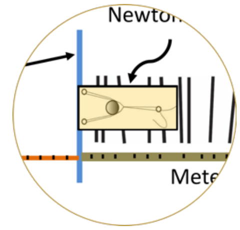
# Exploring the Third Law with a Newton's Cart




**Teachers' Guide**

Some suggestions about making and using Newton's Carts with your students will ne helpful. We will give you some insight to the materials, sources for where to get what we have used, and some tips on classroom implementation. We will also provide you some guidelines on making the carts, yourself.

**Materials (per student group):**

- The Newton's Cart apparatus (1)
- Steel marbles of different masses
- 45-50 short drinking straws (2)
- Masking tape
- Rubber bands (1 large, 20 small) (3)
- Scissors (small and sharp) (4)
- 2 Stop watches (5)
- Long measuring tape
- Meter stick (6)
- Scale to weigh the objects

The video will demonstrate the experiment and show you what you need to make the Newton's Cart apparatus for your class: https://bit.ly/NewtonsCart

**Notes on Materials**

(1) Instructions for the construction of the carts are illustrated in the accompanying video.

(2) You can use any drinking straws, but to minimize friction we suggest (1) cutting longer (whole) straws in half, and (2) using harder surface paper straws rather than plastic. We found good success with Gordon Foods 5.5" straight paper straws (see materials list).

(3) After a good deal of trial and error with rubber bands of different sizes, we used a #61 for the primary firing rubber band and for the smaller secondary rubber band a #8.

(4) Ordinary classroom scissors do not work well; they are just not sharp enough. Smaller (6 inch or so) scissors are also better than larger ones. They need to be sharp.

(5) For us, mechanical stopwatches have proven more successful than mobile phone apps. Touching the app screen can be cumbersome, particularly because the touch sensitive screen is not that reliable and students don't see the problem with pressing the screen a second time, not realizing that that crucial second will affect their data significantly. See what works for your students and if you're using phone stopwatches, just be aware.

(6) You will need at least one meter stick for the cart distances. The cart may go further than one meter, but students can mark the floor at the end of the stick with their finger and slide it ahead to get the remainder of their measurement. The ball will travel a distance of about 20 feet or 6 meters, depending on your environment. We roll out a long measuring tape for the ball and use the meter stick for the cart.

### Techniques for success

Suggestions are made in the accompanying video that will help your students achieve the best results with the experiment, including, cutting the rubber bands, timekeeping and class management. In particular, keep the following in mind:

- Scissors need to be sharp and cutting the rubber band requires practicing a technique to be consistent; being able to replicate the procedure is essential.
- Counting down (3, 2, 1, fire!) will help students synchronize their actions for cutting and timing.
- Your floors will be uneven and the ball may wander from its direction of motion. Develop a protocol for where and when students should stop measuring distance and time, for example when the ball takes a direction more that 45$^{o}$ from the line of travel.
- Student groups select who will do which tasks throughout.

### Sources for selected materials

| Item | Details | Source |
|---|---|---|
| #61 Rubber band | Firing (primary) rubber band | https://amzn.to/3I2PnGM |
| #8 Rubber band | Secondary rubber band | https://amzn.to/3HYadqU |
| 3/4 inch (19 mm) steel bearing | Marble (mass ~28 g) | https://amzn.to/3E3HXAM |
| 13/16 inch (20.6 mm) steel bearing | Marble (mass ~36 g) | https://amzn.to/3rfJe49 |
| 7/8 inch (17mm) steel bearing | Marble (mass ~45 g) | https://amzn.to/3peoF5L |
| 15/16 inch (23.8 mm) steel bearing | Marble (mass ~55 g) | https://amzn.to/3Ia2y9c |
| 1 inch (25.4 mm) steel beaning | Marble (mass ~67 g) | https://amzn.to/3ugkp9I |
| 1 1/16 inch (27 mm) steel bearing | Marble (mass ~81 g) | https://amzn.to/3cYiJrw |
| Scissors | Revlon safety scissors | https://amzn.to/3uH2lpJ |
| Gordon 5.5” paper straws | cart roller bed | https://bit.ly/3GiERJG |

