Lesson 4 Teacher Reference

Cart Construction Instructions

These instructions will only need to be followed once; the carts can then be stored for future use. For each classroom, you will need at least 1 variable force cart and 2 variable mass/initial speed carts. You will split the 3 independent variables across groups; for classes with more than 6 groups, it is suggested to have 2 force groups (because the kit only includes 2 tumble buggies), 2 or 3 speed groups (because those groups will take turns using the smart cart to measure speed), and the rest as mass groups.

Safety Protocols

When working with the lab materials, the following safety precautions are necessary.

- Students must conduct the experiment under the supervision of qualified personnel who can respond quickly to any unforeseen circumstances.
- Students involved in setting up the equipment and conducting the experiment must be properly trained in handling the sensor carts and understand the experimental procedures.
- Wear appropriate personal protective equipment (PPE) including sanitized safety glasses with side shields during the setup, experimentation, and takedown segments of the activities.
- Secure loose clothing, wear closed-toe shoes, and tie back long hair.
- Use caution when using sharps (tools, bolts, hinge, etc.), which can cut or puncture skin.
- Use caution when working with glue guns, which can get hot and burn skin!
- Review and follow all manufacturer safety instructions and warnings before using graphite lubricant.
- Use caution when working with graphite lubricant. Can be toxic and a health hazard.
- Clear the workspace of any obstacles or hazards that could interfere with the experiment or cause accidents during the collision.
- Make sure that all parts of the carts are properly secured and stabilized before conducting the collision test. Follow manufacturer guidelines for setup and operation.
- Immediately clean up anything that falls on the floor, so it does not become a slip or fall hazard.
- Maintain a safe distance from the collision area during the activity to avoid injury from flying debris or malfunctioning equipment.
- Following the activity, inspect all equipment for any damage or wear and tear. Repair or replace any damaged components before further use.
- Wash hands with soap and water once all equipment is put in appropriate storage areas.

Brake Setup for All Carts

You need to construct a brake for all carts. See the last image in the table for the resulting assembly.

Materials for **each** cart brake:

- 1 metal cart with large wheels
- 1 piece of ½" thick pink insulation foam cut into pieces:
 - 1 piece 4" x 3 ½"
 - 1 piece 1 13/16" x 1 ¼"
- 1 metal hinge, 1.33" x 1.5"
- 1 hex head screw bolt, 1/4"-20 x 4"
- 1 fender/braking washer, 1/4" x 2"
- hot glue
- graphite lubricant
- additional fender/braking washers to adjust braking force



Hot glue the hinge to the larger foam piece at the center of a 4" side, and to the smaller foam piece at the center of a 1 13/16" side. Make sure the glue does not touch the pivot of the hinge, or it will not function. Make sure the hinge freely rotates.





Place the assembled brake on the cart with the larger foam piece centered on the wheel at the end of the cart, extending past the wheel.

Hot glue the smaller foam piece snugly between the rails on the top of the cart. Make sure the hinge still freely rotates and the larger foam piece rests on both wheels.



Add graphite lubricant where the bearing of each wheel meets the axle.

Variable Force Cart Setup

Build the following setup for each group that will investigate braking force as their independent variable. See the last image in the table for the resulting assembly.

Materials for **each** force cart:

- 1 metal cart with brake installed
- ½" thick pink insulation foam cut into pieces:
 - 2 pieces 1 13/16" x 4 ½"
 - 1 piece 1 13/16" x 5 ½"
 - 1 pieces 1 13/16" x 1 7/16"
 - 1 piece 1 13/16" x 2 ¼"
- 1 hex head screw bolt, 1/4"-20 x 4"
- 1 small (24-oz) deli container
- 1 piece of string, approximately 3" long
- 1" wide duct tape, approximately 10" long
- hot glue
- graphite lubricant







Add graphite lubricant where the bearing of each wheel meets the axle.

Assemble the mass platform:

Hot glue 1 of the 1 13/16" x 4 ½" foam pieces to the foam that has the brake hinge on it; the second 1 13/16" x 4 ½" foam piece as the upper platform as shown; and the 113/16" x 5 ½" foam piece vertically across those 3 foam pieces for structural support.

Hot glue the bolt to the platform, above the brake bolt. Make sure the brake still has room to raise and lower and for washers to be added to/removed from its bolt.

Further secure the platform by attaching the duct tape from one side of the support, under the cart, to the other side.



Assemble the mass holder:

Hot glue the 113/16" x 17/16" foam piece to the bottom of the container.

Hot glue that foam piece to the cart in front of the support structure. The foam should fit snugly between the rails on the top of the cart.

Hot glue the side of the container to the side of the platform. Further secure the container to cart, if desired, with another piece of tape.



Assemble the pull point:

Hot glue the string to each side of the 113/16" x 2 ¼" foam piece.

Hot glue that foam piece vertically at the front of the cart (the end without the brake). The foam should fit snugly between the rails on the top of the cart.

This is what the assembled cart will look like when mass (gravel or sand) and washers are added.



Variable Mass/Initial Speed Cart Setup

Build the following setup for each group that will investigate either mass or initial speed as their independent variable. See the last image in the table for the resulting assembly.

 Materials for each mass cart and each speed cart: 1 metal cart with brake installed 1 piece of ½" thick pink insulation foam cut into 3 pieces, each 113/16" x 3" 1 large (68-oz) deli container 1 piece of 1" duct tape, about 4" long 2 pieces of ½" duct tape, each about 2" long hot glue graphite lubricant 	
Add graphite lubricant where the bearing of each wheel meets the axle.	
Hot glue 2 of the foam pieces together and then to the bottom of the container.	

Attach the 1" duct tape across the top of the small foam piece with the braking hinge attached and down the sides of the cart. This further secures the brake.

Hot glue the foam that is attached to the container to the cart, in front of the brake. The foam should fit snugly between the rails on the top of the cart. Make sure the brake still has space to move.



Hot glue the third foam piece in 2 places to secure it to the front of the container and to the top of the cart. This gives the container more stability.

Attach a piece of ½" duct tape to each side of that foam piece and the cart. This reinforces the connection.



This is what the assembled cart will look like when fender/braking washers are added. Gravel or sand will be added to the container to change the mass.

