Newton's Laws

Teaching Math Through Science

dawn.hardy@hcbe.net

Newton's First Law

- The Inertia Law
- Objects at rest remain at rest and objects in motion remain in motion in a straight line unless acted upon by an unbalanced force.
- https://www.generationgenius.com/videolessons/newtons-laws-of-motion-video-for-kids/
- https://www.generationgenius.com/videolessons/potential-vs-kinetic-energy-video-for-kids/
- *Unbalanced Force* refers to the sum total or net force exerted on an object.

Newton's Second Law

- Second Law
- The greater the mass, the greater the force needed to move the object
- Force equals mass times acceleration ($f = ma$)

Newton's Third Law

- For every action there is an equal and opposite reaction.
- https://www.generationgenius.com/activities/newtons-laws-and-forces-activity-for-kids/

National Aeronautics and Space Administration

Mass vs. Weight
Air Powered Mass

Objective

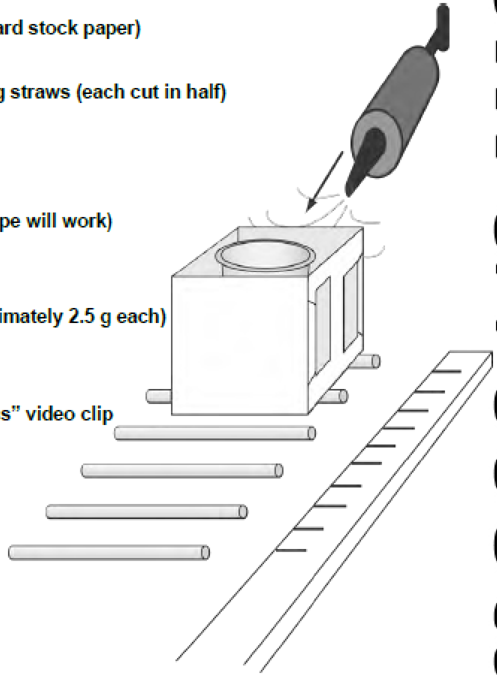
To investigate Newton's Second Law of motion, *F = ma*, by measuring how objects of different mass are accelerated by a constant force.

Description

Student teams build a **mass car** and measure its movement in relation to the amounts of mass it carries as it is propelled by a uniform air blast. Following data collection, students graph and discuss their results and compare it to the video of a similar experiment performed on the International Space Station.

Materials (per student team)

- Mass Car Template (copied onto card stock paper)
- 4 oz paper or plastic drinking cup
- 15 non-flexible, solid color drinking straws (each cut in half)
- Party balloon air pump
- Mass scale
- Scissors
- Cellophane tape (any classroom tape will work)
- Meter stick
- Graphing paper
- 15 pennies (or flat washers approximately 2.5 g each)
- Safety goggles
- Copies of the Student Data Sheets
- *Mass vs. Weight* "Air Powered Mass" video clip



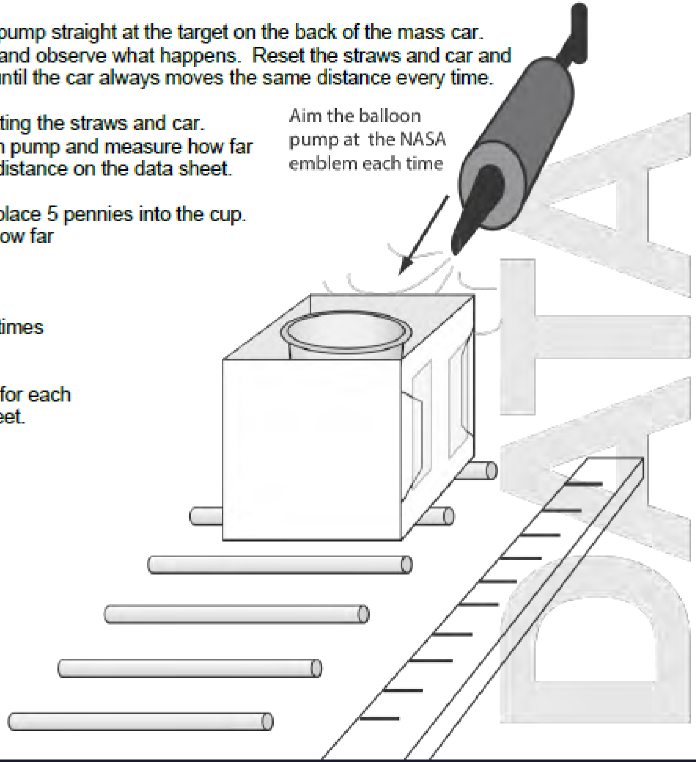
mass vs weight

Name: ______________________________

Air Powered Mass
Student Team Experiment Procedures

PRACTICE SAFETY – WEAR GOGGLES – STAY ALERT

1. Construct the Mass Car using the provided template.
2. Cut fifteen standard straight straws in half to make 30 shorter straw pieces.
3. Place a meter stick on a smooth floor or tabletop. Put one straw next to the end of the meter stick. Place the second straw parallel to the first at the 2-centimeter mark. Continue placing all the other straws 2 centimeters apart. Be sure the straws are not touching the meter stick. The straws should be parallel to each other like the wooden ties of railroad tracks.
4. Set the Mass Car on the straws with the back of the car even with the 0 centimeter straw.
5. Carefully place an empty cup on top of the shaded circle inside the box of the mass car. Measure the mass of the mass car and empty cup. Record mass on the chart on Student Data Sheet
6. Aim the nozzle of the balloon pump straight at the target on the back of the mass car. Shoot a blast of air at the car and observe what happens. Reset the straws and car and propel it again several times until the car always moves the same distance every time.
7. Begin the experiment by resetting the straws and car. Propel the car with the balloon pump and measure how far the car traveled. Record the distance on the data sheet.
8. Reset the straws and car but place 5 pennies into the cup. Propel the car and measure how far it goes with the extra mass. Record your data.
9. Repeat experiment two more times with 10 and then 15 pennies.
10. Record and graph your data for each test on the Student Data Sheet.



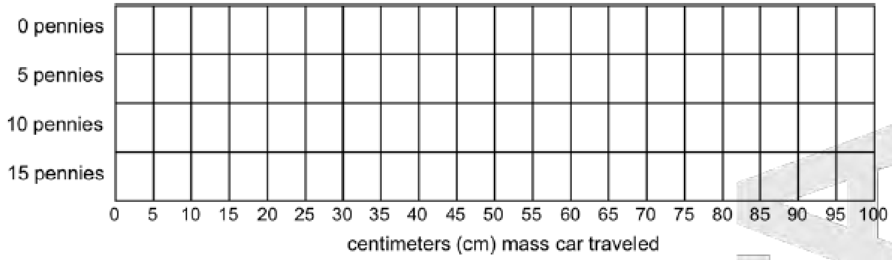
Name: ______________________________

MASS VS WEIGHT

Air Powered Mass
Student Data Sheet

Items	Total Mass (g)	Distance Mass Car Traveled (cm)			
		Test 1	Test 2	Test 3	Average
Car + Cup + 0 pennies					
Car + Cup + 5 pennies					
Car + Cup + 10 pennies					
Car + Cup + 15 pennies					

1. Plot the bar graph showing the average distance of the three tests for each mass:



2. Plot the data on graph paper as a line graph. Give the graph a title and label the axes. Include the units.
3. Examine the data and the graphs. How does the mass affect the distance the mass car traveled?