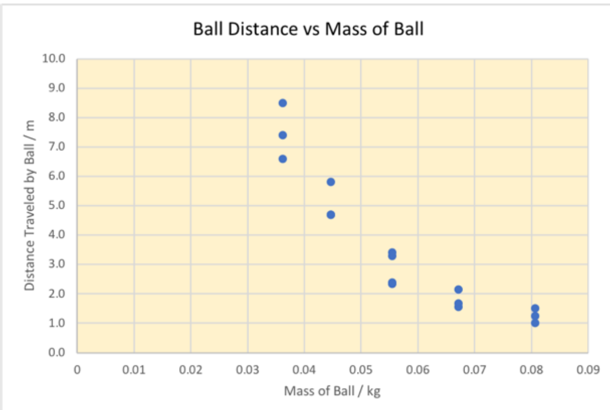
### Acknowledgements

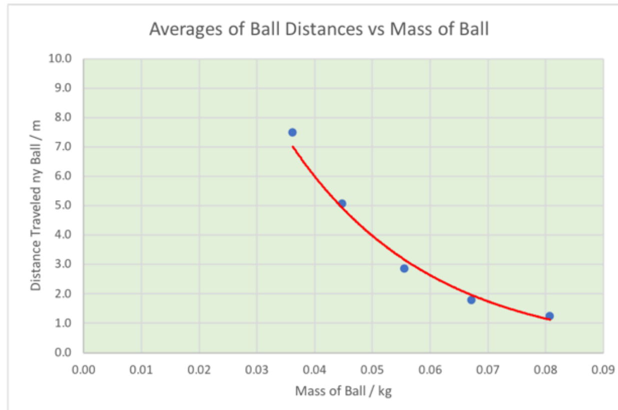
1. Thanks to Zeynep Akdemir, Purdue University, who conducted trials and wrote the original protocol for this experiment.
2. Our inspiration for Newton’s Cart was derived from the YouTube video, “Design and Build – Newton Car;” https://youtu.be/_CRDAjfS22M
3. Special thanks Roncalli High School physics teacher Ben Grimes, Indianapolis, Indiana for his collaboration and advice in instructional goals and in creating this lesson.

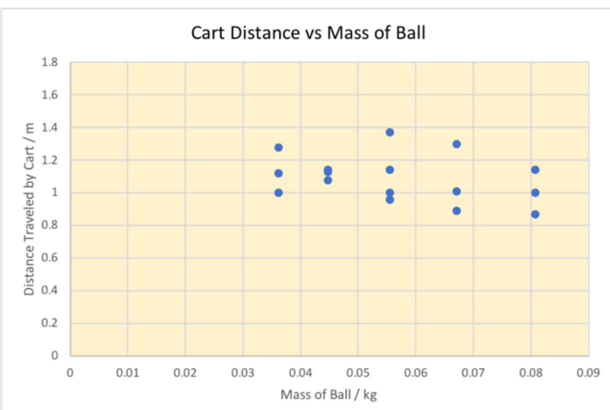
**Sample Data:**

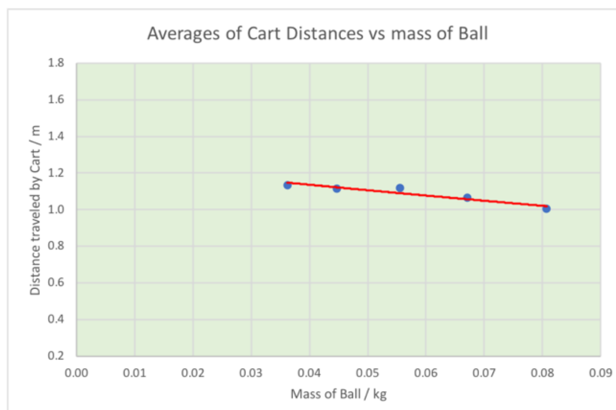
## Distance vs mass if marble

Graphical comparisons are made based on the independent variable – mass of the marble.

