Newton's Second law

Purpose

1. Study Newton's second law and apply it to a cart on a horizontal frictionless track.

2. Verify Newton's second law graphically.

Introduction

Force is an influence of one object on another. It is a vector, because it has direction as well as magnitude. The magnitude represents its strength. If an object is under the effect of one force or more than one force, the net force, which is the vector sum (meaning taking direction into account), is equal to the mass of the object multiplied by the acceleration of the object. This is Newton's second law of motion:

$$\boldsymbol{F}_{Net} = m\boldsymbol{a} \;\; eqn.(1)$$

Notice that both $\boldsymbol{F}$ and $\boldsymbol{a}$ are vectors (they have directions in addition to magnitudes). For a given mass the acceleration of the object is proportional to the net force applied to the object. Also for a given net force, the acceleration is inversely proportional to the mass of the object. So a large force applied to a large mass, can produce the same acceleration as a small force applied to a small mass. Newton's 2nd law has a vast range of application in motion of many objects in our everyday life as well as in motion of planets and other outer space objects.

Recall from experiment 3 that for motion with constant acceleration and If the object does not start from rest but **has an initial non-zero velocity** v_o, then the change in position Δx is given by:

$$\Delta x = v_o t + \frac{1}{2} a\, t^2 \quad (2)$$

Description of the experiment

An object on a horizontal frictionless track, attached to a vertical mass

1) Consider figure 1 for an object (cart) of mass M_C on a horizontal track, attached to a vertical mass m_h by a string over a light pulley. If there is no friction between the object M_C and the track, and the motion of M_C is towards the pulley, The net force on the cart is the tension of the string, pulling the cart towards the pulley. Applying Newton's 2nd law for the cart we have

$$T = M_C a \quad (3)$$

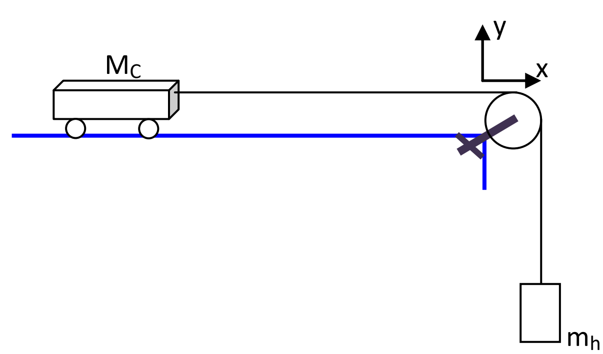

Figure 1: An object on a horizontal track and attached to a vertical mass.

We want to verify Newton's 2nd law by verifying equation 3. We will do that by plotting a graph of T versus a. If the slope is equal to M_C then we have accomplished the verification.

First let's derive an expression for the tension force, T.

Let's apply Newton's second law for the hanging mass m_h. The net force is $T - m_h g$. So

$$T - m_h g = m_h(-a) \quad (4)\,,$$

where the negative is because acceleration is in the negative y-direction.

If we use $a = \frac{T}{M_C}$ from eqn. 3 and solve for T using equation 4, we get

$$T = \frac{M_C m_h}{M_C + m_h}\, g \qquad (5)$$

2) Consider figure 1 and equation 2 mentioned in the introduction. If we know the change in position of the cart, Δx and if we know the time, t for that change in position to happen we can calculate the constant acceleration, a. But we do not know v_o, so if we can let the car start from rest then we know the value of $v_o = 0\ m/s$. Then using equation 2 we can calculate the acceleration $a = \frac{2\Delta x}{t^2} \qquad (6)$

Running the experiment

The data sheet is on page 3

1) Open the simulator https://www.walter-fendt.de/html5/phen/newtonlaw2_en.htm keep all default settings: coefficient of kinetic friction $\mu_K\ to\ 0$ (this means we are in the case where the track is frictionless), keep $M = 100\ g$, and $m = 1\ g$. The simulator will record the time for the cart to reach the photo-gate, and the position of the photo-gate from the starting point of the cart.

2) Start the simulator. When the simulation ends, record the values of the time to reach the photo-gate and the position of the photo-gate and also record the value of the acceleration as measured by the simulator. Calculate (show your work on the data sheet) the value of the acceleration using equation 6 in step 2 above. Compare your calculated value with the value measured by the simulator. Record the value in Table 1 in the data sheet. Click Reset, (you have to click reset in order to be able to change any of the settings values).

3) Increase the hanging mass, m_h in increments of $1g$, and up to 6 g. Each time repeat the previous step 2.

4) For each of masses of the hanging mass, m_h that you used $m_h = 1\ g$ and up to 6 g, calculate, using equation 5, the value of the tension force, T (show your work on the data sheet). Record in table.

5) Plot a graph of the tension force, T versus the acceleration, a. Compute the slope. How does the slope relate to the value of the mass of the cart, M_C? Does this verify Newton's 2nd law?

Data sheet

Name: **Group:** **Date experiment performed:**

Steps 2 to 4

Table

The mass of the cart $M_c = 100\ g = 0.1\ kg$

m_h (kg)	$t\ (s)$	$t^2\ (s^2)$	$\Delta x\ (m)$	$a\ measured$ by simulator $(\frac{m}{s^2})$	$a\ calculated$ using eqn. 6 $(\frac{m}{s^2})$	$T\ tension\ force\ (N)$
0.001						
0.002						
0.003						
0.004						
0.005						
0.006						

Calculations of acceleration, a using eqn. 6 (show your work):

Calculations of tension force, T (show your work):

Step 5

Slope of graph:

Compare to the value of M_c: