrect, or if you do not have a horizontal distance-time graph, try adjusting the angle of the face of the motion detector. (See the picture of the experiment set up above.) Re-collect data and keep making adjustments until you get a horizontal distance-time graph, and the distance the CBR is calculating to the Newton Car is correct. You are then ready to run the experiment.

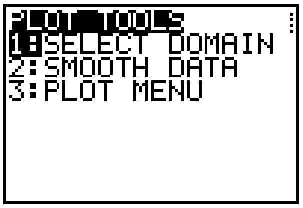
During the experiment, you will need to press the ENTER key to start collecting data **just before** the string is cut. Once your group runs the experiment, you should have data similar to the graph below.



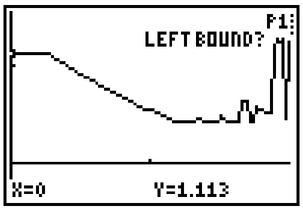
Remember that when the car gets too close to the CBR, extraneous data is gathered and should be ignored. There should be a clear portion of the distance-time graph that appears linear and is decreasing. Pay attention to this portion of the graph.



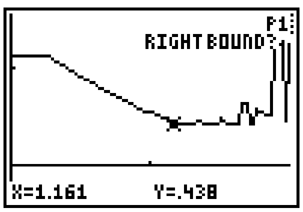
To select the pertinent part of the graph, press ENTER and choose PLOT TOOLS.



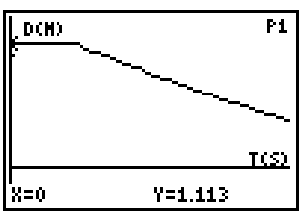
Now choose SELECT DOMAIN.



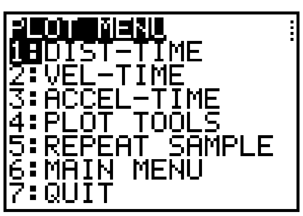
Choose the y-axis as your left bound.



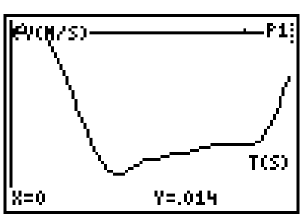
Choose a point for the right bound that is near the end of the decreasing linear portion of the graph.



You should now have a distance vs. time graph similar to the one shown at right. Each member of the group should sketch your group's graph on their data collection sheet.



Press ENTER and now choose VEL-TIME to view the velocity vs. time graph of this data.

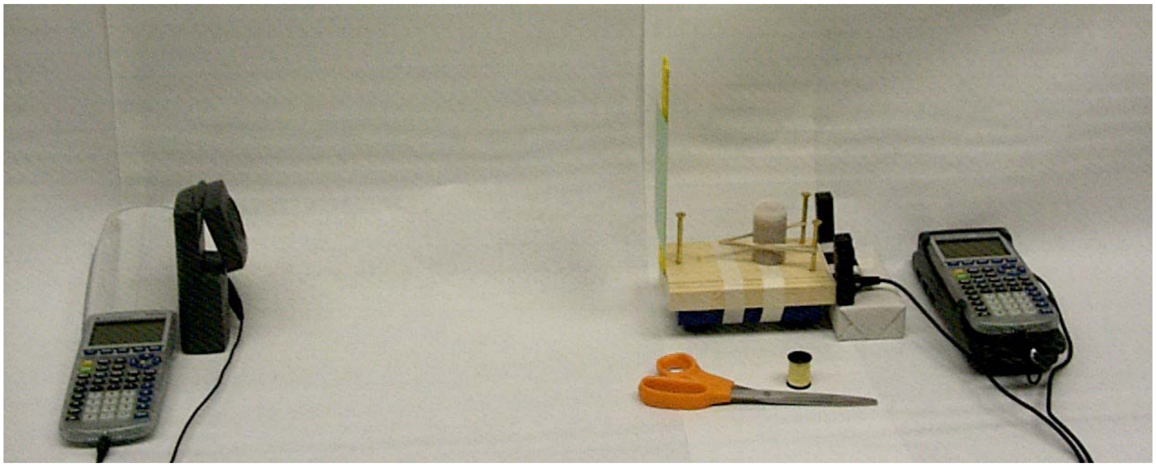


You should now have a velocity vs. time graph similar to the one shown at right. Each member of the group should sketch your group's graph on their data collection sheet.

Trace along the velocity-time graph and find the point that has the smallest y-coordinate. Record this as the maximum velocity of the vehicle.

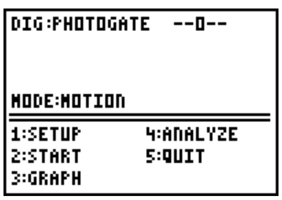
If you need to repeat the experiment, press the ENTER key and choose REPEAT SAMPLE. Go through the above steps again.

CBL2/PHOTO GATE/TI-83 SET-UP GUIDE



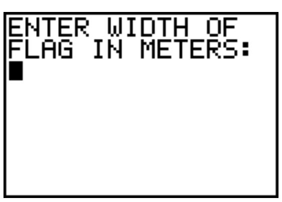
Put on your eye protection!

Attach the photo gate to the DIG/SONIC port of the CBL2, and then attach the graphing calculator to the CBL2. Press the PRGM key and start the DATAGATE program on the graphing calculator. Then follow the steps below.

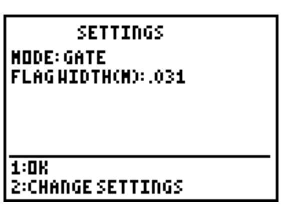


1. Choose SETUP.

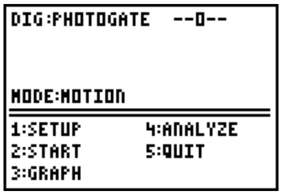
2. Choose GATE.



3. Measure and enter the width of the ejector mass in meters.



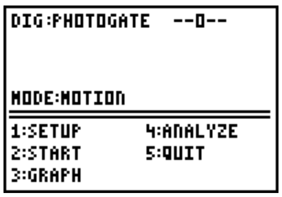
4. Choose OK or CHANGE SETTINGS if you need to re-enter the width.



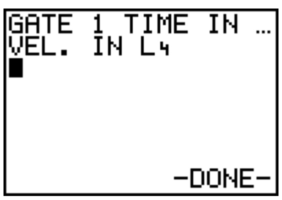
5. Choose START. You are now ready to collect data.

You are now ready to run the experiment. Wait for the rest of the group before continuing.

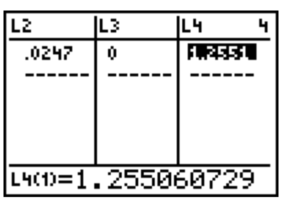
6. When the string is cut, the ejector mass should pass through the photo gate. You should have data similar to that at the left. Press the STO key on the graphing calculator.



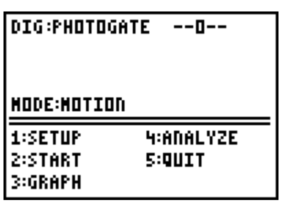
7. Now choose QUIT.



8. The data from the photo gate is now stored in the lists of the graphing calculator. Press the STAT key and choose EDIT.



9. The velocity of the ejector mass is in list 4 and the time is in list 2. Share these values with the group.



10. If you need to redo the experiment, start the DATAGATE program again, and just choose START. You will not need to setup the program again. Follow steps 5 through 9 again.

GROUP LEADER GUIDE

Put on your eye protection!

Your primary role is to lead the group and ensure that the group finishes the experiment in the time allotted.

Once all of the equipment is set up and in place, you are ready to do the experiment. When the string is cut, the ejector mass will slingshot off of the back of the car. You will need to observe what happens to the car.

The experiment may need to be repeated several times before you have usable data.

TESTING THE LAW OF CONSERVATION OF MOMENTUM
DATA COLLECTION SHEET

Name_________________________________ Responsibility________________________

Other Team Members:
Name_________________________________ Responsibility________________________

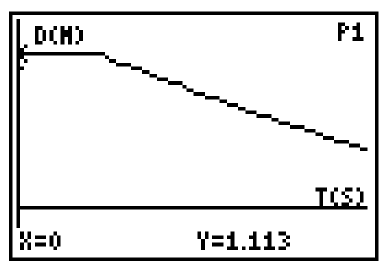
Name_________________________________ Responsibility________________________

Name_________________________________ Responsibility________________________

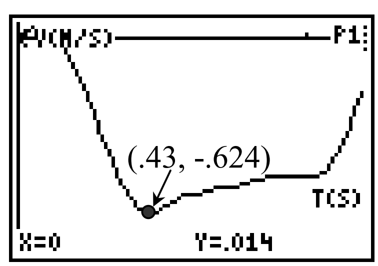
Sample data.

Total Mass of Vehicle (kg)	
Width of the Ejector Mass (m)	
Mass of Ejector Mass (kg)	
Time of Ejector Mass (sec)	
Velocity of Ejector Mass (m/s)	
Maximum Velocity of Vehicle (m/s)	

Make a sketch of your group's distance vs. time graph (with the selected domain) in the box provided at right. Label the graph appropriately.



Make a sketch of your group's velocity vs. time graph in the box provided at right. Label the graph appropriately. In addition, label the x-intercepts and the coordinate with the smallest y-value.



1. Sketch the setup of the experiment and label your drawing with arrows that indicate the direction the objects moved.

2. Using Newton's Laws of Motion, explain what happened in the experiment.

3. Explain why the velocity of the vehicle was negative.

4. Based on the Law of Conservation of Momentum, how should the momentum of the ejector mass and the momentum of the vehicle be related?

5. Calculate the momentum of the ejector mass. Show your work below.

6. Calculate the momentum of the vehicle. Show your work below.

7. How do the results of your calculations compare to your expectations?

8. Describe as many reasons as you can why the empirical results (the lab experiment) differ from the theoretical results (the law of conservation of momentum.)

9. For the photo gate to determine the velocity of the ejector mass, the width of the ejector mass had to be inputted. The photo gate measured the time it took for the ejector mass to pass through. Explain how the photo gate determined the velocity of the ejector mass. Verify the photo gate's calculations.

10. Predict what would happen if you used a heavier ejector mass. Which of Newton's Laws of Motion supports your prediction?

11. Determine the average acceleration of the vehicle in this experiment.

12. Using one of Newton's Laws of Motion, determine the force with which the rubber bands expelled the ejector mass.

13. How much force acted on the car? Explain your answer.

Conservation of Momentum Assessment

1. A toy train and a toy car are headed towards each other on the same track. The train has a mass of 6 kg and is moving at a velocity of 4 m/s. The car has a mass of 8 kg. With what velocity would the car have to be moving so that when the car and the train collide, they stop right when they hit?

2. A rollerblader whose mass is 62 kg is moving along at a constant velocity of 5 m/s. He skates by a table and picks up a stationary mass of 10 kg. Will the rollerblader's velocity change, and if so, to what? Explain your reasoning.

3. If a 90 kg linebacker is running at a velocity of 3 m/s, to what velocity must the linebacker accelerate in order to knock down a 100 kg fullback running at 6 m/s in the opposite direction? Show your work.

