NORTHERN ILLINOIS UNIVERSITY

PHYSICS DEPARTMENT

Physics 210 – Mechanics & Heat   Spring 2022

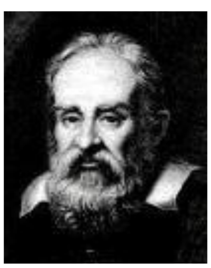
Lab #1

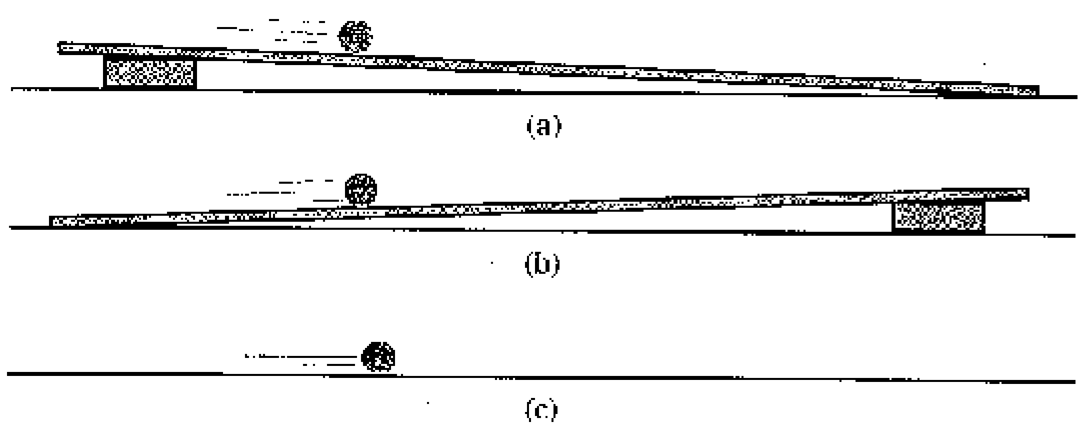
Lab Writeup Due: ***At the end of lab, upload to Blackboard***
Read OpenStax: Chapter 2, Lecture Notes #1

A quadrille ruled lab notebook is required (a USB flash drive is optional).

Inclined Plane

Galileo Galilei (1564-1642) became famous for his study of the motion of objects down inclined planes. This study helped him formulate the law of inertia, understand the properties of friction, and, most of all, develop the scientific process of using experiments and observations to formulate theories and hypotheses about the physical world.





A smooth ball on a smooth incline always (a) speeds up going down and (b) slows down going up, even for a very slight incline. In the limiting case (c) of a perfectly smooth and level surface, the ball should keep going forever once it has started rolling.

In this lab, your goal is to determine the acceleration of a cart down a slide—just as Galileo must have done over 400 years ago but with less sophisticated technology.

Theory

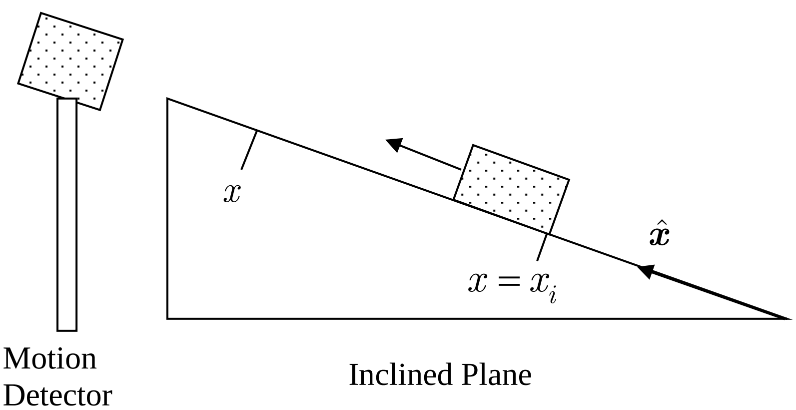
The basic kinematical equations of motion for a body undergoing uniform acceleration, a, are:

$$v_f = v_i + at \tag{1}$$

$$x_f = x_i + v_i t + \tfrac{1}{2}at^2 \tag{2}$$

where the object starts its motion at time $t = 0$ at position x_i and with velocity v_i.

Figure 1: Experimental Setup



* put Flag on cart

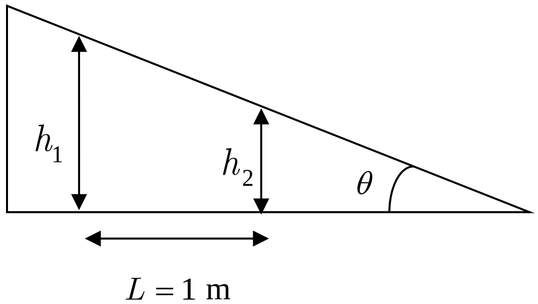
Experiment

For your experiment setup above, at time $t = 0$, the cart will start at position $x_i = 0$. The *motion detector* will measure the position of the cart as a function of time from position $x_i = 0$ to some final point x_f. The computer will collect the signals from the *motion detector*, and the Logger Pro software will display the position and velocity of the cart.

