Newton's Laws

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Introduction

From the time of Vincenzo Galilei in the 16th Century, the inclined ramp has been utilized to better understand the relationship between the tension in a string and the ramp's inclination. Although Vincenzo Galilei and his more famous son, Galileo Galilei reputedly did many experiments with inclined ramps, to properly appreciate the forces at work, we must turn to Newton.

Newton's Second Law may be stated as:

The net force on an object is equal to its mass times its acceleration.

When the motion is at constant velocity (no acceleration), the net force is therefore zero.

In the first part of the lab, we will use the second law to determine the coefficient of kinetic friction of a sliding block. An analysis of the diagram at right shows that the kinetic frictional force, f, is equal to mg *when the mass, m, descends with constant velocity.*

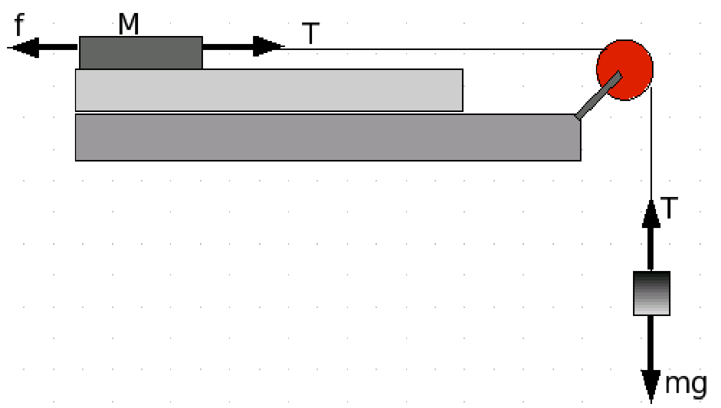

Illustration 1: Setup to find coefficient of kinetic friction

1) $f = mg$

Because the frictional force is proportional to the normal force on the block:

2) $f = \mu N = \mu Mg$

Thus, one can set equations 1) and 2) equal to determine the coefficient of kinetic friction.

3) $\mu = \frac{m}{M}$

In the second part of the lab, we will use this value of μ, to predict the mass needed to move the block at constant velocity up an inclined ramp. In this case, the force balance equation is:

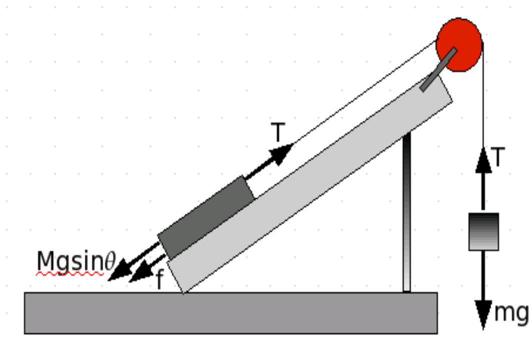

Illustration 2: Setup to test Newton's second law

4) $-Mgsin\theta-\mu Mg\cos\theta+mg=0$

Equation 4) can be solved to find the mass, m, that should be used to pull the block up the track.

Procedure

First, you will need to estimate the coefficient of kinetic friction. Using a track, a block (with attached string), pulley, and mass, set up the apparatus in Illustration 1. To measure the coefficient of kinetic friction the mass and block must be in motion with a constant velocity. Because of the difficulties in visually estimating whether the block moves with constant velocity, we will use the Pasco motion sensor with the computer to verify that there is no acceleration. Set up this sensor as indicated by your instructor.

After choosing a mass and attaching it to the string, nudge the block and note whether the acceleration is constant. Repeat until you find a mass for which the acceleration is constant. Estimate the uncertainty in the mass needed to balance the forces on the system. Then calculate the coefficient of friction and the corresponding uncertainty.

Once you have this value (μ), set up the track using the mounting brackets provided. For the angle of inclination you choose, estimate the amount of mass you need to add to satisfy equation 4). Also estimate the uncertainty in this mass. Then select the mass that is most nearly your estimated value. Attach it to the string-pulley system and then nudge the block up the track. If the block does not move with constant velocity, re-evaluate and try a new mass. Repeat until you find the experimental mass that pulls the block with a constant velocity up the track.

Analysis

Discuss how this experiment validates Newton's 2nd Law. Is the coefficient of friction found in the first part of the lab valid in the second part? Why or why not? If not, what is the coefficient of friction under the conditions shown in Illustration 2? What sources of uncertainty were there in each part of the lab? How did they affect your results? Was the predicted mass for the second part of your lab equal to your expected mass within your predicted uncertainty? Include a derivation of equation 4) as an appendix.

Propagation of Error

To calculate uncertainty in calculated mass, m, in part 2, use the following (long) equation:

5) $$\Delta m=m\sqrt{\left(\frac{\Delta M}{M}\right)^2+\left(\frac{\Delta\mu M\cos\theta}{m}\right)^2+\left(\frac{\Delta\theta(\cos\theta-\mu\sin\theta)}{\sin\theta-\mu\cos\theta}\right)^2}$$