Performance Assessment

Paul has been challenged to a skateboard race with unique rules. Paul is not allowed to touch the ground with any part of his body to move the skateboard forward. To reach the finish line, Paul's skateboard must have a velocity of 3 m/s. Paul is given a slingshot that always exerts varying forces on the ball being slung, depending on the diameter of the ball. The force exerted on each ball from the slingshot can be determined by the function $F(d) = -1.392d^2 + 107.184d$, where d is the diameter of the ball. He is allowed to choose from the following balls to sling:

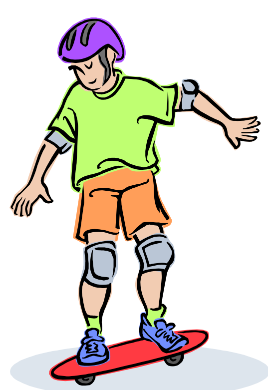
Object	Diameter (cm)	Mass (kg)
Pool ball	5.03	0.164
Basketball	76.2	0.621
Baseball	7.32	0.145
Racquetball	5.6	0.051
Tennis ball	6.35	0.057
Softball	9	0.174
Football	17	0.43
Golf ball	4.26	0.045

a. Make a sketch of how Paul should sling his ball relative to the finish line and explain why it will work to propel him forward.

b. What is the least massive ball Paul could choose to win the race? Explain how you determined this.

Additional information you may need:

Mass of Paul	67 kg
Mass of skateboard	3 kg
Mass of slingshot	1 kg
Time force is exerted	0.3 seconds
Velocity	$v = acceleration \cdot time$



3.1 Who's Pulling My Strings?

Part 1: Answer the following questions on your result sheet

What do you know and what do you think about pulleys:

1. List where have you seen or experienced pulleys in action.
2. Describe the job(s) that they were performing.
3. Describe or draw how the pulley(s) were arranged.
4. Do you think all pulley systems make the task easier? Justify your answer.
5. Do you think all pulley systems make work easier? Justify your answer.

Have the materials person obtain all materials

6: 500g masses
6: 50 cm pieces of string
6: pulleys
30 cm piece of duct tape
6 dowel rods
6 paper clips
1 Preliminary Experience Result sheet

Part 2:

1. Using the 6 pulleys, strings, dowel rods, paper clips, tape , and 0.5 kg mass create 4 **<u>different</u>** pulley systems.

2. For **each** pulley system you create,
   record the following on your *Preliminary Experiences Result Sheet*:
   - a **diagram of each** pulley system to include pulley(s), mass, string and the direction the string is being pulled. Label and number the supporting string(s)
   - a **qualitative description of each** pulley system that describes the force needed to lift 0.5 kg

Names:_______________ ______________ _______________ Date:

Preliminary Experiences Result Sheet

Part 1:

1.

2.

3.

4.

5.

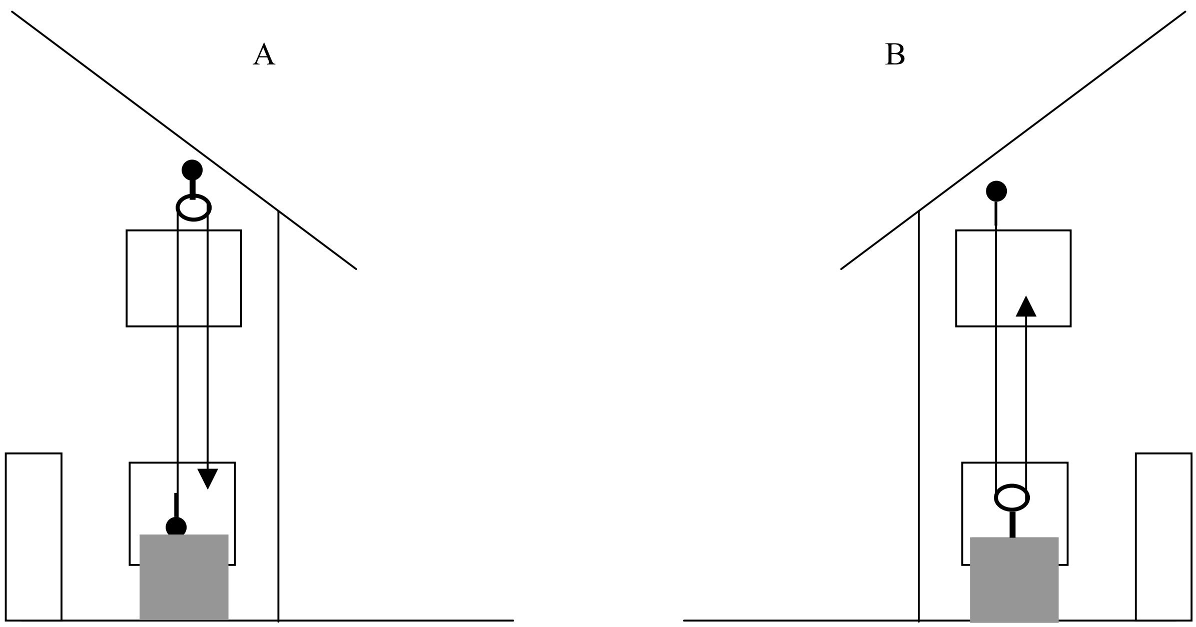
Part 2:

Pulley diagram	Qualitative description	Pulley diagram	Qualitative description
1.		**3.**	
2.		**4.**	

Names:_______________ ______________ ________________ Date:__________

Jose and Sally have just purchased a new washer. Unfortunately, the measurements they made of their front door were not very precise and the washer won't fit through the doorframe. Jose and Sally can either take the washer back and get charged a $50 restocking fee or they can find a way to lift and move it in through their second story window. Money is pretty tight, so Jose and Sally decided to go to their local hardware store and find something that would assist them with their task. The sales person showed them two different ways they could set up a pulley system using only one pulley and some rope for only $10.

Below are the pulley systems the sales person showed them. Which system would Jose and Sally have to exert less of a force on in order to lift the washer, what would be your justification to convince Jose and Sally to choose your selection?



Choice: _____

Justification:

____

____

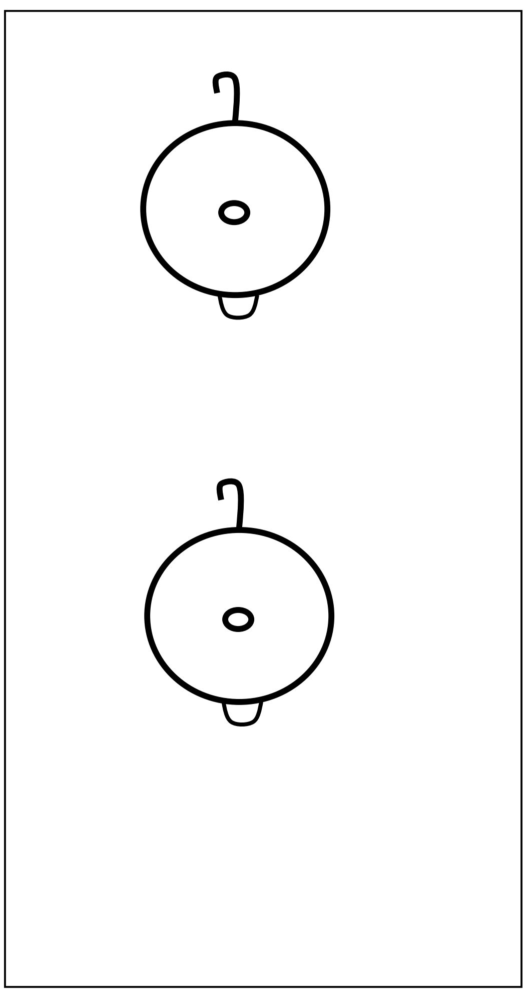
____

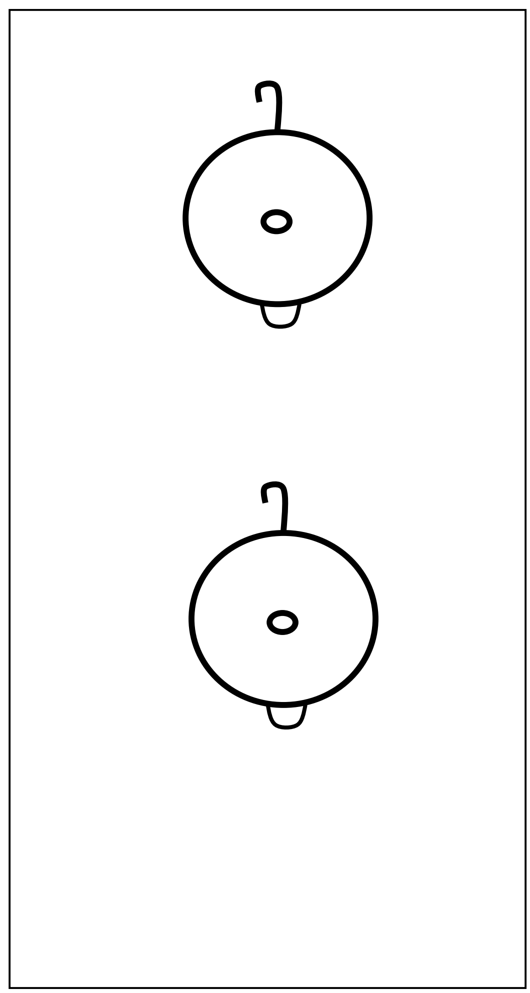
____

Names:_______________ ______________ ________________ Date:__________

Jose and Sally noticed a 2 for 1 pulley sale while they were at the hardware store. They figured if one pulley was good then two should be even better. So, they asked the sales person to demonstrate how they could arrange the two pulleys and rope to produce a pulley system. To their amazement, the salesperson indicated to them there is actually two different pulley systems that can be created.

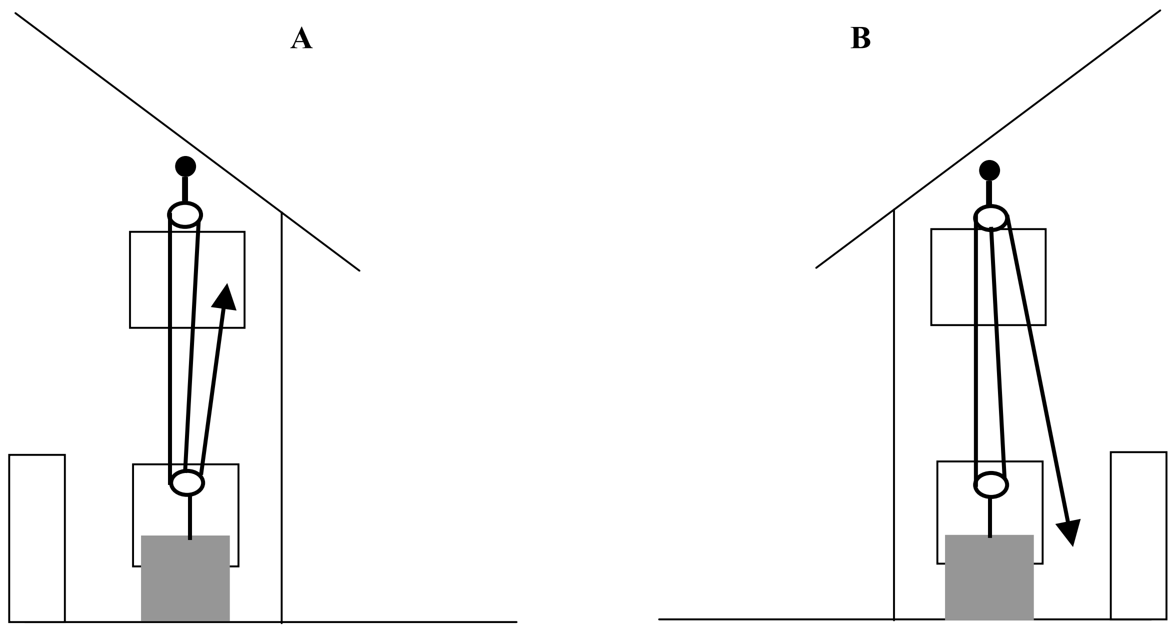
In the space below, draw the two different pulley systems the sales person arranged for Jose and Sally.