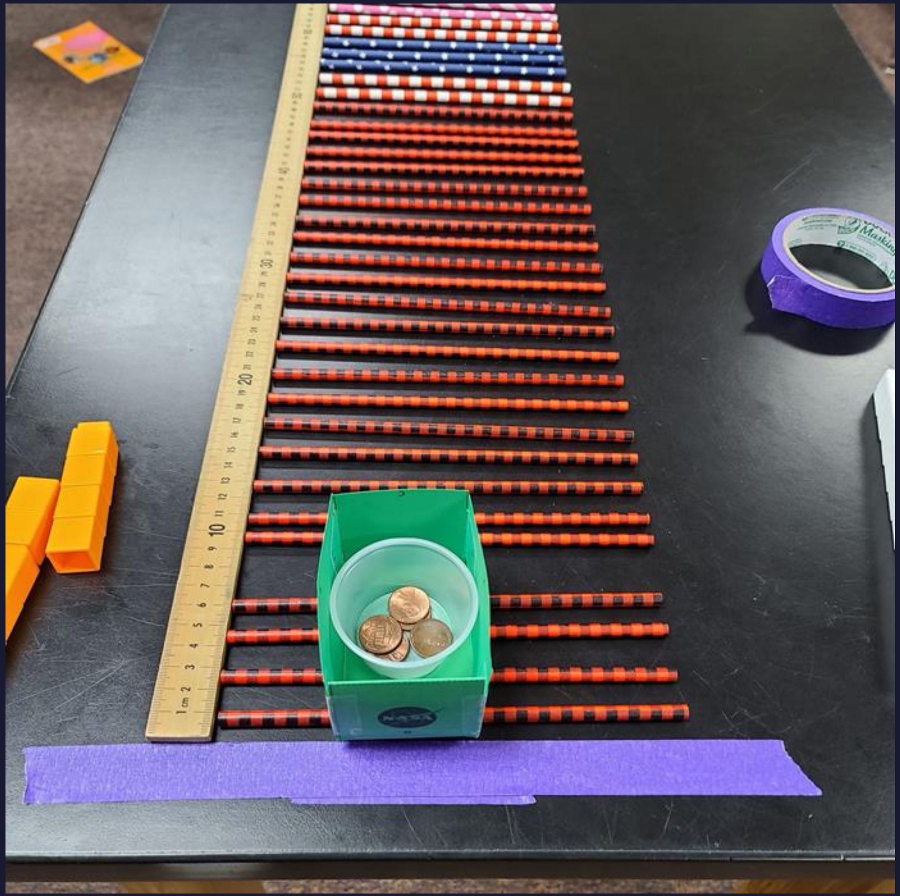
____
____
____

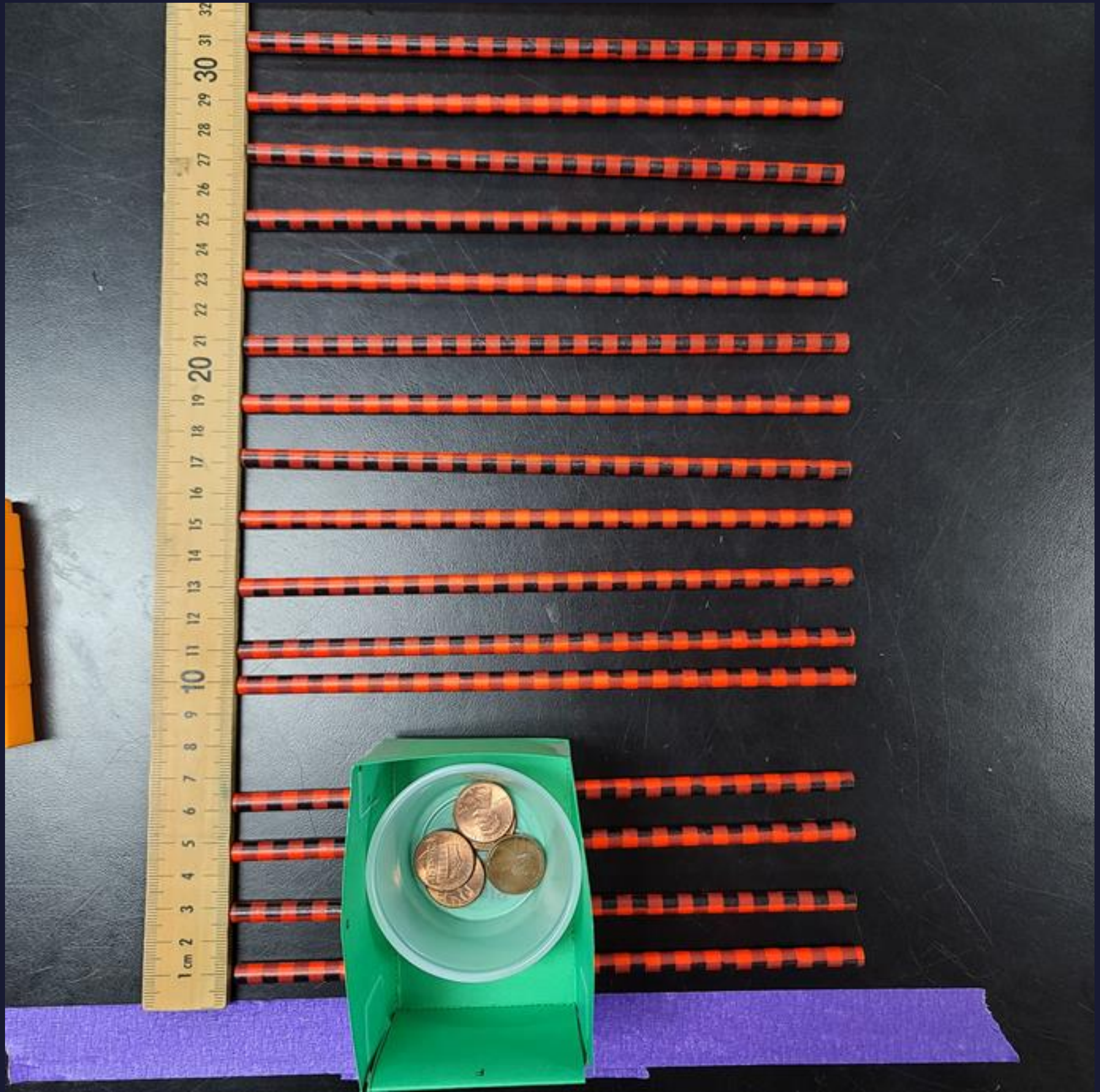
