

PHY 1033C - Lab 6

Mass and Force

Newton's 2nd law, $F = ma$, is likely the most well known physics equation in the world. In today's lab, we will take measurements to show that the acceleration of an object is directly proportional to the net force applied on the object. We will also see that the proportionality factor between F and a is the mass, m , of the object in question.

The apparatus in today's lab will use a ticker-tape timer to measure both time and distance. It uses the 60 Hz AC voltage signal from the power outlet to oscillate a lever at the same frequency. On the end of the lever is a point that, when fully setup, strikes carbon paper onto the ticker-tape to make a mark at even time intervals. Since the frequency is 60 Hz, recall that the period is then

$$T = \frac{1}{f} = \frac{1}{60/\text{s}} = 0.016666\dots\text{s}$$

Hence, the time interval between successive marks is 16.67 milliseconds. Since we can also measure the distance between the marks on the ticker-tape using a ruler or meter stick, we can collect data on objects moving under the action of any kind of force, in particular a constant force provided by a falling object. Since there will be 60 data points per second and the total time will likely be multiple seconds, you will use every 10th data point; so, if the run takes 2 seconds and has 120 data points, you will use points 10 20 30 40 ... 110 120 for a total of 12 pieces of data, each spaced one sixth of a second apart.

1. Start by familiarizing yourself with the cart and track setup. Roll the cart back and forth on the track and make sure it is approximately level by checking if the cart rolls to a stop in the same amount of time for both directions.

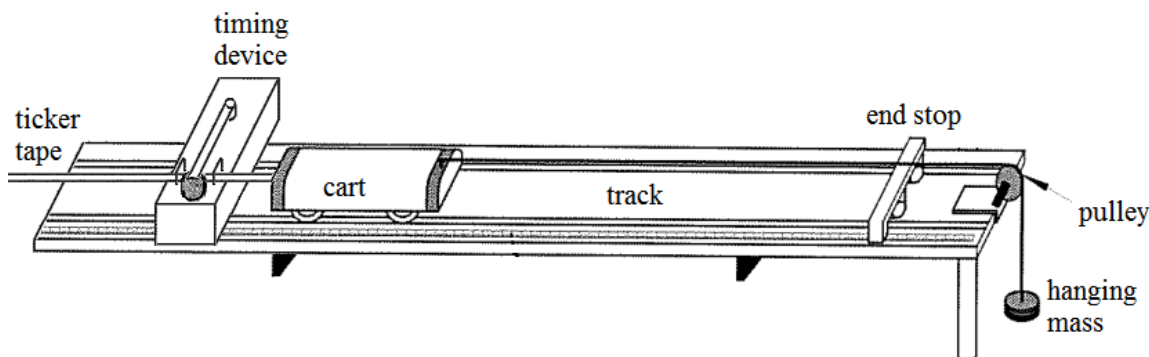


Figure 1: Experimental cart and track setup showing ticker tape timer on the left and cart connected by a string to the hanging mass on the right.

2. Once you are ready to take data, set up your cart as shown in Figure 1, with the heavy bar mass on top of the cart. Tape a piece of ticker tap that is about as long as the track is to the back of the cart and feed it through the metal loops on the timing device. Using the thumb tack, attach a piece of carbon paper to the timer so that the lever needle will strike it into the ticker tape and leave a mark.
3. With one person holding the timing device in place at the far end of the track, and another person holding the cart steady right next to it, loop the string with the mass around the screw at the front of the cart.

4. Turn on the timing device and release the cart. **Stop the cart and turn off the timing device just before the cart reaches the end of the track or the hanging mass hits the floor, whichever happens first.**
5. Your ticker tape should now have many marks on it and they should become progressively further apart. Remember, only use every tenth data point (using all of them would be more accurate but would simply take too much time). Make a table of this data with time for one column and total distance for the other, similar to last week. In this lab however, you need to add an extra column for time squared.
6. Make a plot for distance vs time squared and draw an approximate best fit line on it. Calculate the slope of your best fit line by picking two points on the line (not necessarily data points) and computing rise over run (change in position over change in time squared). From that you can get the acceleration by

$$a = 2 \cdot \text{slope}$$

Record this acceleration in your lab notebook.

7. You're ready to compute the force that was pulling on the cart. Look at the weight on the end of the string, its mass is stamped onto it, and record its mass in your lab notebook with variable name m_h , equal to their sum if you have multiple weights. Because of the fact that the cart and hanging mass must accelerate at the same rate since they are tied together, the force pulling on the cart is not exactly equal to the weight of the hanging mass. The actual force on the cart can be calculated with

$$F = \frac{m_c m_h g}{m_c + m_h}$$

As you can see, we also need to know the cart's total mass, m_c , and the standard gravitational acceleration, $g = 9.81 \text{ m/s}^2$ (we'll be measuring this in a future lab).

8. Weigh the cart and bar using the scale at the front of the classroom and record them in your lab notebook under variable name m_c equal to their sum.
9. Compute and record the above force in your lab notebook. Now you are ready to check Newton's second law, $F = ma$. Since you have the force pulling on the cart, F , and the acceleration of the cart, a , you can compute the mass of the cart by

$$m = \frac{F}{a}$$

Record this mass in your lab notebook.

10. Since you've already measured the cart's total mass, compute the percent error between the calculated mass and the measured mass of the cart and bars and give some plausible reasons for this error.
11. Recall that Aristotle believed force was proportional to velocity and not acceleration. What would have been some potential difficulties in establishing $F = ma$ in Aristotle's time?