Names:_______________ ______________ ________________ Date: __________

Below are two different double pulley systems shown to Jose and Sally. Which pulley system would Jose and Sally have to exert less force on in order to lift the washer, what would be your justification to convince Jose and Sally to choose your selection?



Choice:____

Justification:

____

____

____

____

____

PULLEY INVESTIGATION

Have the materials manager collect all materials

PER GROUP	2 pulleys
CBL2	**3 pieces of duct tape**
TI Graphing Calculator & link cable	**1: 25 cm dowel rod (.6cm diameter)**
DataMate program	**1 Paper clip**
Vernier Dual Range Force Sensor	**Investigation Direction Sheet**
Mass set (1: 100g, 2: 200g, 1: 500g)	**Result sheet**
1: 50 cm string with 1.5cm loops on each end	

1. Plug the Force Sensor into Channel 1 of the CBL2. Use the link cable to connect the TI Graphing Calculator to the interface. Firmly press in the cable ends. Set the switch on the Dual-Range force sensor to 10N.
2. Turn on the calculator, press the APPS button and select the DataMate program. Press Í until you get to the MAIN MENU
3. Select (#1) SETUP from the main screen.
4. Use the down arrow key to move the curser to MODE and press enter.
5. Select (#3) Events with Entry.
6. ZERO the Force Sensor.
   a. Hold the Force Sensor vertical with its hook pointing **UP** if you will be pulling the string down and pointing **DOWN** if you will be pulling the string up.

   <u>**Make sure the hook is not touching anything.**</u>

   b. Select (#3) ZERO from the SETUP menu.
   c. Select (#1) CH1 from the SELECT CHANNEL menu.
   d. Press Í to zero the Force Sensor.
7. **SET UP YOUR ASSIGNED PULLEY SYSTEM**
8. On your Results Sheet complete **PART I**
   a. Draw a prediction of Resistance force vs. Effort force and describe its meaning
   b. Increase the weigth in the table by starting with a mass of .2 *kg* and increasing by .2 *kg* until you reach a mass of 1*kg.* Calculate the Resistance force (aka Weight or Output force) for the corresponding mass and fill in the Resistance force column
9. Select (#2) START to begin collecting data.
10. Use your masses to create a resistance force of.2*N* and attach it onto the appropriate place on your pulley system.

11. Attach the force probe into the loop at the end of the string. Pull on the force probe, either up or down, to lift and hold the mass at 10cm. Once force reading stabilizes on the interface, press Í to collect the effort force data.
12. Enter the Resistance Force (Weight) of the mass being lifted and press Í
    Remember Weight =(9.8 m/s^2)(mass)
13. REPEAT **STEPS 10 - 13** (increasing the mass .2*kg* each time until the Effort force for 1*kg* has been collected)

*****When your group has collected data for all the weights,**

14. Stop collecting data by selecting ¿
15. Record collected data to complete Data Table 1
    a. Move the | ~ cursor keys to trace and identify the Effort force value for each corresponding Resistance force value
    b. Fill in the Effort force next to its corresponding resistance force value in the appropriate column
    c. Calculate the differences of the Resistance & Effort force and record
    d. Calculate the rate of change for your data and the average rate of change for the investigation
    e. Describe your groups thinking of how to relate the Resistance force to the Effort force in the process column

16. a. Draw and label your investigation graph and describe its meaning
    b. Answer Part 2 questions

17. Switching the axes
    a. Press É to break the program then press Í
    b. Press y o , select #1 and press Í
    c. Cursor down to Xlist, highlight L_1 . Press y Á
    c. Cursor down to Ylist, highlight L_2 . Press y À

18. Record collected data to complete Data Table 2
    a. Press s and trace the data points and complete Data Table 2
    b. Draw and label this graph and describe its meaning
    c. Answer PART 3 questions

Results Sheet

Names:_______________ _______________ _________________ Date:________

	Single fixed		**Single movable**		**Single fixed/ Single movable (up)**		**Single fixed/ Single movable (down)**

PART 1:

Prediction Graph

____

____

____

____

____

____

____

Data Table 1

Resistance Force: F_r ***(WEIGHT)*** **(*N*)** **(9.8 *m/s²*)(*mass*)**	**Process Column**	**Effort force: *Fe*** ***(Force probe reading)*** ***(N)***

PART 2:

Investigation Graph

1. Which variable would you identify as the independent variable?

2. Would this data be categorized as discrete or continuous? Justify your reasoning.

3. How does the investigation graph compare to your prediction graph?

4. According to your data table, is this relationship between Fe and Fr proportional? Justify your answer

5. According to your graph, describe the relationship between Effort force and Resistance force.

6. Does the relationship between the Resistance force and Effort force represent a direct variation?

7. What type of function would best fit this graph? Describe your reasoning.

8. What is the physical meaning of the rate of change for this graph?

9. What is the domain and range for the investigation graph?

10. For this investigation graph, can you determine the y-intercept? Justify your answer.

PART 3

Effort force: ***Fe*** ***(Force probe reading)*** **(N)**	**Process Column**	**Resistance Force:** F_r ***(WEIGHT)*** **(N)**

Switched Axes Graph

1. Is there a dependent relationship represented by the tabular or graphical representation of this data?

2. Describe how this graph differs from the graph in part 2?

3. How many supporting strings does your pulley system have? Describe any relationship to the rate of change in Data Table 2?

4. Enter an average rate of change value into the function editor, o , and graph it over your part 3 graph. Manipulate the value for the rate of change and if necessary add a value for a y-intercept to find the equation (trend line) for this graph. What is the function that best fits your graph?

5. Does it seem reasonable that the trend line does not pass through the origin? Justify your answer.

6. With this equation (trend line) and your calculator, describe and demonstrate three different ways to identify what the Resistance force would be with an Effort force of 750N.

7. With this equation (trend line) and your calculator, describe and demonstrate three different ways to identify what the required Effort force would be to lift a weight of 650N using your pulley system.

8. State the appropriate domain and range for the function of this investigative data.

9. Why is finding an equation valuable?

Pulling It All Together

Name: ______________ _____________ _____________ Date:___________

1. Analyze the graphs created from the various pulley systems describe any similarities and differences.

2. How does the steepness of the slope compare to the "ease" of lifting the resistance force?

3. How does the rate of change compare to the steepness of the slope, the ease of lifting the resistance force?

4. How does the number of supporting strings compare to the rate of change, the steepness of the slope, and the ease of lifting the resistance force?

5. What physical meaning does the rate of change have in physics?

6. What is the relationship between mechanical advantage and effort force?

7. Write the function for your graph and describe what each variable represents in terms of resistance force, effort force and mechanical advantage.

8. Describe in words the meaning of mechanical advantage.

9. Would you be able to predict what force would be needed to lift a 200Kg resistance force on any of the graphs? If so, explain how.

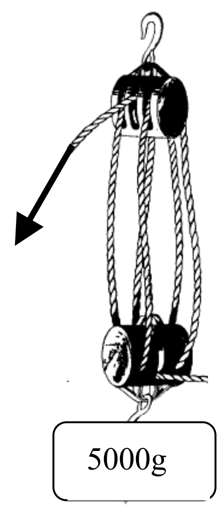
10. How did increasing the number of pulleys affect the input force needed to raise the output force?

11. Which pulley system required the least amount of input force to lift 500g? Explain why that particular pulley system would require the least amount of input force to overcome the output force.

12. Compare the rate of change of the single fixed pulley system to the single fixed/single movable (up) pulley system. Describe what you think is causing the difference.

13. Qualitatively speaking, describe the difference between the single movable pulley system and the single fixed/single movable (pulling up) pulley system.

14. Can you predict what the product will be for the ratio of resistance force to effort force for the pulley system below?

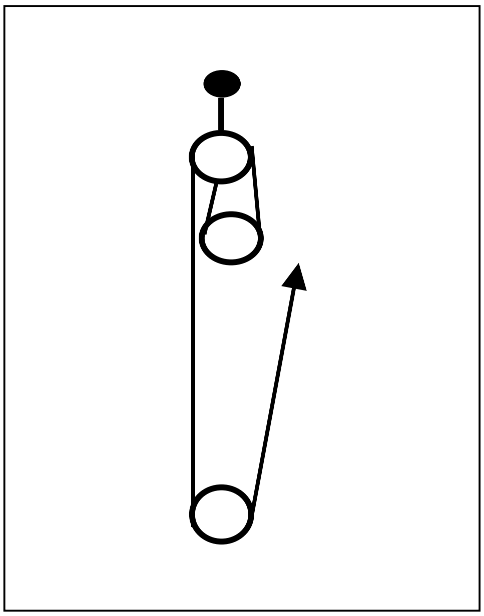


Name: ______________ ______________ ______________ Date:___________

After analyzing the following pulley systems:

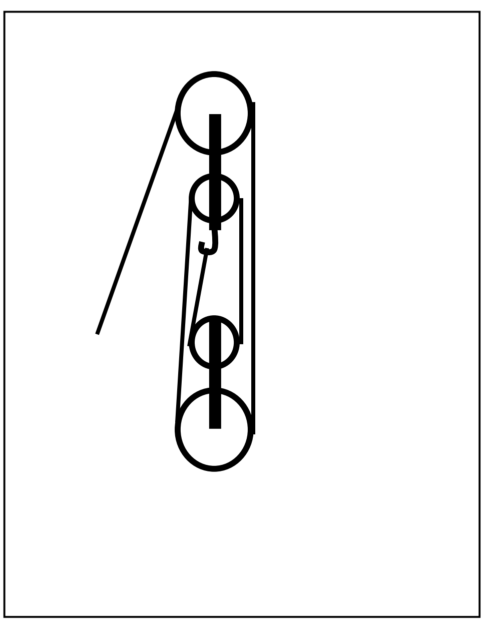
1. Number the supporting strings for A?
2. Number the supporting strings for B?
3. Using the Ideal Mechanical Advantage for each pulley system, complete the following data tables

A



Fe	*Fr*
8	
19.5	
38.3	
57	
75.8	
94.5	
113.3	

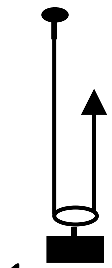
B



Fe	*Fr*
	40
	1040
	2040
	3040
	4040
	5040
	6040

Match the following pulley system with its appropriate data table, graph and equation.

1.