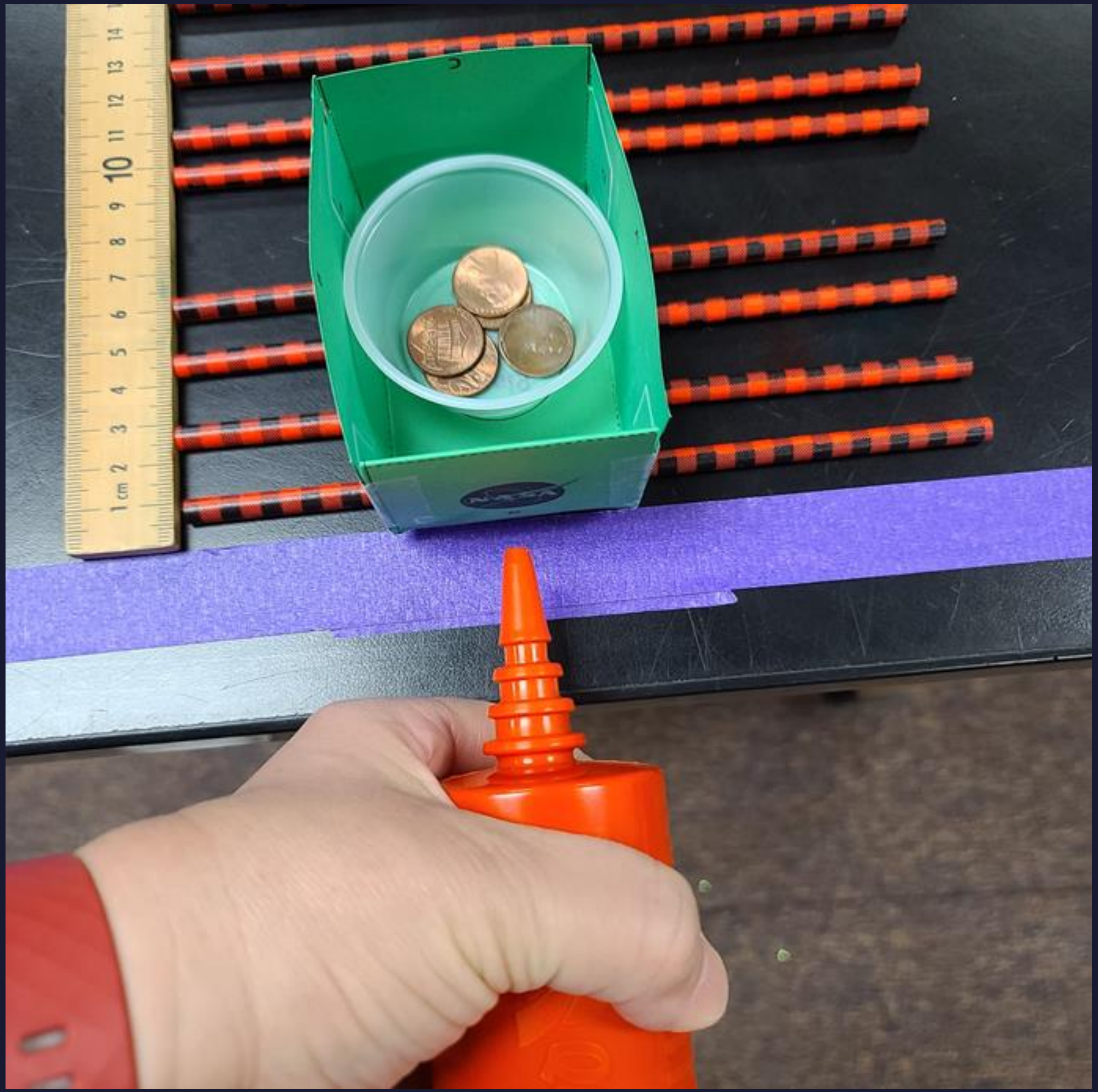
4. How can Newton's Laws of Motion explain the data results?

