General Physics Lab 4

Newton's 2nd Law: F = ma

Objectives:

- To test the hypothesis that force is equal to the product of mass times acceleration (Newton's 2nd Law)

Equipment:

- None

Physical Principles:

Newton's 2nd Law of motion relates forces, masses and accelerations with this simple expression.

$$\vec{F} = m\vec{a} \qquad (1)$$

If there are two key directions (x-direction and y-direction), the vector expression of Eq. (1) becomes two separate equations.

$$F_x = ma_x \qquad (2a)$$

$$F_y = ma_y \qquad (2b)$$

Thus Newton's 2nd Law applies in each direction separately.

An object of mass, m, placed on a frictionless inclined plane experiences two forces. 1) Gravity pulls the object vertically downward with the weight, mg, and 2) the plane exerts a normal force, N, perpendicular (normal) to the surface of the plane (see Fig. 1a). It is convenient to tilt the x-y coordinate system such that the x-axis is aligned down the incline.

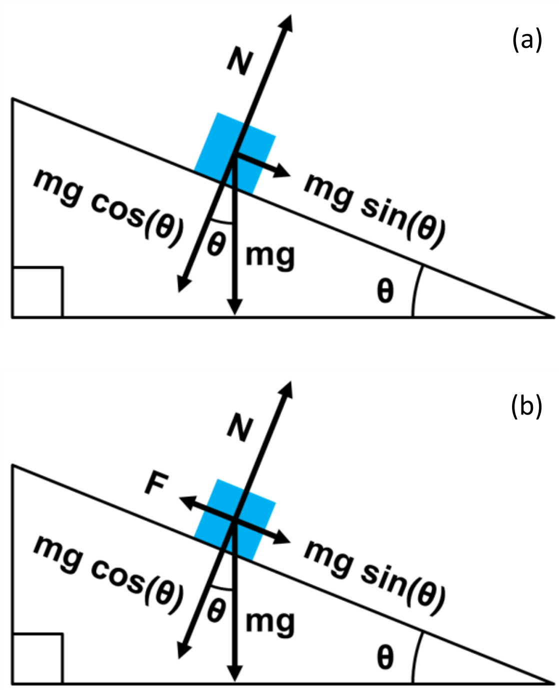

Fig. 1: Forces acting on an object placed on an inclined plane.
(a) Only gravity and the normal force.
(b) A third force, F acts up the incline to cancel gravity.

Gravity then has two components: the component of weight that pulls the object down the hill,

$$W_x = mgsin\theta \quad \text{(3a)}$$

and the component pressing down on the surface of the plane,

$$W_y = mgcos\theta \quad \text{(3b)}$$

where θ is the angle of the incline.

Newton's 2^{nd} Law applied in the x-direction (Eq. 2a) then becomes,

$$mgsin\theta = ma_x \quad \text{(4)}$$

or

$$a_x = gsin\theta \ . \quad \text{(5)}$$

This was the relationship explored in Lab 3.

Suppose a third force, F, such as friction (which opposes the motion) or the tension in a string, were exerted uphill to keep the object stationary (see Fig. 1b). In that case, we have Newton's 1^{st} Law with the sum of forces being zero.

$$F = mgsin\theta \quad \text{(6)}$$

In that case, F equals the component of gravity down the hill.

You may recognize that in Lab 3, you employed a spring balance to measure the force, F, that corresponds to the component of gravity acting down the hill.

In this lab, we will take the forces, F, and corresponding accelerations, a, measured in the previous lab, and plot F (y-axis) vs. a (x-axis) to show that the force is proportional to the acceleration and the constant of proportionality is the mass, m, as predicted by Newton's 2^{nd} Law.

Procedure:

No new setup or data collection is required since force and acceleration data were both collected in Lab 3. In your eJournal, you will want to briefly summarize how you previously collected the data and report the relevant data in an appropriately labeled table.

Please Note: In order to use your data from Lab 3, the data must be collected from a single car (constant mass). If you did not follow the instructions for Lab 3 but instead recorded data with multiple cars (different masses), this experiment will not work and you will need to collect new data with a single car.

Analysis:

Use Google Sheets, Excel, or Graphical Analysis to plot a graph of the component of gravity acting down the hill, F, (y-axis) vs. acceleration, a (x-axis). Do not use the point (0,0) in your graph.

Apply a linear fit to the data and record the slope and correlation coefficient, R. As suggested by Eq. 2a, the slope should be equal to the mass of the penny-loaded Hot Wheels car. Compare the slope and mass.

Note that any friction in the car's wheel bearings will be very small and roughly constant for each run. In this experiment the friction should be negligible (you can ignore it), but if it was greater (think of car brakes), you would see it as a y-intercept on the F vs. a graph.