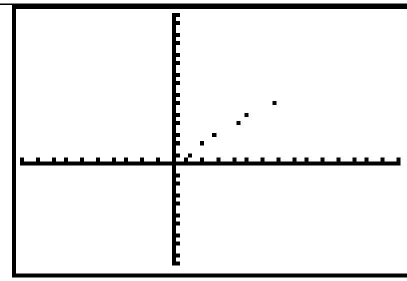


TA

FE	FR	3
0.0	.0	------
1.0	2.2	
2.0	4.1	
3.0	6.3	
4.0	7.9	
5.0	10.1	
6.0	12.0	

L1 =

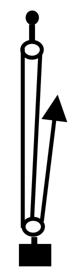
GA



RA

Plot1 Plot2 Plot3
\Y1=1.98X
\Y2=
\Y3=
\Y4=
\Y5=
\Y6=
\Y7=

2.

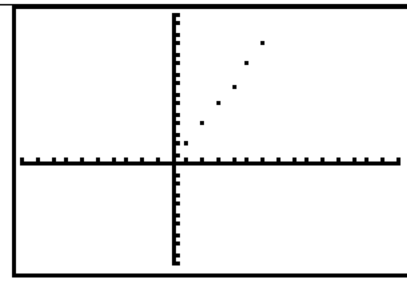


TB

FE	FR	3
0.0	.0	------
1.0	1.2	
2.0	1.9	
3.0	2.8	
4.0	4.3	
5.0	5.0	
6.0	6.7	

L1 =

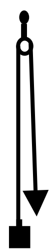
GB



RB

Plot1 Plot2 Plot3
\Y1=2.97X
\Y2=
\Y3=
\Y4=
\Y5=
\Y6=
\Y7=

3.

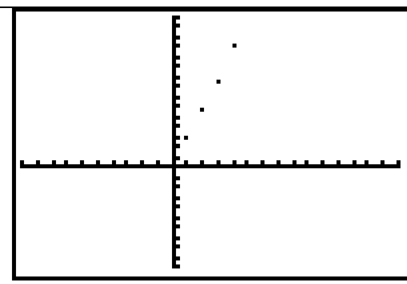


TC

FE	FR	3
0.0	.0	------
1.0	2.2	
2.0	4.1	
3.0	6.3	
4.0	7.9	
5.0	10.1	
6.0	12.0	

L1 =

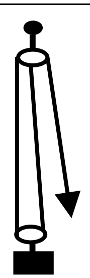
GC



RC

Plot1 Plot2 Plot3
\Y1=1.98X
\Y2=
\Y3=
\Y4=
\Y5=
\Y6=
\Y7=

4.

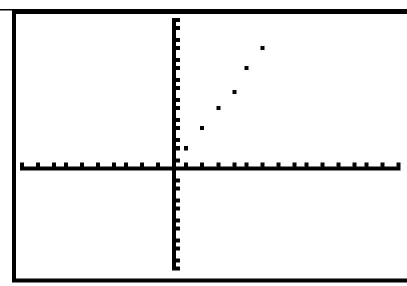


TD

FE	FR	3
0.0	.0	------
1.0	3.2	
2.0	5.9	
3.0	9.2	
4.0	12.0	
5.0	14.9	
6.0	17.9	

L1 =

GD



RD

Plot1 Plot2 Plot3
\Y1=.918X
\Y2=
\Y3=
\Y4=
\Y5=
\Y6=
\Y7=

NAME:

DATE:

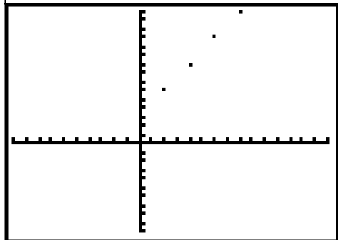
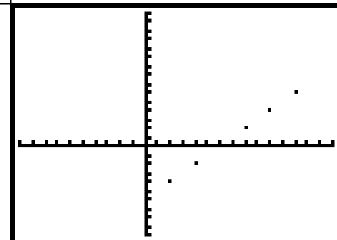
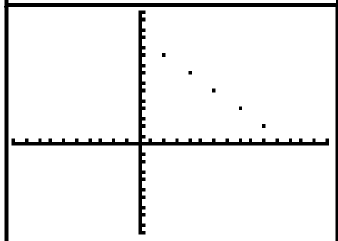
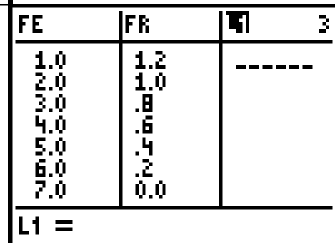
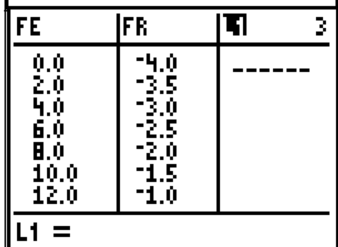
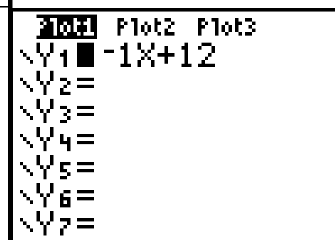
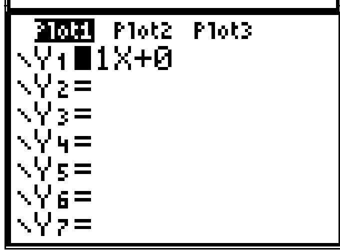
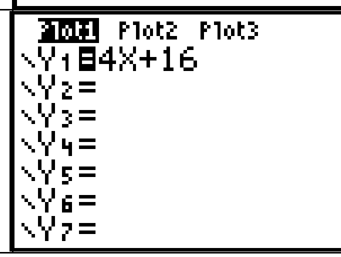
Construct a pulley system and equation that would create the following data table.

Fe (N)	0	1	2	3	4	5	6
Fr (N)	0	4.1	7.8	12.3	16	20.1	24

NAME: _______________ DATE:

The following data tables, graphs, and equations were taken from pulley lab reports by IPC students.

1. Analyze the following data tables, graphs and equations,
2. Determine the reasonableness of these results.
3. Justify your reasoning.

	Reasonableness & Justification		**Reasonableness & Justification**
			
			
			
			

LEVER SYSTEMS:
Everyone Loves Their MA

1. Suppose that you need to move a large rock, but it is too heavy for you to lift. You found a long bar and a small rock. Use the objects below to sketch a lever system that you might use to move the large rock.

2. A parent and a small child visit the playground. They both get on a see-saw (teeter-totter) and arrange it so that the see-saw balances perfectly. Sketch how this might look. Explain your thinking.

3. Where have you seen or experienced levers in action?

4. Do you think all lever systems make a task easier?

Preliminary Experiences:

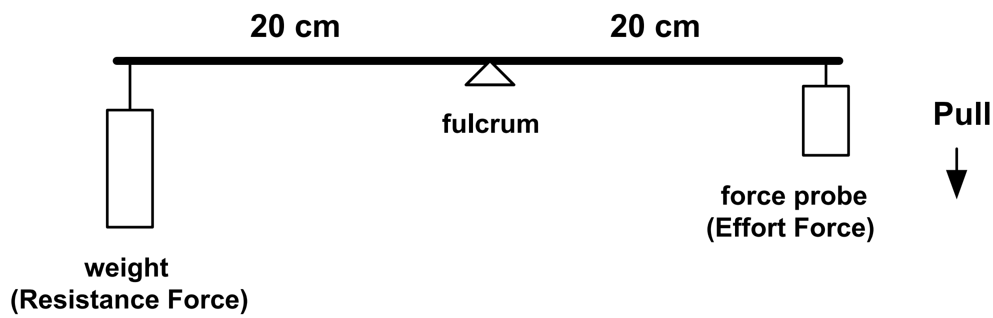
1. Make sure you have all the needed equipment, or have the materials person obtain it for your group.
2. Using the meter stick, fulcrum, weight and string create as many lever systems as possible.
3. For each system you create, record the following on your **Results Sheet**:
   a). a diagram that indicates the location of the fulcrum, where the weight is located, and where you apply force to the lever
   b). a qualitative description of the force needed to move the weight
4. Pick one of your lever systems and describe a real world application of it.

PART A

Experiments

LEVER I

You will set up a lever system that looks something like this, although your teacher may modify it some. You will use several different weights, and use the force probe to measure how much force is needed to balance the system each time. Be careful when you measure the force to be sure that no unwanted forces might interfere. Before you hook up the force probe, use your finger to balance the system and get an idea of how much force is needed.



Data Collection

1. Prepare the force sensor for data collection.
   a. Connect the force sensor to Channel 1 of the CBL 2.
   b. Use the link cable to connect the TI graphing calculator to the CBL 2, Firmly press in both cable ends.
2. Prepare the calculator and interface to collect data.
   a. Launch the DATAMATE program or application. (The Vernier PHYSICS program could also be used.)
   b. Select SETUP (1) from the MAIN MENU.
   c. Arrow down to MODE and press ENTER.
   d. Select EVENTS WITH ENTRY (3).
   e. Select ZERO (3) and pick the appropriate channel.
   f. Hold the Force probe in the position you will use to collect your data. (If you will be pulling up, have the hook pointing down, if you will be pulling down, have the hook pointing up.) Follow the calculator directions to zero the probe.
   g. Select START (2) to begin collecting data.

3. Collect experimental data.
   a. Set up the lever system and hang the first weight in the proper position.
   b. Attach the force probe in the proper position
   c. Make sure the system is balanced, then follow the calculator directions to collect the first data point.
   d. The calculator will ask you to ENTER VALUE. Input the weight that is hanging on the other side of the lever.
   e. Add a different weight to the lever and repeat steps c and d.
   f. Continue collecting data until all the weights have been used.
   g. Press STO on the calculator to stop and graph the data.

Analysis

The program automatically puts the Resistance Force (weight) into List 1 and the Effort Force (Force applied) into List 2. The graph produced plots Resistance Force (weight) on the X axis and Effort Force (Force applied) on the Y axis.

1. Sketch the graph that was produced, and explain in words what it indicates.

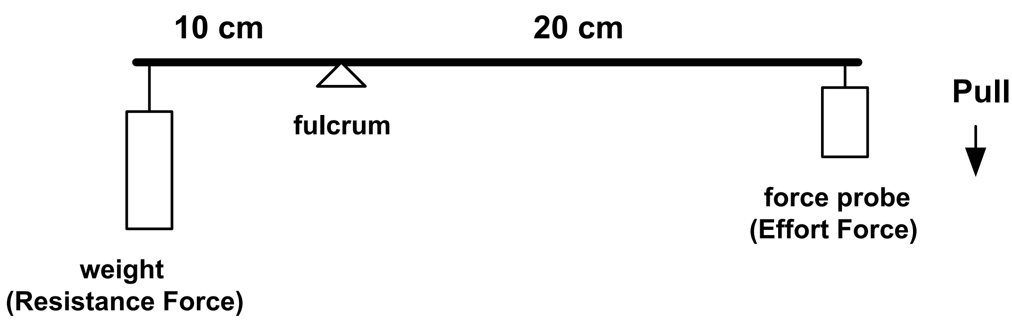
Mechanical Advantage (MA) is a science concept relating forces and distances in simple machines. We compare what goes into the machine with what comes out of the machine. In order to study MA, we need to swap the axes and plot Resistance Force (weight) on the Y axis and Effort Force (Force applied) on the X axis.
1. Press the ON button, which will break the program. Select QUIT.
2. Review how you answered above. Predict what the graph would look like if you swapped the axes. Sketch the graph, and explain in words what it indicates.

3. Enter the STAT PLOT menu, and Select Plot 1.
4. Change the X List to: L2 and the Y List to L1. This will plot the Resistance Force (weight) on the Y axis and the Effort Force (Force applied) on the X axis.

5. Enter the STAT menu and select EDIT. Copy the values from L2 and L1 into the table provided.
6. Enter the WINDOW menu and choose appropriate values based on the data.
7. Press GRAPH to see a graph of the data.
8. Use the first differences of the data to estimate the rate of change.
9. Use the function editor to match a trend line to your data. Record the function that seems to fit your data.
10. Explain in your own words the physical meaning of each function. Pay particular attention to the rate of change (slope). The rate of change (slope) represents the MA. Record the MA's as well.

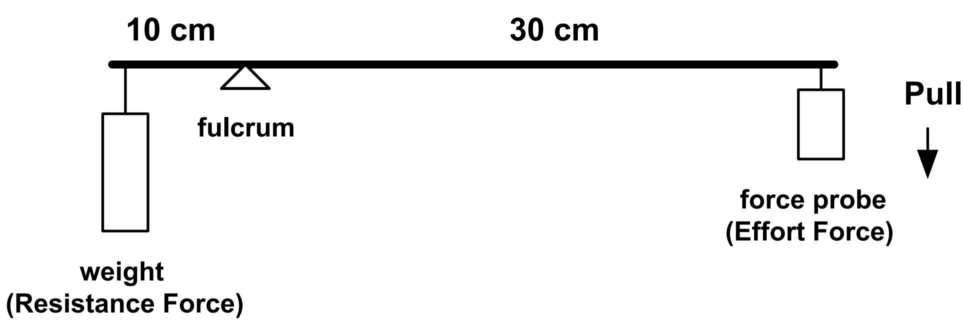
LEVER II

Set up another lever system that looks something like this. Repeat the data collection and analysis activities. Record the function that seems to fit the data.

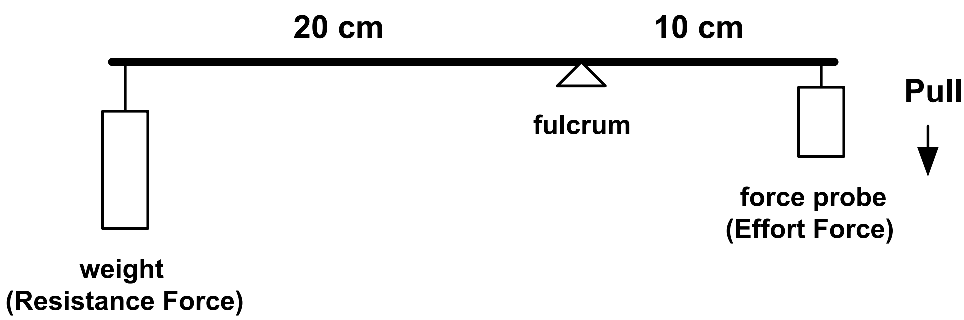


LEVER III

Set up another lever system that looks something like this. Repeat the data collection and analysis activities. Record the function that seems to fit the data.



LEVER IV
Set up another lever system that looks something like this. Repeat the data collection and analysis activities. Record the function that seems to fit the data.

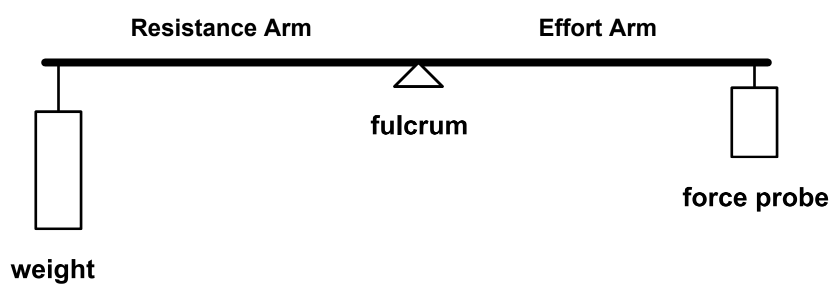


Do you think it appropriate to have the graphs pass through the origin (0,0)? Explain your thinking.

How can we get more force out of a machine than we put in to it? Is it magic? Comment on anything else you may have noticed.

PART B

In Simple Machines we mentioned earlier that both forces and distances are involved. We have already looked at the input forces and output forces of a lever system, now we will look at the distances. In lever systems it is rather difficult to accurately measure the actual distance that the forces move through. However, the various lengths of the lever system are proportionate and can be measured easily. Study the diagram below. Notice that the Resistance Arm is the distance from the weight (load) being lifted to the fulcrum. The Effort Arm is the distance from the fulcrum to the force being exerted to lift the load (force probe).



Record the Resistance Arm distance and the Effort Arm distance for each of the four lever systems that we studied earlier.

One way to compute Mechanical Advantage is to set up a ratio comparing Effort Arm length to Resistance Arm length using this formula:

MA= Effort Arm / Resistance Arm

Use this method to compute MA's for each of the four lever systems and record.

Come up with a "rule" for how the location of the fulcrum is related to MA.

There is also a way to compute MA using forces. Revisit the functions that you came up with from earlier experiments. The rate of change (slope) of these functions also represents MA. Another way is to use this formula:

MA= Resistance Force (weight) / Effort Force (Force applied)

Come up with a "rule" for how the MA relates to how much force you must exert to lift a heavy weight using a lever system.

Compare the MA's that you calculated two different ways.

PART C

Recall that we learned in Parts A and B that Mechanical Advantage can be calculated two ways. We can use distances involved or forces involved. MA calculated using distances is sometimes called Ideal Mechanical Advantage (IMA) since friction really doesn't affect distances. MA calculated using forces is sometimes called Actual Mechanical Advantage(AMA) since friction does affect the results. Efficiency of a machine can be calculated to show how much energy is lost to friction. One method is to compare the work going into the machine (input) with the work coming out of the machine (output). Another method is to set up a ratio comparing AMA to IMA using this formula:

%Efficiency = AMA / IMA x 100

Calculate the efficiency of each of the lever systems you worked with earlier and record.

Results Sheet

Preliminary Experiences

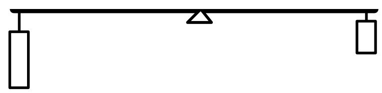
Diagram | Force Description

Real world application

PART A

Experiments

LEVER 1



Qualitative description of force

Data Table

FORCE R (Weight)	FORCE E (Force Applied)

Function

Meaning of function

MA

LEVER 2

Qualitative description of force

Data Table

FORCE R (Weight)	FORCE E (Force Applied)

Function

Meaning of function

MA

LEVER 3

Qualitative description of force

Data Table

FORCE R (Weight)	FORCE E (Force Applied)

Function

Meaning of function

MA

LEVER 4

Qualitative description of force

Data Table

FORCE R **(Weight)**	**FORCE E** **(Force Applied)**

Function

Meaning of function

MA

PART B

Data from Measuring Forces and Distances

	Effort Arm (cm)	Resistance Arm (cm)	MA (distances)	Force $_R$ [weight] (N)	Force $_E$ [Force Applied] (N)	MA (forces)	Efficiency (%)
Lever 1							
Lever 2							
Lever 3							
Lever 4							

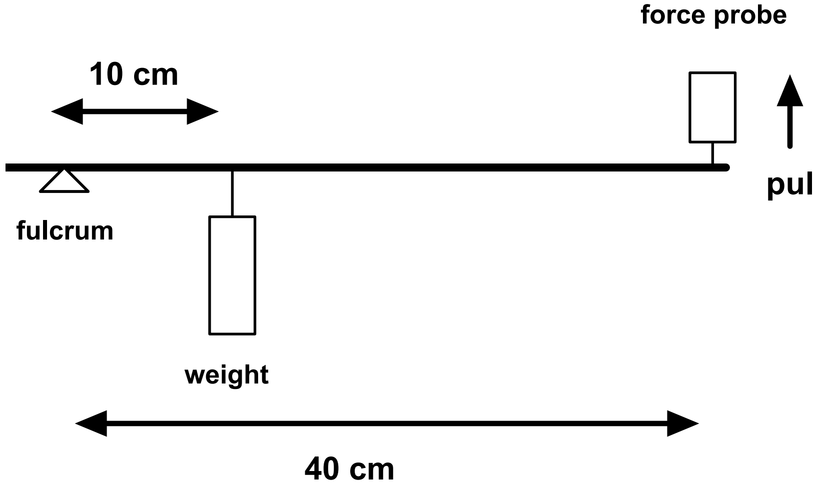
"Rule" for how the location of the fulcrum is related to MA.

"Rule" for how the MA relates to how much force you must exert to lift a heavy weight using a lever system.

Compare the MA's that you calculated two different ways.

Sample Assessment

All four of the lever systems you worked with earlier are called 1st class levers. There are also other types of levers. Study the diagram below, which is an example of a 2nd class lever.



Compare the 2nd class lever with the 1st class levers that you worked with earlier. How are they similar and how are they different?

Use the sample data below to answer the remaining questions.

Resistance Force [Weight] (N)	Effort Force [Force Applied] (N)
50	11.5
100	26.2
150	35.6
200	51.4
250	62.3

Sketch the graph produced.

Fit a trend line to the data, write the function that describes the data, and explain in words the meaning of the function.

Determine the MA of the lever system using the distances indicated in the diagram. Review your earlier information if necessary. Show all your work.

Determine the MA of the lever system using the forces indicated in the table. Review your earlier information if necessary. Show all your work.

Calculate the efficiency of the lever system. Show all work.

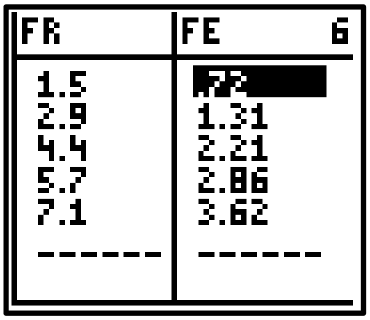
Solve each of the following problems at least two different ways. Explain how you got each answer.

How much force would need to be applied to this lever system in order to lift a weight of 125N?

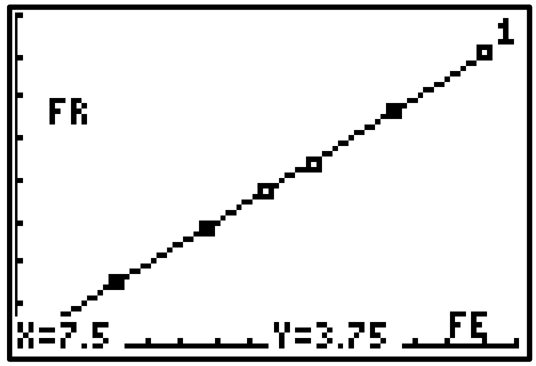
If you pull up with the force probe a distance of 25 cm, how much will the weight be lifted?

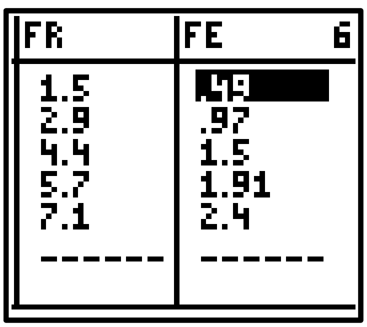
Sample Assessment

Match the table, the graph and the Mechanical Advantage of each lever system. Write the proper MA beside each graph and table.