____
____
____

5. How would this experiment work on the International Space Station? (Use the back of the sheet if needed)

DATA

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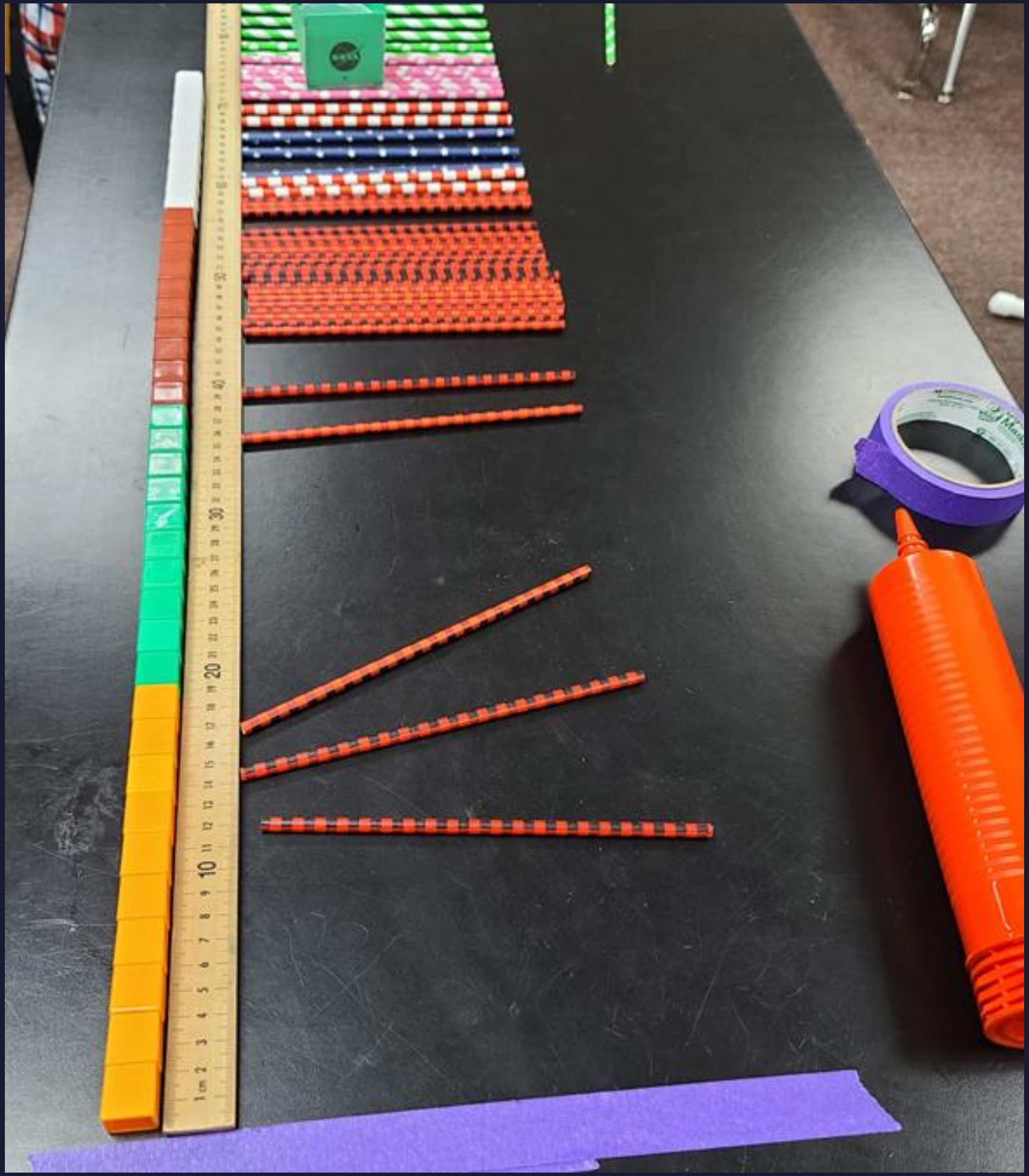
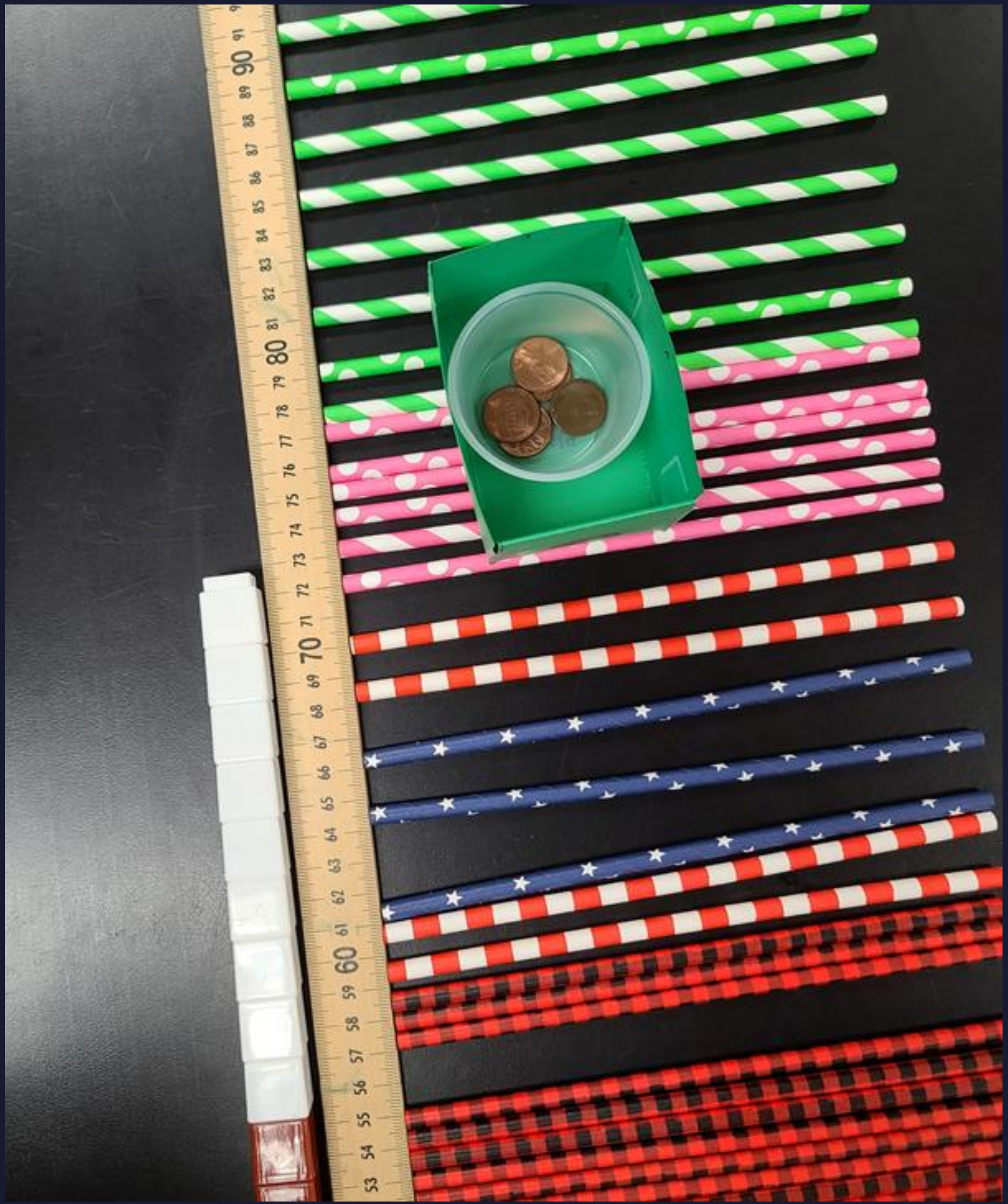




