Physics Lab Experiments with Simulated Data for Remote Delivery

Department of Chemistry and Physics

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Experiment 1.04: Newton's 2nd Law

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I. EXPERIMENT 1.04: NEWTON'S 2ND LAW

A. Abstract

Two masses are connected by a light string over a pulley. One mass (M) sits on a frictionless, inclined surface. The other mass (m) hangs vertically. The theoretical predictions based on Newton's second law are compared to the experimental measurements.

B. Formulas

$$\sum \vec{F} = m\vec{a} \tag{1}$$

$$a = \frac{m - M\sin\theta}{m + M} g \tag{2}$$

where the second formula applies to the acceleration of two masses connected by a light string over a massless, frictionless pulley, one (M) sits on an inclined, frictionless plane (inclination angle θ) and the other (m) hangs vertically (see Fig. 1 below).

C. Description and Background

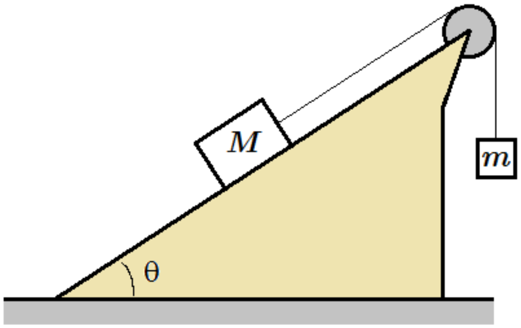

FIG. 1. Idealized depiction of the experiment.

This experiment is realized using an air-track which is designed to reduce sliding friction on a glider. The glider is attached to one end of a light string that runs over a pulley; the other end of the string is attached to a hanging mass. The glider is released from rest and ascends as the hanging mass falls.

To calculate the theoretical acceleration using Eq. (2), the masses and inclination angle are required. The masses are determined using an eletronic scale. Once the height, h, of the prop used to incline the air track is measured, as well as the distance between the track's legs, the angle of inclination can be calculated.

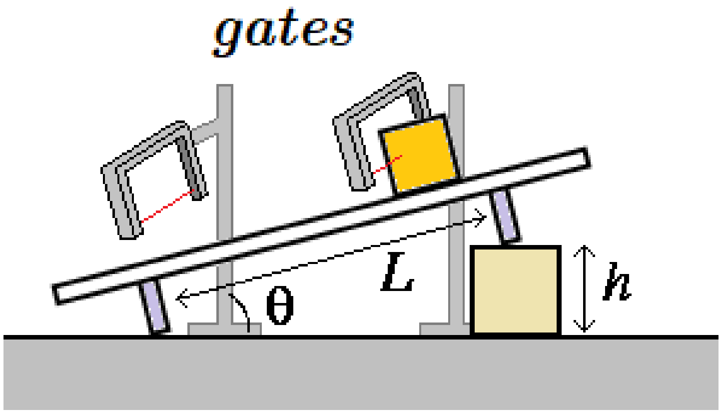

FIG. 2. Schematic depiction of the air track set-up.

The experimental determination of the acceleration is based on the speed of the glider at two locations along the incline and the time interval between these events. Two photogates are postitioned along the air track (see Fig. 2). They will provide three time interevals: The glider time through the first gate, t_A, the glider time through the second gate, t_B, and the glider time in getting from one gate to the other, t_{AB}. The glider has an attached "flag" or

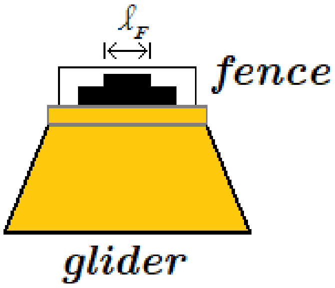

FIG. 3. Glider with flag/fence.

"fence" which is just an opaque strip of known length, ℓ_F (see Fig. 3). The (average) speeds can be calculated as follows

$$v_{A,B} = \frac{\ell_F}{t_{A,B}} \tag{3}$$

The experimental acceleration is then

$$a_{\text{exp}} = \frac{v_B - v_A}{t_{AB} + (t_B - t_A)/2} \tag{4}$$

where the $(t_B - t_A)/2$ term corrects for the fact that $v_{A,B}$ are average speeds and not the speeds at the gate thresholds.

Although the air track does a decent job of reducing slidding friction, some kinetic friction survives and affects the acceleration of the glider. The string used is also not always light enough when compared to the mass of the hanging body. Consequently, the discrepancy between the theoretical acceleration and the experimental one is affected by this kinetic friction and the mass of the string. These two effects oppose each other however. Assuming a truly massless string, if kinetic friction were included in the analysis of the sliding body on the incline, the following equation for a would result

$$a = \frac{m - M(\sin\theta + \mu_k \cos\theta)}{m + M} g \tag{5}$$

By inserting the value of the experimentally determined acceleration (which would tend to be less than theoretically expected), a value for the effective kinetic-frictional coefficient could be calculated

$$\mu_k = \frac{1}{M}\left[m - (m + M)\frac{\bar{a}_{\text{exp}}}{g}\right]\sec\theta - \tan\theta \tag{6}$$

D. Procedure

1. Position the two photogates at two locations, A and B, along the air track.
2. Make sure the photogates are positioned properly so the fence on the glider blocks the gates' light beams.
3. After releasing the glider, it will pass through the gates, and it will bounce off the end of the track, so make sure it does not run through the second gate again.
4. Record the three time intervals (A, B, and AB) from the CPO timer. Repeat this procedure several times.

Nota Bene: The transparent parts of the fence attachement must be free of smudges or marks that could obstruct the photogate beams after the opaque strip has. An indication that this may have occurred is an anomalously short time reading for either t_A and/or t_B.

E. Measurements

glider mass, M [$gram$]	
hanging mass, m [$gram$]	
block height, h [cm]	
distance between legs, L [cm]	
fence length, ℓ_F [cm]	

Time Intervals			
Trial	t_A [sec]	t_B [sec]	t_{AB} [sec]
1			
2			
3			
4			
5			

F. Instructions

1. Calculate the average time intervals from the trials and the speeds, v_A and v_B.
2. Calculate the inclination angle from

$$\sin\theta = \frac{h}{L}$$

3. Calculate the speeds and the experimental acceleration of the glider using the results from the Measurements table and (4), then calculate the average from the trials and its standard error, $\delta\bar{a}_{\text{exp}}$.
4. Use Eq. (2) to calculate the theoretical acceleration, a_{theo}, on the incline.
5. Determine the percent difference between a_{theo} and a_{exp}.
6. If your results are such that $\bar{a}_{\text{exp}} < a_{\text{theo}}$ then use Eq. (6) to calculate an effective μ_k.

G. Calculations

trial	v_A [m/s]	v_B [m/s]	a_{exp} [m/s^2]
1			
2			
3			
4			
5			

θ [$degrees$]	
$\bar{a}_{\text{exp}}$ [m/s^2]	
$\delta\bar{a}_{\text{exp}}$ [m/s^2]	
a_{theo} [m/s^2]	
%-Diff $(\bar{a}_{\text{exp}}, a_{\text{theo}})$	
μ_k	