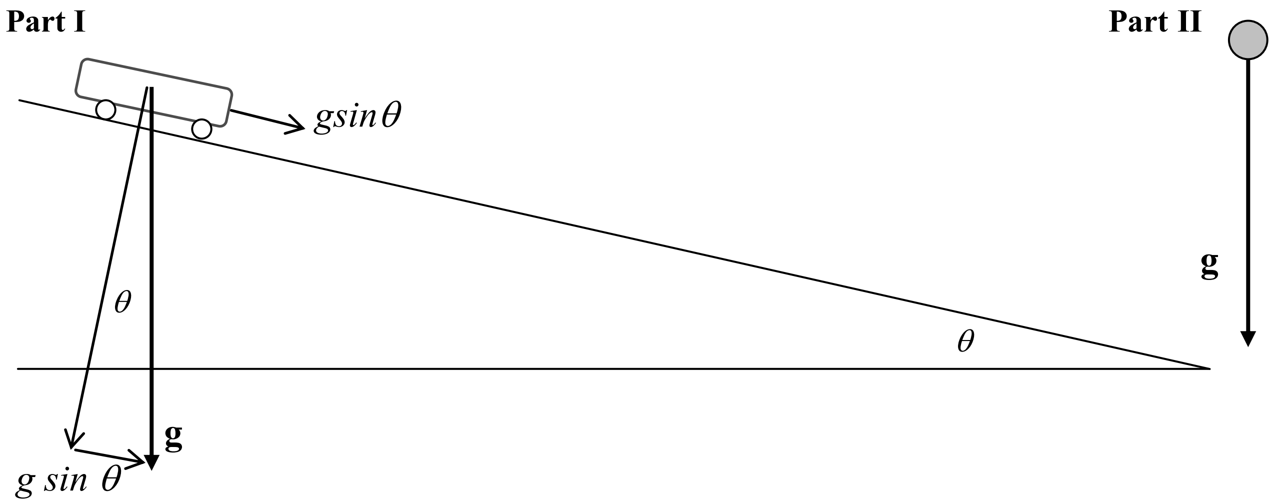
FREE FALL



THEORY

A body freely falling near the surface of the earth falls with a constant downward acceleration, g = 9.8 m/s^2, if air resistance is negligible. This acceleration is so large that it is difficult to directly perceive how the velocity changes. So in Part I, we'll begin as Galileo did, by studying the motion of an object falling down an incline. In this way we effectively slow down gravity so that we can clearly see the acceleration. The acceleration of a body down an incline of angle θ is equal to $g\sin\theta$ when friction plays no significant role. We will justify this more completely after we have studied Newton's laws, but for now just think of $g\sin\theta$ as the component of the vertical acceleration vector **g** along the incline. The other component does not affect the motion. In Part II we will measure the acceleration of a freely falling body, using a special free fall apparatus.

In both parts of this experiment we will use kinematic equations for linear motion at constant acceleration:

$$v_x = v_{x0} + a_x t$$
$$x = x_0 + v_{x0} t + 1/2\, a_x t^2$$

where x denotes position, v_x velocity, and a_x acceleration, and where we take the positive x direction as the direction of motion. In both parts, our "falling" bodies start from rest, and so v_{x0} = 0. We choose the starting point as origin, so that x_0 = 0 also. Our kinematic equations then simplify to:

$$v_x = a_x t$$
$$x = 1/2\, a_x t^2$$

In Part I, $a_x = g\sin\theta$ and in Part II, $a_x = g$

PROCEDURE

Part I

a) Use a carpenter's level to produce a horizontal track for the model car. Then prop up one end of the track at an angle of 0.01 radians. (Note: each small wooden block has a thickness of 1.2 cm. So if you set the legs of the track 1.2 m apart, and raise one of the legs with one block, then the angle of the ramp is $\tan\theta \approx \theta \approx 0.01$ rad) Release the car from rest at the upper end of the track, and use a timer to measure its position at two second intervals. Use chalk to mark the position of the car on the track at $t = 0$, 2 s, 4 s, etc. Repeat several times until you get consistent results

b) Repeat the inclined plane experiment, this time with a much larger angle of 0.05 radians. This time acceleration is so great that you will not be able to make a series of measurements. Just make one measurement of x and t for the entire run, and assume that the acceleration is constant.

c) Repeat part b), this time with a one kilogram mass added to the car.