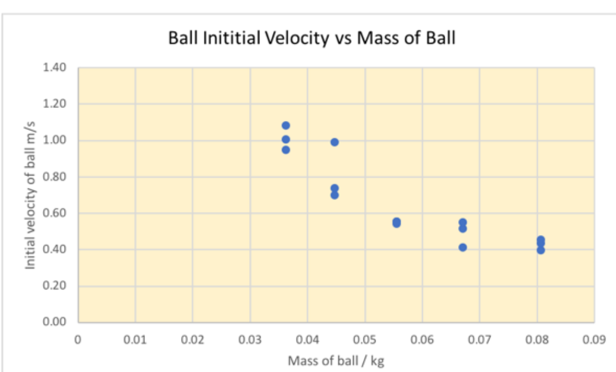


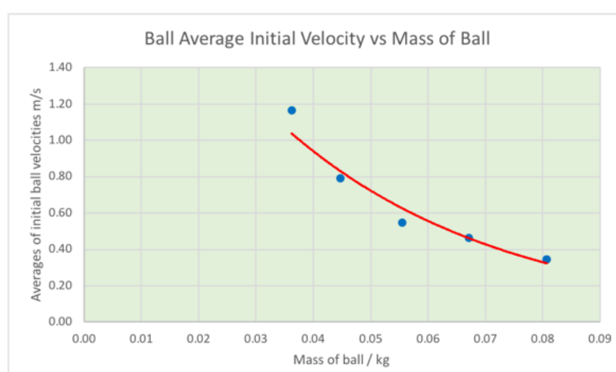



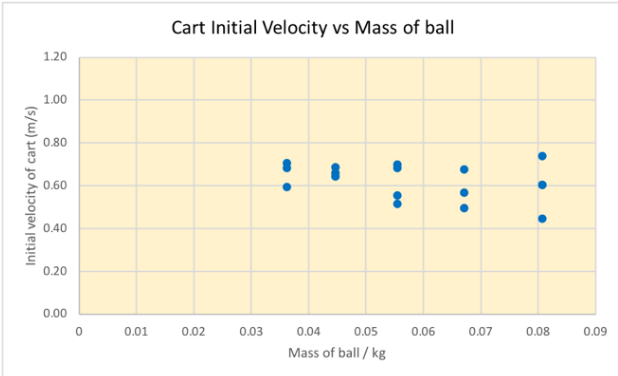



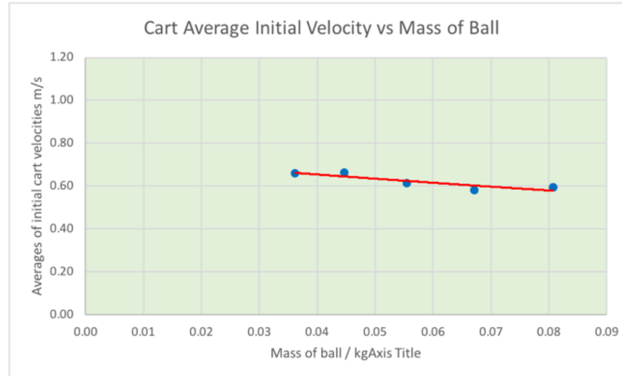




## Launch velocity vs mass if marble






**Combined Launch Velocity vs Mass if Marble**

Plotting the initial velocity versus mass for both the marble and the cart allows students to explore the Law of Conservation of Momentum. During the time of the contraction of the rubber band, energy is transferred, divided equally, to both the marble and the cart. Since the two objects have different masses, their initial velocities will not be the same; their momenta will be, expressed quantitatively and the velocities of each object change over time. Students will find the mass of the cart from their graphs at the point where the two data sets intersect; they can verify their result by actually weighing the cart.