Name ______________________ Section (Period) ______________ Date ______________

Lab Partner(s) ____

PAPER ROLLER COASTER LAB

Calculating Average Speed of a Rolling Marble

INTRODUCTION AND OBJECTIVES

In a typical paper roller coaster, the speed of a marble will increase and decrease many times. In this activity, you will find the speed of the marble in different portions of a paper roller coaster. You will also find the average speed of the marble during the entire trip down the paper roller coaster.

EQUIPMENT NEEDED

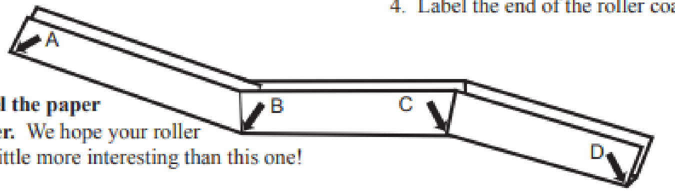
- completed Paper Roller Coaster
- meter stick
- pencil
- calculator
- string

PROCEDURE

I. Selecting starting and ending points.

Divide your paper roller coaster into three different sections by placing marks on the tracks.

1. Label the beginning of the roller coaster with an "A." See the drawing below.
2. About 1/3 of the way down the roller coaster, label the track with a "B."
3. About 2/3 of the way down the roller coaster, label the track with a "C."
4. Label the end of the roller coaster with a "D."



How to label the paper roller coaster. We hope your roller coaster is a little more interesting than this one!

II. Measuring Distances between points

1. Measure the distance that the marble must travel to get from Point A to Point B. To do this, lay one end of a string on the track at Point A. Stretch the string along the path that the marble will travel. Mark the string where it meets Point B on the track. Remove the string from the track and measure the length of the string that reached from Point A to Point B when it was lying on the track. Record the distance in meters in the data table.

2. Use the same procedure to measure the distance from Point B to Point C and the distance from Point C to Point D. Record these distances in the data table.

3. Measure the amount of time it takes for the marble to roll from Point A to Point B. To do this, release the marble at Point A and use a stopwatch to find how long it takes for the marble to reach Point B. Record this time in the data table. Repeat this procedure three times and record your results in the data table. Find the average for the three trials and enter that time in the data table.

