

Hanging Mass Lab

Introduction

According to Newton's second law, an object will accelerate in the direction of the net force. If ΣF is the magnitude of the net force, and if m is the mass of the object, then the acceleration is given by

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

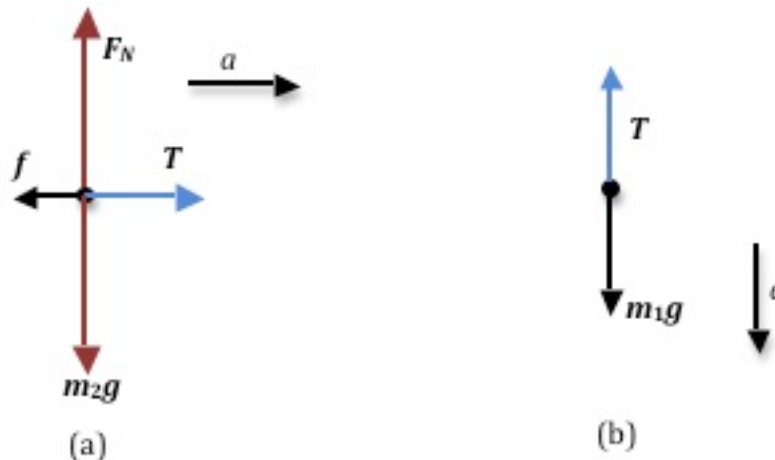
Consider a cart on a low-friction track, as shown below.



A light string is attached to the cart and passes over a pulley at the end of the track, where a second mass is attached to the other end of the string. The weight of the hanging mass provides tension in the string, which will cause the cart to accelerate along the track. A small frictional force will resist this motion.

We assume that the string has no mass, and that there is no friction between the string and the pulley. Therefore, the tension in the string will be the same at all points along the string. This results in both masses having the same magnitude of acceleration (though the directions are different). The cart will accelerate to the right, while the hanging mass will accelerate down.

To simplify the situation, we will consider the positive direction to be clockwise. Thus, both objects will accelerate in the positive direction. The free body diagrams for the two masses are shown below.



For this system of masses, the net force will be equal to the gravitational force on the hanging mass ($F_g = m_1g$) subtract the friction on the cart (F_f).

$$\sum F = m_1g - F_f$$

Since the net force is equal to the system mass ($m_1 + m_2$) times the acceleration, this can be written as

$$(m_1 + m_2)a = m_1g - F_f$$

This can then be rearranged to have the form of a linear equation ($y = mx + b$).

$$m_1g = (m_1 + m_2)a + F_f$$

Note that the slope is the system mass, and the y-intercept is the force of friction.

Objective

The objective of this experiment is to verify the validity of Newton's second law.

Equipment

- low-friction track with pulley
- cart
- string
- 2 photogates
- mass hanger
- assorted masses
- computer
- signal interface
- PASCO capstone software
- Logger Pro software

Procedure

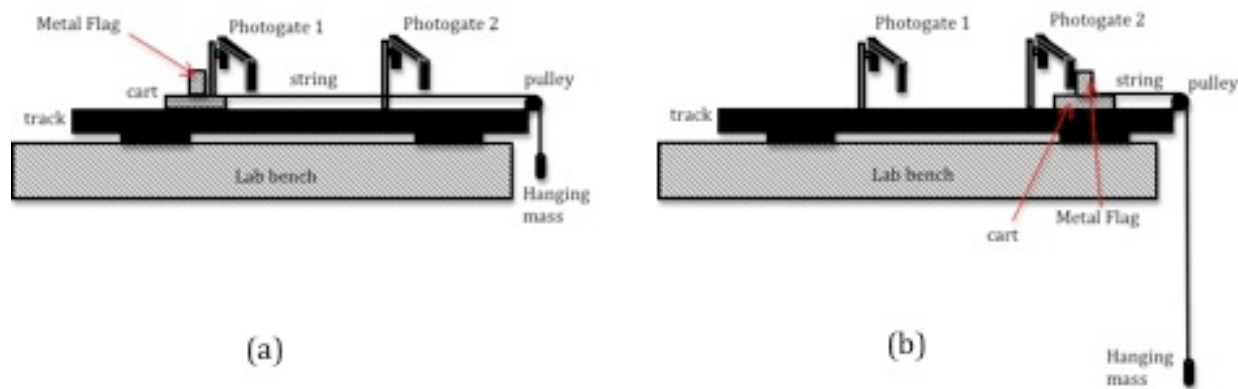
You will conduct several trials, keeping the system mass ($m_1 + m_2$) constant while varying both m_1 and m_2 (by transferring masses from the cart to the hanger). By graphing m_1g versus a , you will be able to determine the system mass from the equation above.

The cart has an attached "flag" that will cause two photogates placed a fixed distance apart to react as the cart passes through them. A computer connected to the photogate will measure and display the speed in each photogate, as well as the time taken to travel from gate to gate. The acceleration between the gates can then be calculated using

$$a = \frac{v_2 - v_1}{\Delta t}$$

Setting up the Equipment

1. Using the adjusting screws underneath, level the track so that the cart does not move when placed in the center of the track.
2. Place the photogates sufficiently far apart. Make sure the flag is before the first gate when the hanger is all the way up near the pulley (see (a) below). Make sure the flag is past the second photogate before the hanger hits the ground (see (b) below).



3. Adjust the height of each photogate so that the black flag blocks the photogate beam as it passes.
4. Connect photogate 1 to digital channel 1 and photogate 2 to digital channel 2. If the photogates are plugged in properly, the red LED on the photogate will light up when the infrared beam is blocked.
5. Launch PASCO Capstone and set up as instructed by your teacher.
6. Measure the length of the black flag on your cart and input it into Capstone. Record it on your worksheet.
7. Measure the spacing of your photogates and input it into Capstone. Make sure to click save.

Data Acquisition

1. Place the cart at the end of the track away from the pulley. Place three 20-gram masses on the cart.
2. Determine the mass of the hanger and record it on your worksheet.
3. Connect one end of the string to the hanger and the other end to the cart, placing the string over the pulley.
4. Hold the cart in position so that the cart will accelerate when released.

5. When ready to record data, click the Preview button.
6. Release the cart and catch it when it reaches the end of the track.
7. Click the Keep button to record the trial. The time and speed data will be automatically recorded in the table.
8. Move the cart back to the beginning (without passing through the photogates).
9. Transfer one 20-gram mass from the cart to the hanger.
10. Repeat steps 4 to 9 three times, until you have a total of 4 trials with a different value of the hanging mass for each trial.

Analyzing the Results

1. Calculate the acceleration for each trial using the equation below.

$$a = \frac{v_2 - v_1}{\Delta t}$$

2. Calculate the gravitational force acting on the hanging mass for each trial.

$$F_g = m_1 g$$

3. Using Logger Pro, graph F_g versus a . (Gravity on the vertical, acceleration on the horizontal.)
4. Use Logger Pro to draw a line of best fit to the data.
5. Record the slope and y-intercept on your worksheet.
6. From the slope, determine the system mass.
7. Use a digital balance to measure the mass of the cart. Add this to the mass of the hanger and the added masses to determine the system mass.
8. Compare your measured mass (M) to the mass determined from the slope (E) by calculating the percent difference (see below). Record this on your worksheet.

$$\% \text{ difference} = \frac{|M - E|}{M} \times 100\%$$