Part II

Use the free fall timing apparatus to time a ball bearing falling a measured distance. Vary the distance from 0 to 1 m, and repeat enough times to provide sufficient data for graphing. Make sure that when you measure the distance, you measure between two points that gives the distance the ball falls. For best results, be sure to include several data points for distances less than 20 cm.

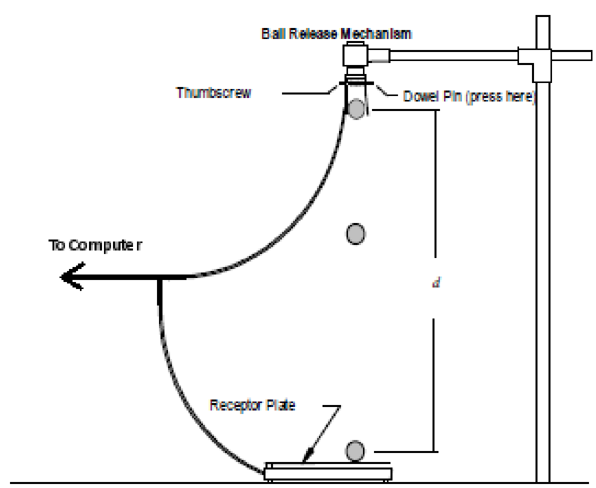
Begin by double-clicking the "Free Fall drop timer" file in the "Physics Lab Files" folder on the computer desktop to open the Logger Pro experiment file. Follow the instructions given in the file. Position the ball receptor plate directly under the apparatus. Place the cardboard tube around the receptor so that the ball doesn't roll away after it falls. For each run, go through the following steps:

a) Click on "Collect" in the Logger Pro toolbar (or tap spacebar) to begin data collection. Insert the steel ball into the release mechanism, pressing in the dowel pin so that the ball is clamped between the plates of the apparatus.

b) Release the dowel, allowing the ball to fall onto the receptor plate.

c) Repeat as needed.

d) Read the time in the Logger Pro display window. This is the time for the ball to fall a distance x.



Data, Analysis --Free Fall

Name __________________
Partners ________________
TA ______________________

PART I

a) Car rolling down plane inclined at 0.01 rad

t (s)	0	2	4	6	8
x_1 (cm)					
x_2 (cm)					
$\bar{x}$ (cm)					

Use Excel to graph x vs. t and x vs. t^2. Label axes and units. Plot the curve that best fits your data. If the graph is approximately linear, plot the best straight line through your data points.

Which of your graphs clearly indicates that the motion you observe is at constant acceleration? Explain. ____
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Slope of graph of x vs. t^2:__________

Acceleration of car: ______________

Value of $g\sin\theta$:_________________

Percent difference between acceleration and $g\sin\theta$: __________

Try to account for the percent difference.
____
____

b) Car rolling down plane inclined at 0.05 rad
Time for 2m run

t_1 (s)	t_2 (s)	t_3 (s)	$\bar{t}$ (s)

Compute the acceleration of the car and compare with $g \sin \theta$. Show your work.

Acceleration of car: ______________________

Value of $g\sin\theta$: _________________________

Percent difference: ___________________________

Your percent difference should be considerably less than in part a). Explain.

____

____

c) Car rolling down plane inclined at 0.05 rad, with one kilogram mass added
Time for 2m run

t_1 (s)	t_2 (s)	t_3 (s)	$\bar{t}$ (s)

Compute the acceleration of the car and compare with $g\sin\theta$. Show your work.

Acceleration of car: _____________________

Value of $g\sin\theta$: ________________________

Percent difference: ______________________

The theoretical prediction for the acceleration of the car ($g\sin\theta$) is a result independent of the mass of the car. Is this result borne out by your experiment? Explain. _____________________________

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PART II FREE FALL

Distance *x* (m)	Time, trial 1 (s)	Time, trial 2 (s)	Average time *t* (s)	t^2 (s^2)
0	0	0	0	0
0.050				
0.100				

Use Excel to graph *x* vs *t*. Plot the best smooth line you can through the points. How is the slope changing as *t* increases? Is it increasing, decreasing, or constant? _______________

What does this tell you about how the velocity is changing? _________________________________

What does the slope tell you about the acceleration?_______________________________________

Use Excel to graph *x* vs t^2, and to compute the slope of the graph.

Slope of graph: ____________

Measured value of *g* = _________

Standard value of gravitational acceleration = 9.80 m/s^2

Percent difference: __________