4. Measure the amount of time it takes for the marble to roll from Point B to Point C. Do not release the marble at Point B. Instead, release the marble at Point A again and start the stopwatch when it passes Point B. Stop the timer when the marble passes Point C. Repeat for three trials and calculate the average.

5. Measure the amount of time it takes for the marble to roll from Point C to Point D. Do not release the marble at Point C. Instead, release the marble at Point A again and start the stopwatch when it passes Point C. Stop the timer when the marble reaches Point D. Repeat for three trials and calculate the average.

6. Calculate the average speed of the marble between Point A and Point B. Divide the distance between Point A and Point B by the average amount of time that it took to get from Point A to Point B. Enter the speed of the marble in the data table. Use the correct units in the table.

7. Calculate the average speed of the marble between Point B and Point C. Record your result in the table. Repeat the same steps to calculate the average speed of the marble between Point C and Point D.

	TRIALS			AVERAGE
	1	2	3	
Distance A to B				
Time from A to B				
Speed between A and B				
Distance B to C				
Time from B to C				
Speed between B and C				
Distance C to D				
Time from C to D				
Speed between C and D				

III. Questions

1. Between which two points did the marble have the highest average speed? ______________

2. Why do you think that the marble was moving the fastest on this part of your roller coaster? ______________

3. Between which two points did the marble have the lowest average speed? ______________

4. Why do you think that the marble was moving the slowest on this part of your roller coaster? ______________

5. If you wanted to make a roller coaster on which the marble would have the slowest average speed from the top to the bottom, how would you design it? ______________

6. Calculate the average speed of the marble during the entire trip down the paper roller coaster.

	TRIALS			AVERAGE
	1	2	3	
Distance from A to D				
Time from A to D				
Speed from A to D				

Name ______________________ Section (Period) _____________ Date ______________

Lab Partner(s) ____

PAPER ROLLER COASTER LAB

The Great Paper Roller Coaster Challenge

INTRODUCTION AND OBJECTIVES

The local amusement park has issued a challenge to roller coaster designers to determine who should build their next roller coaster. You'll need to prove that you can make an exciting roller coaster that meets their requirements, using as little money as possible.

EQUIPMENT NEEDED

- Paper Roller Coaster pieces on card stock
- Scissors
- Tape
- cardboard base
- Paper Roller Coaster instruction manual
- ruler (optional)
- pen (optional)
- magazine (optional)

OBJECTIVE

Your Paper Roller Coaster must meet all of the following requirements:

1. height between 30 cm and 100 cm
2. track length must be at least 150 cm
2. at least one loop
3. at least six turns
4. bucket at end to catch marbles
5. decorations

COST OF MATERIALS

Type	Cost	Type	Cost
Column	$0.50	Straight track	$1.00
Beam	$0.50	Sharp turn	$1.25
Diag. Support	$0.10	Wide turn	$1.25
Shelf	$0.05	Funnel	$2.50
Bracket	$0.05	Loop	$1.50

PROCEDURE

While trying to spend as little "money" as possible, build a Paper Roller Coaster using the supplies that your teacher provides. The roller coaster should be exciting, reliable, and take a long time for the marble to travel from the start to the finish. Look at the scoring sheet below before you begin. Good luck!

TESTING

After you're done building, your teacher will test your Paper Roller Coaster by placing one marble at a time on it. Record the amount of time that it takes for each marble to reach the bucket at the end of the track. If the marble gets stuck or falls off of the track, write N/A for that trial.

Trial #1 _________ seconds

Trial #4 _________ seconds

Trial #2 _________ seconds

Trial #5 _________ seconds

Trial #3 _________ seconds

Total time for all trials = ______________ seconds

Enter your total time for the five trials in the chart at the right. Your teacher will help you complete the rest of the chart.

Category	Points
Total time (5 trials) each second = 1 point	
Reliability Bonus (30 points if all trials reached the bucket)	
Height > 30 cm and < 100 cm (10 points)	
Track length > 150 cm? (10 points)	
At least one loop? (10 points)	
At least six turns? (10 points)	
Bucket at end to catch marbles (10 points)	
Uphill sections (5 points for each section of the track where the marble goes uphill)	
Decorations (up to 30 points)	
Construction quality (up to 30 points)	
Excitement value (up to 30 points)	
total construction score	
Cost of Materials ($1 = 1 point)	-
Final score (total construction score - cost)	

Calculating Potential Energy and Kinetic Energy of a Rolling Marble

INTRODUCTION AND OBJECTIVES

The Law of Conservation of Energy states that energy can be neither created nor destroyed. However, energy can change from one form to another. In the case of a marble on a paper roller coaster, a marble starts at the top of the roller coaster with a relatively large amount of potential energy and no kinetic energy. As the marble starts rolling down the roller coaster, the amount of potential energy stored in the marble decreases while its kinetic energy increases. Potential energy is also converted into heat energy due to friction. In this experiment, you will be calculating the change in potential energy of a marble traveling between two points on a paper roller coaster and compare that to the kinetic energy that was gained by the marble during that same time.

