Kinematics of One-Dimensional Motion:
Motion of a Cart on a Ramp

1. OBJECTIVE

In this lab, we wish to analyze the motion of a mass (e.g. a cart) moving in a straight line down a ramp that is inclined at two different angles. For each angle, there will be three files – each file is a dataset that contains information about the cart's position, velocity and acceleration as functions of time.

2. THEORY

2.1 Motion of an object along an inclined plane

A block of mass *m* will accelerate in a straight line when it is placed on a smooth, frictionless, inclined, surface in the presence of a gravitational field. In the case of an inclined plane, the gravitational force can be split into two components. One component of the gravitational force will be parallel to the surface of the inclined plane; this component is responsible for accelerating the mass down the plane. The other component is perpendicular to the inclined plane and creates a normal force. The Free-Body Diagram (FBD) is shown below in Fig. 1.

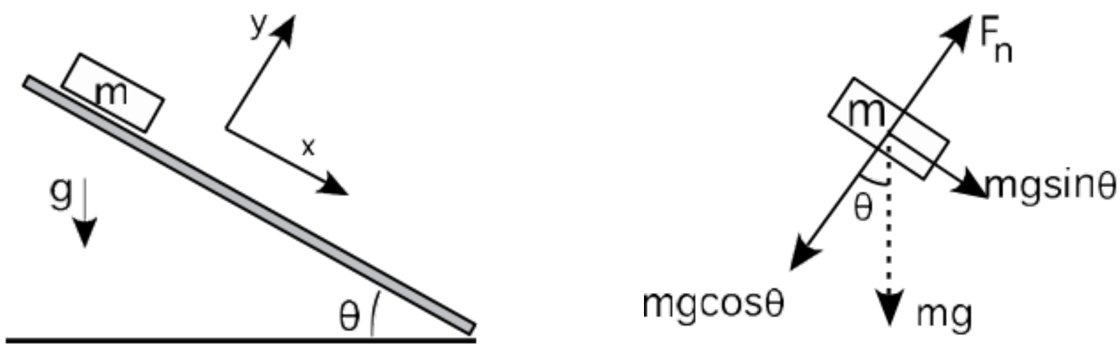

FIGURE 1: FBD of a mass on an inclined plane in a gravitational field.

Fig. 1 indicates a coordinate system with the x-axis parallel to the incline and the y-axis is perpendicular to the incline. The components can then be written as:

$$F_x = mgsin\theta$$
$$F_y = mgcos\theta$$

For the purposes of this lab, we can take g to be constant at 9.8 meters per second squared. It is important to notice that the acceleration is ultimately independent of the mass. Thus, we should be able to place any mass we want on the cart and it will always accelerate at the same rate.

Now, we also want to keep in mind how position, velocity and acceleration are related. The following link gives an in-depth analysis about time-dependent motion undergoing constant acceleration:

http://hyperphysics.phy-astr.gsu.edu/hbase/acons.html

We see that we can write the velocity and acceleration in terms of the derivative of position. We also see how our kinematic equations relate to the derivatives – which can also be related to the slope of x(t), v(t), and a(t). Thus, for x(t), our kinematic equation (given in the link above) shows that we expect a parabolic trend in the data. For v(t), we expect a linear trend and a flat trend for a(t). (**Note:** When fitting equations to the data during your lab session, only fit to the data when the cart is experiencing constant acceleration – not when the cart has hit the spring).

3. Experimental Set-up:

This experiment consists of using an inclined plane that can be set at various angles. A cart that has small, frictionless, wheels is placed in tracks on the ramp. The cart can be let go from the top of the ramp or pushed up the ramp. At the top of the ramp is an ultrasonic sensor that detects/records the motion of the cart. At the bottom of the ramp is a spring is compressed when hit by the cart.

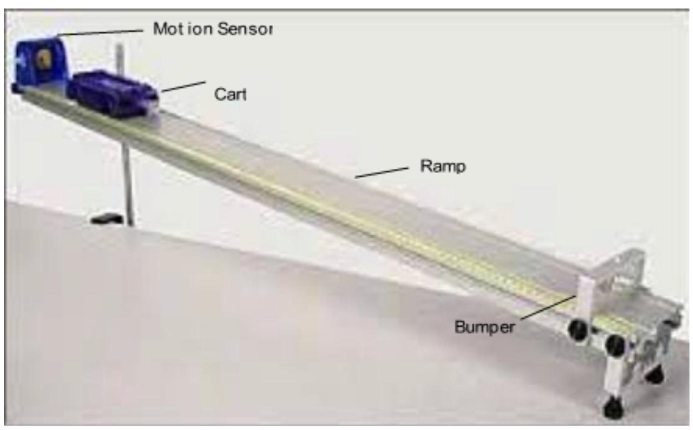

FIGURE 2: A similar set up to our experiment. The full set up can be viewed in the videos available on the Phys 101 Blackboard page.

3.1 Data Collection

In this lab, we have collect data while the ramp is inclined at two different angles. For each angle, we record data using a frequency of 50 Hz three separate times. Thus, we have three datasets per angle. Each dataset provides cart position, velocity, and acceleration as functions of time.

3.2 Data Analysis:

The data analysis component of this experiment will be completed in your respective lab session on the Lab Worksheet. When analyzing data and writing your explanations, be sure to show all your work! Also, you should include all the plots you make (overlaying x(t), v(t) and a(t) will conserve space) are turned in. Finally, be sure to track the error on calculations (e.g., when calculating the angle of the inclined plane).