The track is inclined at an angle where one end of the track is higher than the other end. As the cart slides down the inclined track from the high end to the low end over a length L the motion detector measures the position of the cart at various times t.

Data Collection

Do not leave the lab until you have shown the TA your answers and plots in the Data Analysis section of this lab. You must upload your lab to Blackboard before you leave.



(1) For your first measurement, adjust the height at the high end of the air track so that it is around 10 to 20 cm above the surface of the table (there is no need to be exact).

(2) Using a ruler, carefully measure the height of the top of the air track at any two points, exactly 1 meter apart. This information will yield the inclination angle, θ as shown in the Figure above. Make certain you record these heights (draw the picture above) in your lab notebook. Also, *take a cell phone picture* of your lab setup. You will need it later.

(3) Open the Logger Pro software on the computer. You should have a window on the left side of the screen showing columns labeled time, position, and velocity. On the right side of the screen should be two graphs, one for position verses time and the other for velocity verses time. Right-click on each graph and select **graph options**, select the tab **axes options**, and make certain the scaling is set to **auto scale**.

(4) One student will operate the Logger Pro software, another will release the cart up the track, and another will be responsible for catching the cart if something goes wrong.

(5) Make sure the "flag" is magnetically attached to the cart. Start data collection by clicking on the **collect** button. Then push the cart up the track so that it goes up the track and then comes back down. *Make certain you catch the cart before it hits the bottom to avoid damaging anything*. The position verses time graph should show a nice parabola (why?—read the theory section again if you cannot answer this). Repeat the measurement until you get a nice parabola (with no flat bottoms—if the cart gets too close to the motion detector, flat bottoms are produced since the motion detector fails to detect motion if the object is too close) for position verses time and a nice straight line for the velocity verses time graphs (why?—read the theory section). Store onto a USB flash drive (or upload it to your computer account) the data in the columns showing the time, position, velocity, and acceleration (select **file**, then select **export as**, and then select **text** and give it an appropriate filename). There should be about 100 data points in each column, so *ask the TA if your data looks ok before you record all this data*. ***Make certain you save your data as a *.txt file!!!***

Data Analysis

You must upload your results to Blackboard before you leave lab

Again: Make certain you save your data as a *.txt file (not as a *.cmbl file)!!!

(1) Plot, by hand, in your lab notebook the *position verses time* graph for your data. Make certain *time* is the *horizontal axis* in your plot. Only plot every other (or every third) data point so that only about 11-15 data points are plotted. NOTE: Only use the data for the time period where you have a nice parabola. Make certain the axes are properly labeled with the correct units. Shift the plot so that that the bottom of the parabola lies at the origin $(t = 0, x = 0)$. This shift is done by subtracting a constant factor from all the (*time, position*) data points.

(2) Do the same for the (*time*, *velocity*) data—shift it by the same amount that you did for the (*time*, *position*) data.

(3) For your (*time*, *velocity*) data, draw the best straight line through your data using a ruler. Determine the slope of this straight line. This gives an experimental, or measured, value of the acceleration. Write this number in your lab notebook.

(4) Determine the inclination angle θ from the heights you measured in **Data Collection** Part (1) (show your calculation in your lab notebook).

(5) The theoretical acceleration is $a = g\sin\theta$ where $g = 9.8\,\text{m/sec}^2$ and θ is the inclination angle. Using your inclination angle from Part (4), what is the theoretical acceleration a? Write this value (and show your calculation in your lab notebook).

(6) How does your experimental value of acceleration compare with the theoretical value? In this comparison, compute a *percent error* between your measured value of a (*experimental value*) and the theoretical value:

$$\%Error = \left|\frac{Experimental - Theoretical}{Theoretical}\right| \times 100$$

Note that percent errors of 0.1% are excellent, 1%-5% are good, 5%-15% are reasonable (expected in this lab course), and greater than 15% are poor measurements. Write your answer to this question in your lab notebook.

(7) Take careful cell phone pictures of your lab notebook. Make certain that they are clearly readable. Upload your pictures to Blackboard. ***This must be completed before you leave lab***. No further lab writeup is required for this 1st lab.

Before you leave lab: Make certain you have saved all your data as a *.txt file onto a USB drive or have uploaded it to your computer account. Also, take a cell phone picture of the experimental setup. You will need this information for lab next week.