Experiment 3

Equations of Motion

In this experiment you will explore the various motions of a ball rolling down an incline, and rolling across the table top. You will then apply the appropriate equations of motions to the ball’s motions.

50 cm

50 cm

Side View

Over Head View

The first three equations that are listed above are known as the first, second, and third equations of motion. All three incorporate a constant acceleration a. These equations involve instantaneous velocities and instantaneous positions of an object in motion. The last equation determines the average velocity of an object during a particular time interval.

In the illustrations above you see the set up for using a 12-inch ruler (with a continuous groove along its entire length) being used as an inclined plane. The use of various sized objects (books, boxes, magazines, etc.) can be used to set the height of one side of the ruler. Three different angles of the inclined plane will be used. Your lab instructor will tell you which angles are to be used during the lab session on Collaborate Ultra. If you have not downloaded the app for Phyphox, you can do so to use one of its features—measuring an angle. When you open the Phyphox app, scroll down to the Tools portion and select “Inclination”. You will see a pulsating “play” button to start measuring the angle. Place your phone on the inclined ruler and adjust to the angles asked for. You can even use it to see how level the table (or floor) that you will set up on. Just press the stop/pause button when you are finished.

In the Side View of the illustration you see the green ball at the top of the inclined plane. I have placed lighter colored versions of the ball at the bottom of the inclined plane, and across the table, showing different positons the ball will have as it rolls. Make sure that the surface of the table (or the floor) is a bare surface. No table cloths (or carpet/rug). This will cause too much friction on the rolling ball. The harder and flatter the surface, the better. If you are using a wooden plank floor make sure you are running along the length of one of the planks, and not across the joints.

In the Over Head View you can see I have depicted two sheets of printer paper, taped together and marked with a beginning line and an ending line. These two lines are 50 centimeters apart. The lines are drawn at the points where the ball first makes contact with the paper as it comes off of the inclined plane, and where it is stopped by another book, or box at the other end. You can see that this stopping block is moved over by an amount equal to the radius of the ball from the end line.

You will use the 50 centimeter length to determine at what velocity the ball has at the bottom of the inclined plane. While the ball rolls down the inclined plane it is subjected to the force of gravity, accelerating the ball down the inclined plane. Once the ball reaches the bottom of the inclined plane and rolls across the horizontal table (or floor) there is no longer a force vector in the direction of motion, and the ball rolls at a constant velocity.

Weight Force

Weight Force

Weight Component into the plane

Weight Component down the plane

Normal Force

Normal Force

Here is a force diagram:

It is the Weight Component down the plane that accelerates the ball.

You will also use your cell phone as a stopwatch. This function is probably in the clock app. You will time how long the ball takes to 1.) roll down the inclined plane, and 2.) roll across the 50 centimeter length. Since the amount of time that it takes the ball to roll is not very long, practice using your stopwatch app while allowing the ball to roll. It might take a little while to get used to holding the ball with one hand at the top of the inclined plane, while starting and stopping the stopwatch with the other. Also, once you have the ruler and paper and blocks set up, roll the ball down the inclined plane a couple of time to make sure that the ruler is angled straight and the ball rolls along the dashed line on the sheets of paper (as shown in the Over Head View). If the ball deviates from the line, then it is rolling more than 50 centimeters before it hits the stop block. Two small bits of tape at the bottom of the ruler may be helpful. Just make sure the tape does not cross into the central groove and affect the rolling ball.

Once you have practiced, start taking data. Enter the data into the tables on the Excel spread sheet for this experiment. These tables are titled: “Time Ball Rolls Across 50 cm Distance”, and “Time Ball Rolls Down Inclined Plane”. Calculate each of the indicated total uncertainties (δ), using the proper systematic uncertainties and standard deviations for the measured quantities, and the proper equations for the calculated quantities.

For each of the angles of the inclined plane you will determine the average times.

The average velocities for each of the angles corresponds to the final velocities the ball has after it has rolled to the bottom of the inclined plane for the same angles. You will use these calculated final velocities, the times for the ball to roll down the inclined plane, and the distance the ball rolled down the inclined plane to determine the accelerations for each of the angles. You will use all three of the equations of motion to determine these accelerations.

Results

Comment, for each of the angles, how the accelerations determined with the 3 equations of motion compare to each other. Use the ranges of values in our comment.

Questions for Discussion

1. Describe the motion of the ball as it rolls down the inclined plane and compare it to the motion of the ball rolling along the horizontal surface.
2. How does the angle of the inclined plane affect the motion of the ball rolling down the inclined plane? What is the reason for this? Draw a force diagram for all three angles to help to explain your reasoning.
3. Ideally, an object should move down an inclined plane under the force of gravity with an acceleration of: . The value for g is 9.81 meters/sec2. Do the accelerations that you determined for each angle compare to this expected value? If not, state why they do not.
4. If the length of your inclined plane was increased to twice its length, how would this affect the acceleration determined for each of the angles of the inclined plane?