Name _____

Exploring the Third Law with a Newton's Cart

Objective:

How do forces affect the motion of objects? With a small slab of wood, some rubber bands and a few steel marbles, you will be able uncover and learn about laws governing the motion of objects that were discovered over 300 years ago by Sir Isaac Newton.

Materials (per group):

- The Newton's Cart apparatus
- Steel marbles of different masses
- 45-50 short drinking straws
- Masking tape
- Rubber bands (1 large, 20 small)
- Scissors (small and sharp)
- 2 Stop watches
- Long measuring tape
- Meter stick
- Scale to weigh the objects
- Scientific calculator

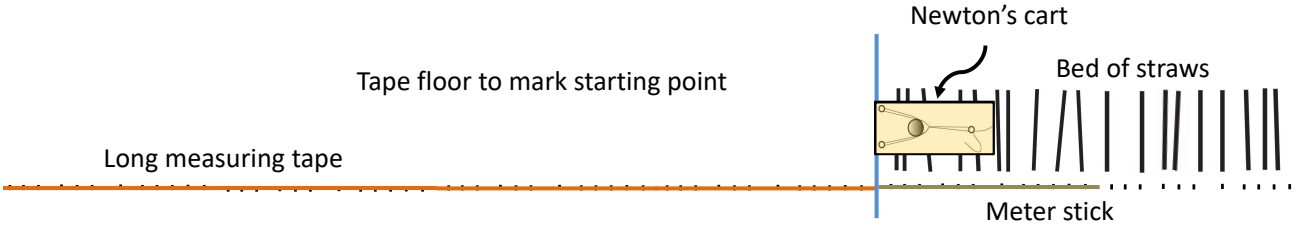
Watch the video:

Watch the short Newton's Cart lesson intro video; https://bit.ly/CartIntro

Getting started:

Read through all of the steps below before you start working, to get an overview of what you will be doing. Looking down to the floor from above, your set-up will look something like this:

View from above Newton's Cart Set-up



- You will need a smooth , level surface (floor) where you have 6-7 m (about 20 feet) of free space.
- Before collecting data, do some trial runs to learn and practice your techniques.

- Assign duties for each person in your group (timers cutter, recorder, etc.), based on the procedures below.
- You've got 1 cart and steel marbles of different masses. You should do three trials with each mass marble, and record the distance and time for both the marbles and the cart for each of your data sets.

Procedure:

1. Place a piece of masking tape on the floor to mark your staring point (see the diagram above). The tape will be your starting point for each trial.
2. Arrange about 50 short straws on one side of the tape over a distance of about 1½ meters. Space the straws about every 2-3 cm.
3. Lay a meter stick alongside the line of straws.
4. Lay out a long measuring tape extending 5-6 meters in the opposite direction.
5. To make your cart, place the larger rubber band across the two screws at the end. Wrap the smaller rubber band around the larger one and hook both ends back to the single screw. See the sequence of drawings below.
6. Do as many data sets as you have marbles of different masses, making copies of the sample data table below; a different table for each marble mass.

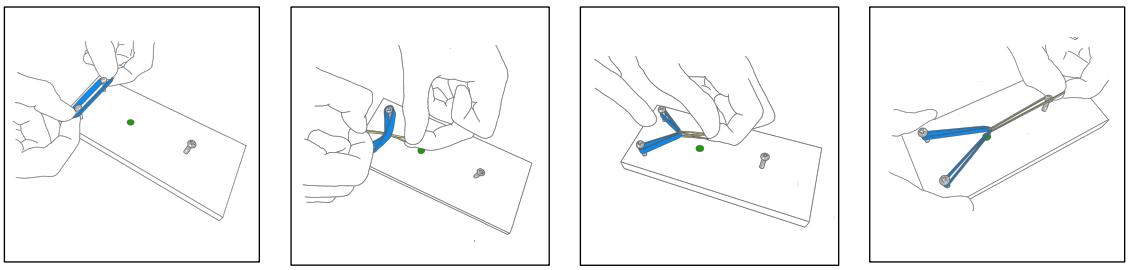


Table 1 – Distance and Time; Marble mass _____ kg Cart mass _____ kg

	Marble Data			Cart Data		
	Distance (m)	Time (s)	Velocity (m/s)	Distance (m)	Time (s)	Velocity (m/s)
Trial 1	_____	_____	_____	_____	_____	_____
Trial 2	_____	_____	_____	_____	_____	_____
Trial 3	_____	_____	_____	_____	_____	_____
Average	_____	_____	_____	_____	_____	_____

