

Lab 4: Newton's 2nd Law

Materials:

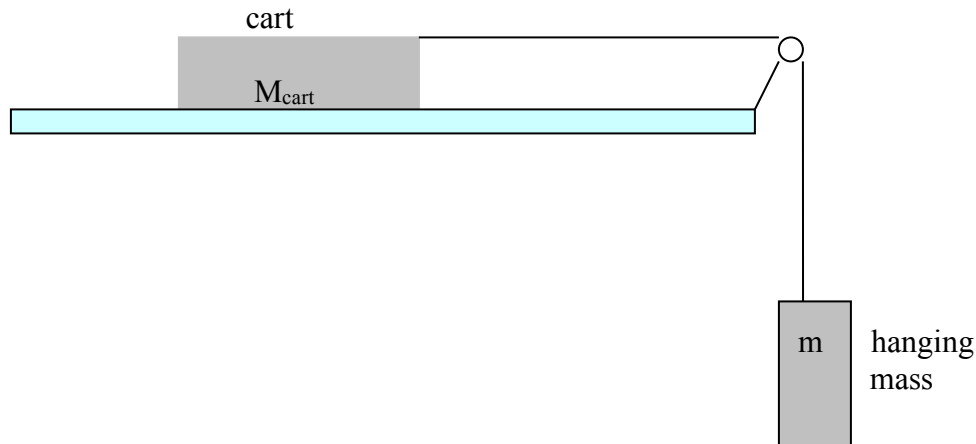
Tracks
Carts (Dynamic or Collision) with String attached
Weight set
Levels
Cart Weight Sets
Pulleys
Balance
Motion Detector
Foam Board
Capstone
850 Interface



Lab 4: Newton's 2nd Law

Part 1: Computing the Acceleration of the System

You will use Newton's 2nd Law ($\Sigma F = ma$) to calculate the acceleration of two masses which are attached to each other by a string over a pulley. You will use a motion detector to measure the acceleration. You will also investigate the frictional force.



- 1) Measure the mass of your cart and the two black rectangular masses, in kg.

A. $M_{\text{cart}} = \underline{0.5031 \text{ kg}}$

B. $m_{\text{bar1}} = \underline{0.4929 \text{ kg}}$

C. $m_{\text{bar2}} = \underline{0.4975 \text{ kg}}$

- 2) Place both 500g masses on the front of the cart.

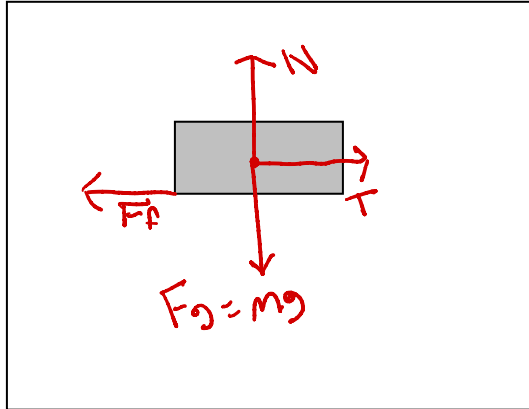
Total mass cart + rectangular masses $M = \underline{1.4935 \text{ kg}}$

- 3) You will start with a 50g hanging mass.

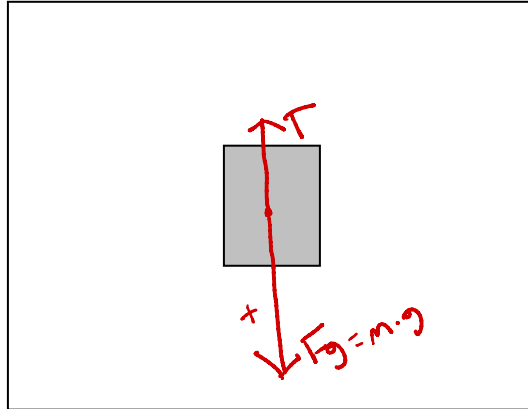
$m_{\text{hanging}} = \underline{0.050 \text{ kg}}$

- 4) Draw a force diagram for the cart and the mass in the boxes below. Label the positive x and y directions for each diagram. **Let down be positive for the hanging mass.** Include friction on the cart.

Cart, M_{cart}



hanging mass, m_{hanging}



- 5) Use Newton's 2nd Law to write two equations for the cart, one for the x direction and one for the y direction. Use M for the total mass of the cart plus the two weights. Leave the frictional force as f_k and the acceleration as a .

$$\sum F_y = Ma_y \quad F_u - F_g = 0$$

$$\sum F_x = Ma_x = F_T - F_f = Ma$$

- 6) Use Newton's second law to write an equation for the hanging mass, (m_{hanging}).

$$F = ma \quad F_g - F_T = ma$$

- 7) Solve the equations simultaneously to get an equation for acceleration.

$$F_g - F_f = (M+m)a$$

$$a = \frac{F_g - F_f}{(M+m)}$$

- 8) Assume there is no friction ($f=0$) and compute the acceleration of the cart, a_{cart} .

$$a = \frac{mg}{(M+m)} \quad a = \frac{(0.050)(9.80)}{1.4935 + 0.050} = 0.32 \text{ m/s}^2$$

Part 2: Measuring the acceleration

The cart must be located at least 20 cm from the motion detector

1. Level your track.
2. Set the sample rate for the motion detector to 10 Hz.
3. Set up Capstone to make a graph of velocity vs. time.
4. Make sure the hanging mass goes over the pulley.
5. Make a graph of the cart's velocity from rest.

The acceleration = slope of v vs. *time*. Highlight the straight part of the graph and make a linear fit to the data. Take three measurements of acceleration and take an average. Don't worry about the sign of the slope. Find the standard deviation of the three acceleration measurements.

- 1) $a_1 = 0.24 \text{ m/s}^2$
- 2) $a_2 = 0.25 \text{ m/s}^2$
- 3) $a_3 = 0.27 \text{ m/s}^2$
- 4) $a_{\text{avg.}} = 0.24 \text{ m/s}^2$
- 5) standard deviation = 0.010

Find the % error between this average measured acceleration and the calculated acceleration.

- 6) % error = 25% $\frac{|0.24 - 0.32|}{0.32} = 0.25$

- 7) Does the predicted value of the acceleration fall within one standard deviation of the average acceleration you measured?
- 8) What do you think caused most of the difference in your measured and calculated values?

We believe that friction caused the most difference in our values.

Part 3: Calculating the frictional force

Your measured acceleration should have been less than your calculated acceleration. The main cause of this is the force of friction between the cart and the track. We will use your measured accelerations to calculate the force of friction.

Using the measured average acceleration from part 2, find the force of friction acting on the cart. (Use the equation you found before you set $f=0$).

$$-(M+m)a + mg = F_f = -(1.4935 + 0.050)(0.24) + (0.050)(9.8)$$

Part 4: Computing the Acceleration taking friction into account = 0.12 N

Using the frictional force with two masses that you calculated above, calculate the acceleration if you use 100g as the hanging mass.

1) $m_{\text{hanging}} = 0.100 \text{ kg}$

$$a = \frac{F_g - F_f}{(M+m)}$$

2) $a = 0.540 \text{ m/s}^2$

$$a = \frac{(0.100)(9.8) - 0.12}{(1.4935 + 0.100)} =$$

Adjust the sample rate for the motion detector to 25 Hz. Use Capstone to measure the acceleration with 100g added as the hanging mass.

3) $a_1 = 0.57 \text{ m/s}^2$

4) $a_2 = 0.54 \text{ m/s}^2$

5) $a_3 = 0.55 \text{ m/s}^2$

6) $a_{\text{avg}} = 0.55 \text{ m/s}^2$

7) Standard deviation = 0.015

$$\frac{0.540 - 0.55}{0.54} =$$

8) %error = 1.9%

9) Is this percent error better than when you ignored friction?

Yes

10) Does the predicted value of the acceleration fall within one standard deviation of the average acceleration you measured?

Yes