EQUIPMENT NEEDED

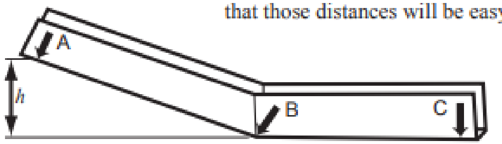
- completed Paper Roller Coaster
- ruler
- pencil
- calculator
- stopwatch (optional)
- video camera (optional)
- photogate timer (optional)

PROCEDURE

I. Selecting the starting and ending points.

Choose a portion of the roller coaster in which the marble accelerates and then keeps a fairly constant speed. Ideally, this would mean a gentle downhill section followed by a level section. The marble does not need a steep hill to accelerate.

Place three marks on the roller coaster. Label the beginning of the hill "A", the end of the hill "B", and the end of the level section "C". You will be measuring the distance between each of these points so make sure that those distances will be easy to measure.



II. The gravitational potential energy of the marble

To simplify calculations, treat the height of point B as the reference point where gravitational potential energy equals zero. The gravitational potential energy of the marble depends on the height of the starting point compared to the ending point of the marble's path. Gravitational potential energy equals (mass)*(acceleration due to gravity)*(height). This can be written as $P.E. = mgh$.

Find the mass of the marble. Measure the mass of ten marbles and divide that by ten. Convert the mass of the marble to kilograms. Enter your result below.
Find point A's height above point B in meters.

1. Mass of the marble, m (kg)	
2. Acceleration due to gravity, g (m/s^2)	
3. Height of point A above point B, h (m)	
4. Gravitational potential energy at point A, mgh, (J)	

III. Calculating the kinetic energy of the marble

The total kinetic energy of the marble is made of two parts, the kinetic energy due to its linear motion and the kinetic energy due to its rotation. A marble that is rolling has more kinetic energy than a marble that is sliding along at the same speed. You will calculate those two amounts separately before adding them together.

A. Kinetic energy of the linear motion

The marble's kinetic energy due to the its linear motion is one half its mass times its velocity squared. It can be written as $K.E._l = \frac{1}{2}mv^2$.

1. Find the mass of the marble. Enter all results below.
2. Find the velocity of the marble between points B and C. There are many ways to do this. The simplest way (although the least precise) is to use a stopwatch to determine how long it takes to get from point B to point C after you release the marble at point A. Divide the distance between points B and C by the time elapsed. Conduct three trials to determine the average velocity between points B and C.*
3. Calculate the average linear kinetic energy of the marble.

Trial #	Linear Distance from B to C (m)	Time (s)
1		
2		
3		
Average		

Average Velocity (m/s)	
Mass (Kg)	
Linear Kinetic Energy (J) $K.E._l = \frac{1}{2}mv^2$	

B. Kinetic energy due to rotation (optional)

The marble's kinetic energy due to its rotational speed is $1/2I\omega^2$, where I is the moment of inertia of the marble and ω is the marble's angular speed. The moment of inertia of a solid sphere is $\frac{2}{5}mr^2$, where m is the mass and r is the radius of the marble, so the kinetic energy of a rotating marble is $K.E._r = \frac{1}{2}(\frac{2}{5}mr^2)\omega^2$. For a marble that is rolling without slipping, $\omega = v/r$, so $K.E._r = \frac{1}{2}(\frac{2}{5}mr^2)(v/r)^2$, or

$K.E._r = \frac{1}{5}mv^2$.

Mass of marble (Kg)	
Velocity of marble (m/s)	
Rotational Kinetic Energy (J) $K.E._r = \frac{1}{5}mv^2$	

C. Total kinetic energy of the rolling marble

The marble's total kinetic energy is the sum of its linear kinetic energy and its rotational kinetic energy.

Total kinetic energy of the rolling marble = __________________ $(Kg)(m^2)/s^2$ = Joules.

IV. Conclusion

1. What is the total Mechanical Energy of the marble at point A, before the marble starts to roll? __________
2. What is the total Mechanical Energy of the marble at point C? __________
3. Compare your answers to questions 1 and 2. Should these answers be the same? __________

why or why not? ______________________________

*For more precise measurement of the marble's velocity, use either a photogate timer or a video camera. A video camera can be used if it allows for frame by frame advance and an on-screen display showing elapsed fractions of a second.