LAB 18. FORCE AND MOTION

Background

From before we learn to walk, we all acquire a great deal of personal experience with objects in motion. We know that motion involves distance—how far something moves—and time—how long it takes to get there. In this lab, we will investigate how motion is affected by pushes and pulls.

Supplies

String mass, tennis ball, baking tray, large ball, striking stick, 2 rails, 2 rail carts with strings attached, 4 auxiliary mass bars, 2 pulleys, 2 mass hangers, disk masses

Activity 1: Mass on a String

Suspend the bob from your hand by holding the free end of the string. Accelerate your hand gradually and steadily in one horizontal direction. (Again, be mindful of the difference between acceleration and constant velocity!) Observe the motion of the bob with respect to your accelerating hand and with respect to the unmoving ground.

1. Sketch the string and bob during their acceleration.

2. What forces act on the bob when it is accelerating?

Activity 2: Ball on a Tray

Rest a tennis ball on a baking tray.

1. Predict: what will the tennis ball do if you give the tray a slow horizontal push?

2. Predict: what will the tennis ball do if you give the tray a sudden horizontal push?

3. Now, check your predictions. Push the tray slowly and gradually. Do this several times until you have a good idea of how the ball responds to moving the tray. Have everyone in your group do this. What does the ball do?

4. Repeat, this time pushing the tray more suddenly and quickly. Does the ball stay with the tray? Or does it stay with the table? Does the ball move? If it moves, in which direction does it move?

5. Move the tray and ball together so that the ball moves along with the tray, that is, the ball does not change its position on the tray. Quickly stop the tray. What does the ball do?

Activity 3: Stickball

Put a ball on an open area of the floor. Move it around by tapping it on the side with a stick. (Hands tend to catch and stick to the ball; it's easier to give a pure push with a stick.) Don't push on the top of the ball—just on the side!

1. While the ball is rolling, try to push it with the stick to change its **speed** (make it faster and slower), but not the **direction** it is moving. Take turns until everyone in the group can do this easily. What do you need to do?

2. Predict: If the ball is moving in one direction (→), how will it move if you tap it with the stick in a direction *perpendicular* to the direction that it is moving (↑ or ↓)?

3. Check your prediction. As the ball rolls, tap the ball in a perpendicular direction with the stick. How does it move? Sketch it, showing the directions of the initial motion, the tap, and the final motion.

Activity 4: Rail cart drag races

In this activity, you will apply a pulling force to a cart using a weight on a string. A pulley transforms the vertical force of the weight to a horizontal pull on the cart. You will determine how changing the force of the pull on the cart or changing the mass of the cart affects the cart's motion.

Make sure that the two tracks are parallel, level, and side-by-side. Place a cart in the center of each track. Check that both tracks are level by giving the carts pushes in each direction. The carts should neither speed up nor stop quickly (some friction is unavoidable). Also check the carts: they should roll smoothly, with no grinding sounds.

One of the carts ("cart 1") is pulled by a string tied directly to a 15-g weight. This weight should not be changed. The other cart ("cart 2") is pulled by a string that can be loaded with different weights. The beds of the carts can also be loaded with metal bars. The two carts have about the same mass, and each metal bar has about the same mass as a cart.

Qualitative

Begin with 15-g weights pulling both carts. Have someone ready to catch each cart when it reaches the end of the track. Pull both carts to the backs of their tracks and run the strings over the pulleys. Release both carts at the same time.

1. How does the motion of the two carts compare? Does one cart reach the end of its track before the other? If so, which cart, and by about how much?

2. Predict: What will happen if you increase the force pulling cart 2, but not cart 1?

3. Check your prediction. Add some weight to the string for cart 2. Release both carts together from the backs of their tracks again. Does one cart reach the end of its track before the other one? If so, which cart, and by about how much?

4. Predict: What will happen if one cart is more massive than the other, but both carts have the same force pulling them?

5. Check your prediction. Make the pulling weights for both carts 15 g again. Load a metal bar onto the bed of cart 2. Run the drag race again as before. How does the motion of the two carts compare this time? Does one cart reach the end of its track before the other one? If so, which cart, and by about how much?

Quantitative

This time, you will vary the mass of cart 2 by loading it with metal bars. Instead of simply seeing how fast it moves compared to cart 1, you will adjust the weights on the string to make cart 2 move exactly as fast as cart 1.

Begin with the weights pulling both carts at 15 g. Run the drag race to confirm that they finish close to each other. If they do not, check the masses, the tracks, the pulleys, and the wheels of the carts.

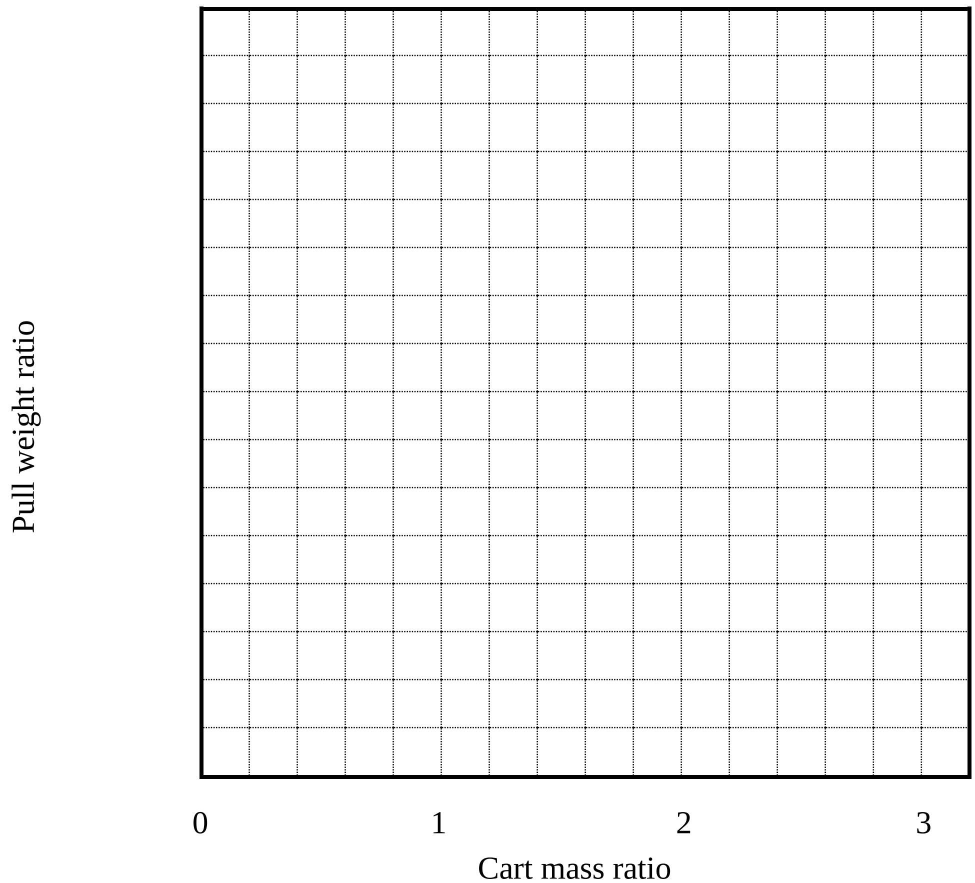
1. Load a metal block onto cart 2. Adjust the weight hanging from its hook so that when you run the drag race, both carts finish close to each other. Record the weight used in the table below.

2. Now load two metal blocks onto cart 2. Again, adjust the weight pulling cart 2 to make it run the drag race as fast as cart 1. Record the weights in the table below.

Weight pulling cart 1's string: __________ g

blocks on cart 2	**mass ratio (cart 2)/(cart 1)**	**weight on 2's string**	**Pull weight ratio (cart 2)/(cart 1)**
0	1		
1	2		
2	3		

3. Graph your data in the grid below.



4. Draw a straight line through the data points on your graph and project it back to the *y*-axis (vertical). Does the straight line fit the three data points reasonably well?

5. If your line fits the data, where does it cross the *y*-axis? (This is the projected force required to accelerate cart 2 as quickly as cart 1 when cart 2 has zero mass.)

6. What is the slope of the line? To find the slope, pick two convenient points on the line (not necessarily data points) where you can easily read the *x*- (horizontal) and *y*- (vertical) values. We'll call these points point 1 = (x_1, y_1) and point 2 = (x_2, y_2). The *rise* of the line between point 1 and point 2 is $rise = y_2 - y_1$, (the vertical distance between the two points) and the *run* of the line between these points is $run = x_2 - x_1$ (the horizontal distance between the two points). The slope is $slope = rise/run$.

- *rise* =
- *run* =
- *slope* =

7. If the weight pulling cart 1 were 50 g, and you otherwise ran the experiment as above, do you suppose the plot would be linear? If not, why not? If so, what do you suppose the slope of the plot would be?

8. If the masses of the carts and blocks were greater, but still the same as each other, what do you suppose the slope of the plot would be?

9. What is the physical significance of the linearity of the force ratio-mass ratio plot?

10. What is the physical meaning of the slope of the plot?

11. What does the slope's value tell us about the physical principles involved?

Getting Credit

Show this completed worksheet to your instructor for check-off.