7. When you're ready, put the marble in the "V" of the large rubber band, and place the cart apparatus squarely on the straws at the starting point.
8. When the time-keepers on your team are ready to start recording, count down and snip the smaller rubber band.
9. Record the distance traveled and time measurements for both the marble and the cart in **Table 1**.
10. Repeat the process to record a total of three trials and then calculate the averages of distance and time values for each trial.
11. Calculate the ***velocity*** for both the marble and the cart for each of your trials, and find the average.

Making sense of your data

1. Think about the motions of the wooden cart and the marble during your experiments.
    a. In what ways did your observations agree with what you thought would happen?

    b. What was different from what you thought would happen?

2. When you use your distance and time measurements to calculate the **velocity** of your marble or cart in motion, it is actually the ***average velocity***.
    a. Why do you think the velocity you calculated for the cart and marble is called an "average velocity"?

    b. What was the ***final velocity*** of the marbles, the velocity at which they stopped rolling?

3. You already know that an ***average*** of two quantities is the sum of the quantities divided by 2.

$$velocity\ (average) = \frac{velocity\ (initial) + velocity\ (final)}{2}$$

4. With what you know about the **final velocity** of the marble, show how you would re-arrange the above equation to solve for the ***initial velocity*** (the "launch" velocity") of your marbles, and then calculate the initial velocity for each of your trials for both the marble and cart.

Copy the two tables below to construct your own data tables for as many runs as you make for marbles of different masses.

Table 2a – Velocities for Marble; for marble mass of _____ kg

	Average velocity (m/s)	Final velocity (m/s)	Initial velocity (m/s)
Trial 1	_____	_____	_____
Trial 2	_____	_____	_____
Trial 3	_____	_____	_____
Average	_____	_____	_____

Table 2b – Velocities for Cart; using a marble mass of _____ kg
(You will be comparing the velocities of the cart to mass of marbles.)

	Average velocity (m/s)	Final velocity (m/s)	Initial velocity (m/s)
Trial 1	_____	_____	_____
Trial 2	_____	_____	_____
Trial 3	_____	_____	_____
Average	_____	_____	_____

5. The relationships between the forces affecting motion, and the resulting motion are better understood using graphical representations of the quantities being measured.

   Construct graphs, using either all of the data points you collected or your calculated averages, for each of the following, with the mass of the ball as the independent variable. Label both axes with appropriate titles and units and give each graph a title.

   a. Graph 1 – Distance of ball vs mass of the ball
   b. Graph 2 – Distance of the cart vs mass of the ball

6. Describe what each of the graphs tell you about the relationships between the variables.

7. Construct two more graphs, this time with these data:

   a. Graph 3 – Launch velocity of the ball (initial velocity) vs mass of the ball.
   b. Graph 4 – Launch velocity of the cart vs mass of the marble.

8. Describe the effect that the mass of the ball has on the initial (launch) velocity of each the ball and the cart.

9. List the sequence of all of the events you can think of that result from the cutting of the rubber band,

Analysis

1. Newton's Third law states, "For every action there is an opposite and equal reaction." Explain how do you think the movement of the objects in this experiment relate to the Third Law?

Going further

1. Newton's Second Law recalls that "Acceleration of an object increases as the force causing acceleration increases." Write a hypothesis for how you think the **initial speed** of the marble might be affected by how heavy it is?

2. Construct a graph of launch velocity (dependent variable) versus mass of marbles (independent variable). On the same graph, plot the launch velocity of the cart versus marble mass. Be sure to label both axes and sets of data.
    a. Describe how the shapes of the two curves compare.

    b. Multiplying the mass of a moving object times its velocity gives a quantity we define as **momentum**. Ideally, when objects in motion interact, momentum is conserved. Identify the point on your graph where the lines for the cart and marble intersect.
        i. What is significant about this point in terms of momentum?

        ii. Show your calculation for the momentum of the ball at this point.

        iii. Show the calculation of the momentum of the cart at this point

        iv. How well does your data support the Law of Conservation of Momentum?

    c. Explain how you could use your the graph to find the mass of the cart. According to your graph, what ***is*** the mass of the cart?