

Experiment 6

Newton's Second Law

A mass is allowed to fall vertically while pulling another mass over a horizontal surface. The motion of the system is investigated, and the application of Newton's Second Law to the system allows the determination of the acceleration of the system.

Theory

Newton's Second Law states that the resultant of the forces acting on a body to accelerate in the direction of the resultant force. This can be expressed mathematically as

$$\sum \vec{F} = m\vec{a}, \quad (1)$$

where m is the mass of the body and a is its acceleration. When expressed in terms of the force components,

$$\sum F_x = m a_x; \quad \sum F_y = m a_y, \quad (2)$$

where a_x and a_y represent the x and y components of the acceleration.

In this experiment, a body of mass m_1 falls vertically. One end of a string is attached to m_1 . The other end is attached to a body of mass m_2 which is pulled along the surface of the air track. (Refer to Figure 1.) The string passes over a pulley that is of very low mass and practically frictionless. Because of this, the effect of the pulley on the system can be neglected.

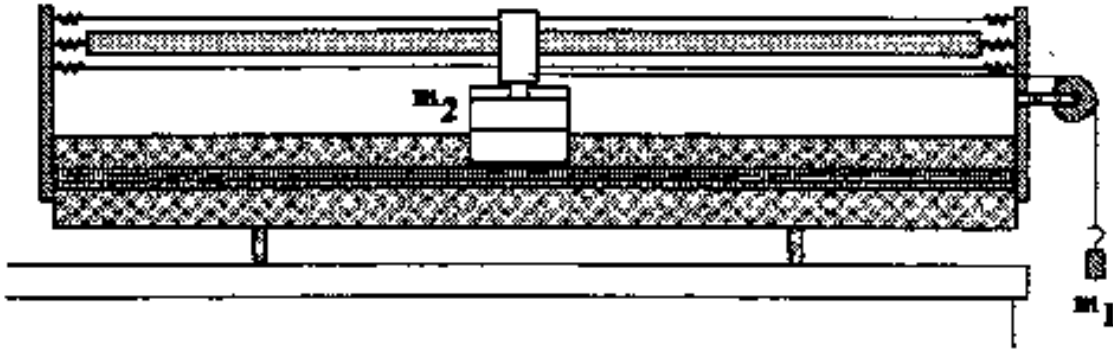


Figure 1. The air track with the first mass moving downward and pulling the second over the surface of the air track.

When Newton's Second Law is applied to the two bodies, the acceleration of the system is

$$a = \frac{m_1 g}{m_1 + m_2} . \quad (3)$$

Apparatus

- o air track with air supply and sparker
- o glider
- o meter stick
- o hanging masses
- o spark tape
- o masking tape
- o masses to be attached to glider

The air tracks have been leveled. Please do not move them.

Procedure

- 1) Use masking tape to attach a one meter length of spark tape to the pulley end of the yellow-colored mounting strip on the air track.

Group Number	m_1 (grams)	mass added to glider (grams)	Timing Interval (sec)
1	12	0	1/6
2	13	0	1/6
3	14	0	1/6
4	15	100	1/6
5	16	100	1/6
6	17	100	1/6
7	18	100	1/6
8	19	200	1/6
9	20	200	1/6
10	21	200	1/6

Figure 2. Mass values for the hanging mass and the mass to be added to the glider.

- 2) Attach the amount of mass corresponding to your group number to the glider. (Refer to

Figure 2.) Be sure to equally distribute the total mass to both sides of the glider. Record the mass of the glider and the total mass added to the glider. This mass is m_2 .

- 3) Carefully place the glider on the air track. Pass the string over the pulley and attach to the end of the string the amount of mass listed for your group number.
- 4) Turn on the air supply. (The air flow is adjusted high enough so that the glider floats above the surface of the track.) Set the spark timer to the proper frequency. Prevent the glider from moving by placing your finger on the air track in front of the glider.
- 5) Start the spark timer, then release the glider. Keep the spark timer engaged until the glider reaches the end of the air track.
- 6) Carefully remove the spark tape and affix it on a flat surface with making tape. Cross out the dot corresponding to the starting position. Circle the remaining dots and number the dots successively. Place the meter stick on the tape and record the position of each dot. A suggested form for the table for each set of data is shown in Figure 3.

data point	time, multiples of Δt	distance, s	change in distance, Δs	average velocity
1	0	s_1		
2	1.00	s_2	$s_3 - s_1$	$(s_3 - s_1) / 2\Delta t$
3	2.00	s_3	$s_4 - s_2$	$(s_4 - s_2) / 2\Delta t$
4	3.00	s_4	$s_5 - s_3$	$(s_5 - s_3) / 2\Delta t$
		(etc.)		

Figure 3. A suggested form for the data table.

Analysis

Draw free-body diagrams for the two masses, m_1 and m_2 . Apply Newton's Second Law and derive (3).

Complete the calculations of the average velocities for the data. First calculate the distance from one data point to the second data point away, Δs . Then find the average velocity by dividing Δs by the time taken to travel that distance, $2\Delta t$, which is twice the spark timing interval. Because the acceleration is constant, the average velocity is numerically equal to the instantaneous velocity at the point halfway in time between the data points.

Graph the values of instantaneous velocity versus time, with velocity as the ordinate and

time as the abscissa. Draw two lines that best fit the data: one with maximum slope, a_{\max} , and one with minimum slope, a_{\min} . Find the slopes of these lines. The best value for the acceleration of the system is then

$$a = \frac{1}{2}(a_{\max} + a_{\min}), \quad (4)$$

and the corresponding uncertainty in the acceleration is

$$\Delta a = \frac{1}{2}(a_{\max} - a_{\min}). \quad (5)$$

Calculate the best value for the acceleration, (4) and the uncertainty, (5).

On a one-dimensional graph, use points and error bars to plot $a \pm \Delta a$. Be sure to displace vertically the error bar from the axis so that it is clearly visible. Now calculate the theoretical value of the acceleration from (3) and plot it on the graph described above so that the point is displaced slightly above the error bar.

Report in a results table, $a \pm \Delta a$ and the theoretical value of a .

Conclusions

Indicate what the major sources of error are, and explain how the experimental values are affected by these sources of error. Explain whether or not the experimental value of the acceleration shows the effects of the sources of error.

Questions

- 1) If friction is present between the glider and the air track, then how will the experimental value of the acceleration be different from the theoretical value? Explain why. Do the results indicate the presence of friction? Explain.
- 2) If the mass of the pulley is not negligible, then how will the experimental value of the acceleration be different from the theoretical value? Explain why.
- 3) If the experimental value of the acceleration is greater than the theoretical value, then what is the most likely reason for this?