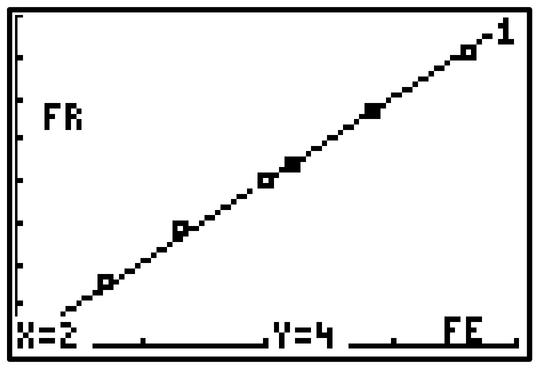


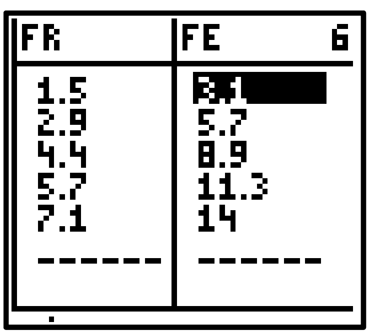
FR	FE
1.5	[illegible]
2.9	1.31
4.4	2.21
5.7	2.86
7.1	3.62



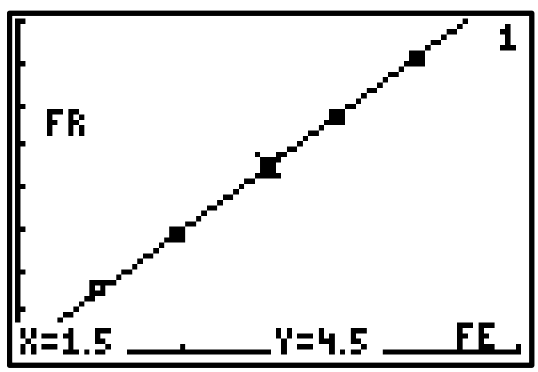


FR	FE
1.5	[illegible]
2.9	.97
4.4	1.5
5.7	1.91
7.1	2.4





FR	FE
1.5	[illegible]
2.9	5.7
4.4	8.9
5.7	11.3
7.1	14



MA = 0.5 **MA = 2** **MA = 3**

Which one of three would make it easiest for you to lift a heavy load?

Sample Assessment

A lever system has a Mechanical Advantage of 5. Fill in the table values below.

Weight (N)	Force Applied (N)
50	
100	
150	
200	
250	

Sketch below what the lever system might look like. Indicate the length of the effort arm and the resistance arm.

Effort Arm ____________ **Resistance Arm ____________**

4.1 Kidwork

Materials:

One set per group
1 m of string
100 - 500 g mass (use a mass that will register on the spring scale)
Tape
Meter stick
Four spring scales (Newton measurements)

Part A:

On your table, you have some objects (1 m of string, mass, tape, meter stick). Your task is to move the mass 50 cm. How could you do this using only the objects on your table to assist you? Answer each of the following questions in your logbook or journal.

1. What is the easiest way to move the mass?

2. Because we have studied force, we know that nothing moves unless a force acts upon it. Using a spring scale, how much force does it takes to move the mass 50 cm?

.

3. When should you take your measurement? At the beginning of your pull or during your pull?

4. Would your answers change if you changed the distance that you had to move the mass? Experiment, by increasing the distance that you move the mass. You should change the distance at least 5 times. Create a data table to compile this data.

5. What patterns if any, do you see in your data?

Experiment now with the amount of force needed by each person to move the same mass. Choose the distance that you are going to move the mass. Create a data table to record each person in the group and the amount of force needed for them to move the mass the same distance.

1. Does everyone at your table use the same amount of force to move the same mass?

2. What patterns if any do you see?

3. Without experimenting, predict the amount of force needed to move the object a different distance.

Part B:

Predict! How much force would be needed if two people pulled the mass?

Experiment! Using four different combinations of two people test your prediction about the amount of force needed for two people to move the mass 50 cm. Create a data table to record your data. Make sure that you are looking at only one variable at a time when you experiment. For this activity, you should move the object the same distance each time and you should each pull equally on your spring scales. If you are pulling equally on your spring scales, then the forces should be equal.

1. Was your prediction correct? Why or why not?

2. How will you know if each person is pulling equally?

3. What patterns or tends if any do you see?

Part C:

Predict! What would happen to the force needed if three people pulled the object?

Experiment! Using four different combinations of three people test your prediction about the amount of force needed for two people to move the mass 50 cm. Create a data table to record your data. Make sure that you are looking at only one variable at a time when you experiment. For this activity, you should move the object the same distance each time and you should all pull equally on your spring scales. If you are pulling equally on your spring scales, then the forces should be equal.

1. Was your prediction correct? Why or why not?

2. What patterns or tends if any do you see?

Part D:

Predict! What would happen to the force needed if four people pulled the weight?

Experiment! Using all four people in your group, test your prediction about the amount of force needed for all four people to move the mass 50 cm. Create a data table to record your data. Make sure that you are looking at only one variable at a time when you experiment. For this activity, you should move the object the same distance each time and you should all pull equally on your spring scales. If you are pulling equally on your spring scales, then the forces should be equal.

1. Was your prediction correct? Why or why not?

2. What patterns or tends if any do you see?

Using the data that you just recorded, what would you predict as an outcome for the following problem.

A friend’s car stops running and they need help to push the car out of the street. What would be the easiest way to get the car out of the street using students?

4.2 Kidwork, The Sequel

Work

In physics, work occurs when a force causes a displacement of an object. In order for a force to qualify as having done work on an object, there must be a displacement and the force must cause the displacement. What does that statement mean? In Kidwork, you moved an object a distance across the table by pulling on a string. You applied a force and the object moved 50 cm. The force you applied to the object caused the displacement so work was done.

In this lesson, we will focus on work where the force applied is parallel to the displacement. The formula for work in this situation is $W = Fd$. The unit for work is the Joule,

1 Joule = $\dfrac{1\text{kilogram}*1\text{meter}^2}{1\text{second}^2}$ or $1\text{Newton}*1\text{meter}$.

Part A:

Anne pulls a mass across the table with a force of 2.7 Newtons. Complete the table using W=Fd.

Distance (m)	Process (Fd)	Work (J)
.25		
.50		
.75		
1.0		
1.25		
1.5		
1.75		
2		

1. Describe any relationships you see in the table.

2. Enter the distance in L1 and enter the work in L2 of your graphing calculator. Create a scatter plot of work vs. distance. Sketch your graph on the grid below.

3. What type of function appears to model this data?

4. Enter the model into the equation editor of your graphing calculator. Graph the equation. Sketch the graph in the grid below.

5. Is this a direct linear proportion? How do you know?

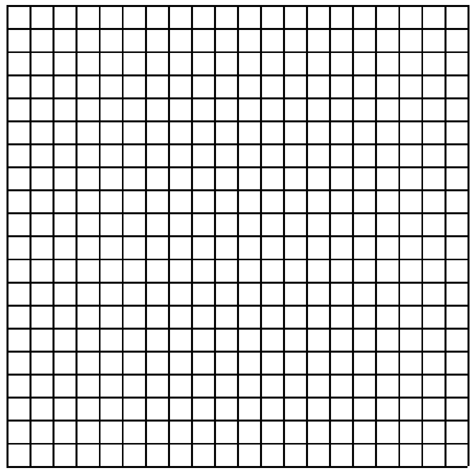
Part B:

This time we will keep the distance constant (2 meters) but we will vary the force by adding kids who each pull with a force of .5 Newtons. Complete the table using W=Fd.

Force (N)	**Process (Fd)**	**Work (J)**
.5		
1		
1.5		
2		
2.5		
3		
3.5		
4		

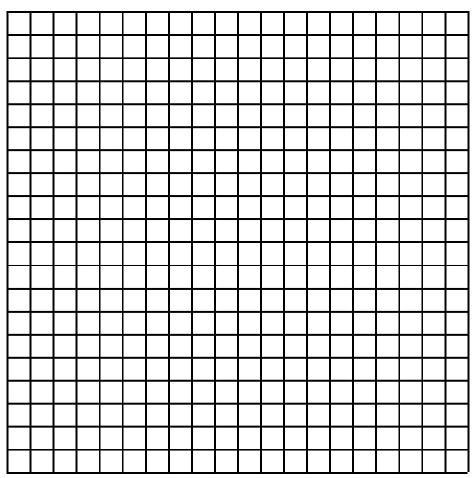
1. Describe any relationships you see in the table.

2. Enter the Force in L1 and enter the work in L2 of your graphing calculator. Create a scatter plot of work vs. distance. Sketch your graph on the grid below.



3. What type of function appears to model this data?

4. Enter the model into the equation editor of your graphing calculator. Graph the equation. Sketch the graph in the grid below.



5. Is this a direct linear proportion? How do you know?

4.3 Levers and Work

In this Lesson we will investigate the work done when a 1st class lever is used to lift an object vertically.

The questions that we are investigating are:

1. Do simple machines (1st class levers) reduce the amount of work done when moving an object?
2. What are the relationships between force, displacement, and work?

Materials:

2 meter sticks, 1 binder clip, 1 ring stand, plastic cup, between .5 kg and 1 kg of mass, jumbo paperclips, string, tape, graphing calculator, Dual Range Force Sensor or a spring scale that measures in Newtons

Part A:

1. Place the mass in the cup and determine a way to suspend the cup above the table hanging from the force sensor. Hold the sensor stationary so that the bottom of the cup is 10 cm above the table. According to the definition of work, does any work take place when the cup is being held stationary? Why or why not?

2. When is work being done?

3. Use the force probe or a spring scale to find the resistance force in Newtons. When using the dual range force probe be sure it is set on $\pm 10N$ setting. Run the Datamate program and zero the probe in the orientation it will be used to collect data. Hold the cup stationary 10 cm from the table. Measure the resistance force and record it in the blank below.

   Resistance Force F_R __________

4. Read the force measurement as you raise the cup. Does it take more force or less force to raise the cup than to hold it stationary? Why?

5. Read the force measurement as you lower the cup. Does it take more force or less force to lower the cup than to hold it stationary? Why?

6. Do <u>we</u> do more work raising the cup or lowering the cup? Explain why.

7. Calculate the amount of work done raising the cup 10 cm. The amount of force needed to move the object is only slightly more than the force measured when the object is stationary so we will use the resistance force recorded in number 3.

Part B:

1. Set up a first class lever system that has an ideal mechanical advantage of one so that you can raise the mass in the cup 10 cm from the table. You will need to zero the probe in the orientation that you will be using to collect data. Sketch your lever system.

2. Predict whether this lever system will reduce the amount of work done lifting the cup. Explain your thinking.

3. Measure and record the effort force and the effort distance needed to raise the cup 10 cm from the table. Sketch or describe your method for making these measurements.

   Effort distance __________ Effort force F_E _________

4. Find the ratio of effort distance to the resistance distance (height of cup). How does this distance compare to the IMA?

5. The work done by the lever system is the work done raising the mass in the cup 10 cm, which you calculated in part A, number 7. This is often referred to as the work output of the lever system. The amount of work that we put into the system, work input, can be found by calculating the work done on the effort side of the lever. Calculate the work input of this lever system and compare to the work output.

   Work input ___________

6. Did the lever system reduce the amount of work required to lift the object?

Part C:

1. Set up a first class lever system that has an ideal mechanical advantage of $\frac{3}{2}$ so that you can raise the mass in the cup 10 cm from the table. You will need to zero the probe in the orientation that you will be using it to collect data. Sketch your lever system.

2. Predict whether this lever system will reduce the amount of work done lifting the cup. Explain your thinking.

3. Measure and record the effort force and the effort distance needed to raise the cup 10 cm from the table. Sketch or describe your method for making these measurements.

   Effort distance __________ Effort force F_E __________

4. Find the ratio of effort distance to the resistance distance (height of cup). How does this distance compare to the IMA?

5. The work done by the lever system is the work done raising the mass in the cup 10 cm, which you calculated in part A, number 7. This is often referred to as the work output of the lever system. The amount of work that we put into the system, work input, can be found by calculating the work done on the effort side of the lever. Calculate the work input of this lever system and compare it to the work output.

   Work input ___________

6. Did the lever system reduce the amount of work required to lift the object?

Part D:

1. Set up a first class lever system that has an ideal mechanical advantage of two so that you can raise the mass in the cup 10 cm from the table. You will need to zero the probe in the orientation that you will be using to collect data. Sketch your lever system.

2. Predict whether this lever system will reduce the amount of work done lifting the cup. Explain your thinking.

3. Measure and record the effort force and the effort distance needed to raise the cup 10 cm from the table. Sketch or describe your method for making these measurements.

Effort distance __________ Effort force F_E __________

4. Find the ratio of effort distance to the resistance distance (height of cup). How does this distance compare to the IMA?

5. The work done by the lever system is the work done raising the mass in the cup 10 cm, which you calculated in part A, number 7. This is often referred to as the work output of the lever system. The amount of work that we put into the system, work input, can be found by calculating the work done on the effort side of the lever. Calculate the work input of this lever system and compare it to the work output.

Work input __________

6. Did the lever system reduce the amount of work required to lift the object?

Part E:

1. Set up a first class lever system that has an ideal mechanical advantage of $\frac{5}{2}$ so that you can raise the mass in the cup 10 cm from the table. You will need to zero the probe in the orientation that you will be using to collect data. Sketch your lever system.

2. Predict whether this lever system will reduce the amount of work done lifting the cup. Explain your thinking.

3. Measure and record the effort force and the effort distance needed to raise the cup 10 cm from the table. Sketch or describe your method for making these measurements.

   Effort distance __________ Effort force F_E __________

4. Find the ratio of effort distance to the resistance distance (height of cup). How does this distance compare to the IMA?

5. The work done by the lever system is the work done raising the mass in the cup 10 cm, which you calculated in part A, number 7. This is often referred to as the work output of the lever system. The amount of work that we put into the system, work input, can be found by calculating the work done on the effort side of the lever. Calculate the work input of this lever system and compare it to the work output.

   Work input __________

6. Did the lever system reduce the amount of work required to lift the object?

Part F:

1. Set up a first class lever system that has an ideal mechanical advantage of $\frac{1}{2}$ so that you can raise the mass in the cup 10 cm from the table. You will need to zero the probe in the orientation that you will be using it to collect data. Sketch your lever system.

2. Predict whether this lever system will reduce the amount of work done lifting the cup. Explain your thinking.

3. Measure and record the effort force and the effort distance needed to raise the cup 10 cm from the table. Sketch or describe your method for making these measurements.

   Effort distance __________ Effort force F_E __________

4. Find the ratio of effort distance to the resistance distance (height of cup). How does this distance compare to the IMA?

5. The work done by the lever system is the work done raising the mass in the cup 10 cm, which you calculated in part A, number 7. This is often referred to as the work output of the lever system. The amount of work that we put into the system, work input, can be found by calculating the work done on the effort side of the lever. Calculate the work input of this lever system and compare it to the work output.

   Work input ___________

6. Did the lever system reduce the amount of work required to lift the object?

Analysis:

1. Record the data from the exploration in the table below.

Lever System Data

Ideal Mechanical Advantage	Resistance Distance (meters)	Resistance Force (Newtons)	Effort Distance (meters)	Effort Force F_E (Newtons)

2. Copy the Data columns into the table below. Describe any patterns or relationships that you see in the data table below.

Ideal Mechanical Advantage	Effort Distance (meters)	Effort Force F_E (Newtons)

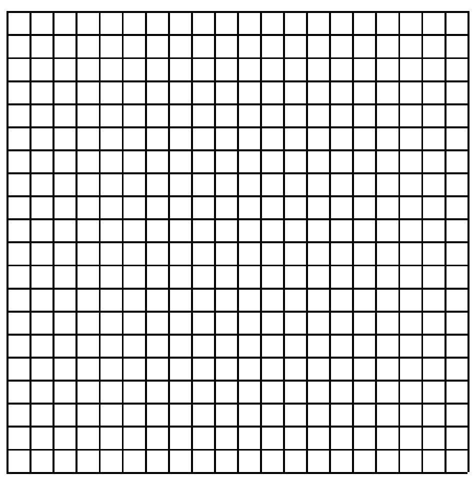
3. Enter the effort distance into L1 and effort force into L2 of your graphing calculator. Create a scatter plot of Effort Force vs. Effort Distance. Sketch your graph on the grid provided.

4. Is there a constant rate of change between the data points? Why?

5. Use the data collected to determine a mathematical model for the relationship between effort force and effort distance this situation.

6. How is the model developed in number 5 related to the work input of the system.

7. Test your model by graphing it over your scatterplot. Sketch your graph on the grid provided.



8. Use your model to predict the effort force needed to raise the cup .1 m when the effort distance is .4 m.

9. How should the lever system be configured to produce this result? Test your configuration to see if you obtain the same result as number 8.

10. Summarize the relationship between work, force, and distance in various 1st class lever systems where the work output is constant.

4.4 Pulleys and Work

In this lesson, we will investigate the work done when a pulley system is used to lift an object vertically.

The questions that we are investigating are:

1. Do simple machines (pulley systems) reduce the amount of work done when moving an object?
2. What are the relationships between force, displacement, and work?

Materials:

One set per group

2 single pulleys, 2 double pulleys, 1 meter stick, 1 ring stand (a .5 meter stand is used in this experiment), plastic cup, between .5 kg and 1 kg of mass to place in cup to create a resistance force (washers are used in this example), jumbo paperclips, string, tape, Dual Range Force Sensor or a spring scale that measures in Newtons

Part A:

1. Place the mass in the cup and determine a way to suspend the cup above the table hanging from the force sensor. Hold the sensor stationary so that the bottom of the cup is 10 cm above the table. According to the definition of work, does any work take place when the cup is being held stationary? Why or why not?

2. When is work being done?

3. Use the force probe or a spring scale to find the resistance force in Newtons. When using the dual range force probe be sure it is set on $\pm 10\text{N}$ setting. Run the Datamate program and zero the probe in the orientation it will be used to collect data. Hold the cup stationary 10 cm from the table. Measure the resistance force and record it in the blank below.

   Resistance Force F_R ___________

4. Read the force measurement as you raise the cup. Does it take more force or less force to raise the cup than to hold it stationary? Why?

5. Read the force measurement as you lower the cup. Does it take more force or less force to lower the cup than to hold it stationary? Why?

6. Do <u>we</u> do more work raising the cup or lowering the cup? Explain why.

7. Calculate the amount of work done raising the cup 10 cm. The amount of force needed to move the object is only slightly more than the force measured when the object is stationary so we will use the resistance force recorded in number 3.

Part B:

1. Set up a pulley system that has an ideal mechanical advantage of one so that you can raise the mass in the cup 10 cm from the table. You will need to zero the probe in the orientation that you will be using it to collect data. Sketch your pulley system.

2. Predict whether this pulley system will reduce the amount of work done lifting the cup. Explain your thinking.

3. Measure and record the effort force and the effort distance needed to raise the cup 10 cm from the table. Sketch or describe your method for making these measurements.

   Effort distance __________ Effort force F_E __________

4. Find the ratio of effort distance to the resistance distance (height of cup). How does this distance compare to the IMA?

5. The work done by the pulley system is the work done raising the cup 10 cm, which you calculated in part A, number 7. This is often referred to as the work output of the pulley system. The amount of work that we put into the system, work input, can be found by calculating the work done on the effort side of the pulley system. Calculate the work input of this pulley system.

   Work input __________

6. Did the pulley system reduce the amount of work required to lift the object?

Part C:

1. Set up a pulley system that has an ideal mechanical advantage of two so that you can raise the mass in the cup 10 cm from the table. You will need to zero the probe in the orientation that you will be using to collect data. Sketch your pulley system.

2. Predict whether this pulley system will reduce the amount of work done lifting the cup. Explain your thinking.

3. Measure and record the effort force and the effort distance needed to raise the cup 10 cm from the table. Sketch or describe your method for making these measurements.

   Effort distance __________ Effort force F_E __________

4. Find the ratio of effort distance to the resistance distance (height of cup). How does this distance compare to the IMA?

5. The work done by the pulley system is the work done raising the cup 10 cm, which you calculated in part A, number 7. This is often referred to as the work output of the pulley system. The amount of work that we put into the system, work input, can be found by calculating the work done on the effort side of the pulley system. Calculate the work input of this pulley system.

   Work input __________

6. Did the pulley system reduce the amount of work required to lift the object?

Part D:

1. Set up a pulley system that has an ideal mechanical advantage of three so that you can raise the mass in the cup 10 cm from the table. You will need to zero the probe in the orientation that you will be using to collect data. Sketch your pulley system.

2. Predict whether this pulley system will reduce the amount of work done lifting the cup. Explain your thinking.

3. Measure and record the effort force and the effort distance needed to raise the cup 10 cm from the table. Sketch or describe your method for making these measurements.

   Effort distance __________ Effort force F_E __________

4. Find the ratio of effort distance to the resistance distance (height of cup). How does this distance compare to the IMA?

5. The work done by the pulley system is the work done raising the cup 10 cm, which you calculated in part A, number 7. This is often referred to as the work output of the pulley system. The amount of work that we put into the system, work input, can be found by calculating the work done on the effort side of the pulley system. Calculate the work input of this pulley system.

   Work input __________

6. Did the pulley system reduce the amount of work required to lift the object?

Part E:

1. Set up a pulley system that has an ideal mechanical advantage of four so that you can raise the mass in the cup 10 cm from the table. You will need to zero the probe in the orientation that you will be using to collect data. Sketch your pulley system.

2. Predict whether this pulley system will reduce the amount of work done lifting the cup. Explain your thinking.

3. Measure and record the effort force and the effort distance needed to raise the cup 10 cm from the table. Sketch or describe your method for making these measurements.

   Effort distance __________ Effort force F_E __________

4. Find the ratio of effort distance to the resistance distance (height of cup). How does this distance compare to the IMA?

5. The work done by the pulley system is the work done raising the cup 10 cm, which you calculated in part A, number 7. This is often referred to as the work output of the pulley system. The amount of work that we put into the system, work input, can be found by calculating the work done on the effort side of the pulley system. Calculate the work input of this pulley system.

   Work input __________

6. Did the pulley system reduce the amount of work required to lift the object?

Analysis:

1. Record the data from the exploration in the table below

Pulley System Data

Ideal Mechanical Advantage	Resistance Distance (meters)	Resistance Force (Newtons)	Effort Distance (meters)	Effort Force F_E (Newtons)

2. Copy the Data columns into the table below. Describe any patterns or relationships that you see in the data table below.

Ideal Mechanical Advantage	Effort Distance (meters)	Effort Force F_E (Newtons)

3. Enter the effort distance into L1 and effort force into L2 of your graphing calculator. Create a scatter plot of Effort Force vs. Effort Distance. Sketch your graph on the grid provided.

4. Is there a constant rate of change between the data points?

5. Use the data collected to determine a mathematical model for the relationship between effort force and effort distance this situation.

Pulley System Data

Effort Distance (meters)	**Process**	**Effort Force F_E (Newtons)**
d		F_E
d		F

6. How is the model developed in number 5 related to the work input of the system.

7. Test your model by graphing it over your scatterplot. Sketch your graph on the grid provided.

8. Use your model to predict the effort force needed to raise the cup 10 cm when the effort distance is .5 m.

9. How should the pulley system be configured to produce this result? Sketch your configuration. Test your configuration to see if you obtain a result close to number 8.

10. Summarize the relationship between work, force, and distance in various pulley systems where the work output is constant.

4.5 Efficiency

Efficiency is a measure of how much work a machine can do relative to how much work is put into the machine. For example, take two cars that are identical in every respect except that one of the cars needs a tune-up. The car that is in tune will run more miles on the same amount of gas than the car that is out of tune. We would say that the car that is in tune is more efficient than the car that is out of tune. In an earlier lesson we learned that the efficiency of a simple machine could be found by this formula, $\%\text{Efficiency} = \frac{\text{Actual Mechanical Advantage}}{\text{Ideal Mechanical Advantage}} \times 100$ or $\%\text{Efficiency} = \frac{\text{AMA}}{\text{IMA}} \times 100$. Efficiency can also be found using this formula, $\%\text{Efficiency} = \frac{\text{Work Output}}{\text{Work Input}} \times 100$ or $\%\text{Efficiency} = \frac{W_O}{W_I} \times 100$.

1. Complete the data table using the lever data collected earlier.

Ideal mechanical Advantage	Resistance Distance (meters)	Resistance Force (Newtons)	Work Output	Effort Distance (meters)	Effort Force F_E (Newtons)	Work Input

2. Find the efficiency of each lever system.

Ideal mechanical Advantage	Efficiency

3. Based on your data how would you describe the efficiency of the lever system?

4. What are some factors that might affect the efficiency of the lever?

5. Complete the data table using the pulley data collected earlier.

Ideal mechanical Advantage	**Resistance Distance (meters)**	**Resistance Force (Newtons)**	**Work Output**	**Effort Distance (meters)**	**Effort Force F_E (Newtons)**	**Work Input**

6. Find the efficiency of each pulley system.

Ideal mechanical Advantage	**Efficiency**

7. Based on your data how would you describe the efficiency of the pulley system?

8. What are some factors that might affect the efficiency of the pulley system?

4.6 Power

If you walk up a flight of stairs, you are doing work. You are lifting your body's mass the height of the stairs. If you run up the stairs, you are still doing the same amount of work but you are doing it at a faster rate. Power is simply the rate of doing work. Power can be calculated using the formula; $P = \frac{Work}{time} = \frac{W}{t}$ the units for power are joules per second. One joule per second is a watt. Another way of looking at power can be found by remembering that work is force multiplied by distance, W=Fd, Fd can be substituted into $P = \frac{W}{t} = \frac{Fd}{t}$.

Another way is by remembering that Velocity is displacement divided by time, $v = \frac{d}{t}$, v can be substituted into $P = \frac{Fd}{t} = FV$.

1. Let's investigate power with data similar to what we collected in the Kidwork activity in the previous section. We will keep the distance constant (2 meters) but we will increase the mass of the object that we are pulling so that the force needed to pull increases by .5 Newtons per pull. We will be very careful and the time it takes to pull the object will always be 4 seconds. Complete the table using $P = \frac{Fd}{t}$.

Force (N)	**Process** $\frac{Fd}{t}$	**Power (W)**
F		P

2. Describe any relationships you see in the table.

3. What is the velocity in this situation?

4. Enter the force in L1 and enter the Power in L2 of your graphing calculator. Create a scatter plot of power vs. force. Sketch your graph on the grid below.

6. What type of function appears to model this data?

7. Enter the model into the equation editor of your graphing calculator. Graph the equation. Sketch the graph on the same grid as the data points you plotted.

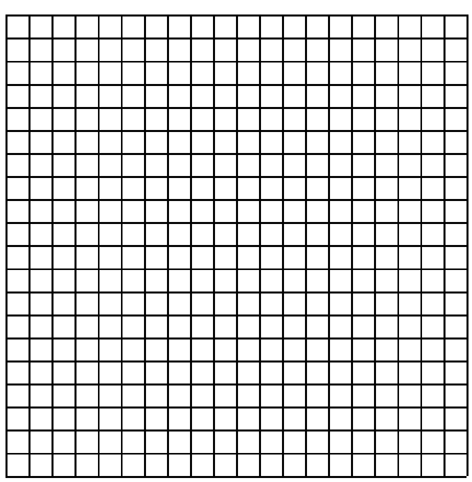
8. Is power vs. force a direct linear proportion? How do you know?

9. Now lets vary the distance that we will pull and keep the force a constant .5 Newtons per pull. We will be very careful and the time it takes to pull the object will always be 4 seconds. Complete the table using $P = \frac{Fd}{t}$.

Distance (m)	**Process** $\frac{Fd}{t}$	**Power (W)**
d		P

10. Describe any relationships you see in the table.

11. Enter the force in L1 and enter the Power in L2 of your graphing calculator. Create a scatter plot of power vs. force. Sketch your graph on the grid below.



12. What type of function appears to model this data?

13. Enter model into the equation editor of your graphing calculator. Sketch the graph on the same grid as the data points you plotted.

14. Is power vs. force a direct linear proportion? How do you know?

15. Now we will vary the time we take to pull the object keeping the distance and the force constant. The distance will be 2 meters and the force will be .5 Newtons. Complete the table using $P = \frac{Fd}{t}$.

Time (s)	$\frac{Fd}{t}$	**Power (W)**
t		P

16. Describe any relationships you see in the table.

17. Enter the force in L1 and enter the Power in L2 of your graphing calculator. Create a scatter plot of power vs. force. Sketch your graph on the grid below.

18. What type of function appears to model this data?

19. How much work is being done?

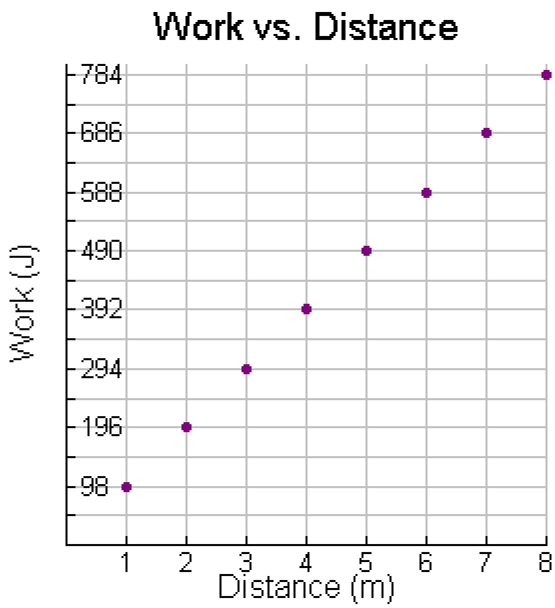
20. Enter model into the equation editor of your graphing calculator. Sketch the graph on the same grid as the data points you plotted.

21. Is power vs. time a direct linear proportion? How do you know?

4.7 Work and Power Sample Assessment

1. You push against the wall as hard as you can for as long as you can until you are exhausted. How much work did you do?
   .

2. Using the graph of work (in joules) vs. distance (in meters) below determine the mass of the object that is being raised vertically slow and steady. Use 9.8 m/s^2 for the acceleration due to gravity.



3. A 1210 kg piano is raised 36 meters to a third floor apartment. How much work is done?

4. If 40J of work is done lifting a rock 2.7 m off the ground, what is the mass of the rock? Use $9.8\ {}^{m}\!/_{s^2}$ for the acceleration due to gravity.

5. In an experiment, the following data was collected.

Time (s)	Power (W)
3	1989.33
12	497.33
17	351.06
28	213.14
35	170.51
48	124.33
61	97.83
77	77.51

a. Enter the data into your calculator, set an appropriate window and plot a scatter plot of power vs. time. Label and sketch your graph below.

b. Determine a model and sketch it on the same graph as your data.

c. What is the amount of work done in this problem in joules?

Appendix A

VERNIER
DUAL-RANGE FORCE SENSOR

Step 1

```
VERNIER SOFTWARE
DateMate

(Ver. 6.13)

ROM 1.12        (C) 2000
```

Opening screen, once the program has loaded press clear

Step 2

```
CH 1: FORCE (n)    .024

MODE: TIME GRAPG-3.6
1:SETUP        4:ANALYZE
2:START        5:TOOLS
3:GRAPG        6: QUIT
```

Press 1:SETUP

Step 3

```
CH 1:DUAL R FORCE10(n)
CH 2:
CH 3:
DIG :
MODE: TIME GRAPH-3.6

1:ON           3:ZERO
```

Use the down arrow key to move the curser to MODE and press enter

Step 4

```
SELECT MODE
1:LOGDATA
2:TIMEGRAPH
3:EVENTSWITH ENTRY
4:SINGLEPOINT
5:SELECTEDEVENTS
6:RETURN TO SETUP
SCREEN
```

Press 3: Events With Entry

Step 5

```
CH 1:DUAL R FORCE10(n)
CH 2:
CH 3:
DIG :
MODE: EVENTS WITH ENTRY

1:ON           3:ZERO
```

Press 3: ZERO

Step 6

```
SELECT CHANNEL
1:CH1:FORCE
2:ALL CHANNELS
```

Press 1: FORCE

Step 7

```
CH 1:FORCE(n)          .024

PRESS [ENTER] TO ZERO
```

Press ENTER to ZERO

Step 8

```
CH 1: FORCE (n)    0

MODE: EVENTS WITH ENTRY
1:SETUP          4:ANALYZE
2:START          5:TOOLS
3:GRAPG          6: QUIT
```

Press 2 to start collecting data

Step 9

```
PRESS ENTER TO COLLECT
OR [STO] TO STOP
1                    2.874
```

Press ENTER when the force sensor has stopped moving and you believe you have an accurate reading

Step 10

```
ENTER VALUE
?
```

Enter the mass of the object (1) you placed on the force sensor

Continue to collect data.
Press STO► to stop collecting data.

Step 11

```
CH 1: FORCE (n)    8.67

MODE: EVENTS WITH ENTRY
1:SETUP          4:ANALYZE
2:START          5:TOOLS
3:GRAPG          6: QUIT
```

Press 6 to quit the program.
Press ENTER to return to home screen.