Computer Experiment

12A

Centripetal Acceleration

INTRODUCTION

The typical response when one hears the word acceleration is to think of an object changing its speed. You have also learned that velocity has both magnitude and direction. So, an object traveling at constant speed in a circular path is undergoing an acceleration. In this experiment you will develop an expression for this type of acceleration.

OBJECTIVES

In this experiment, you will

- Analyze velocity vectors of an object undergoing uniform circular motion to determine the direction of the acceleration vector at any given moment.
- Collect force, velocity, and radius data for a mass undergoing uniform circular motion.
- Analyze the force *vs.* velocity, force *vs.* mass, and force *vs.* radius graphs.
- Determine the relationship between force, mass, velocity, and radius for an object undergoing uniform circular motion.
- Use this relationship and Newton's second law to determine an expression for centripetal acceleration.

MATERIALS

Vernier data-collection interface
Logger *Pro*
Vernier Photogate
Dual-Range Force Sensor
Vernier Centripetal Force Apparatus
masses

PRE-LAB INVESTIGATION

Tie something soft (such as a stopper) to a one-meter length of string. Taking care not to hit anyone nearby, swing the stopper so that it travels in a horizontal circular path over your head. Feel the tension force you must apply in order to keep the stopper moving at a nearly constant speed. Now, see what effect varying the speed of the stopper or the length of the string has on the force you apply to keep the stopper moving in a circular path. Record your observations.

Your instructor will lead a discussion that will enable you to determine the direction of the acceleration vector for an object moving at constant speed in a circular path. For this experiment, you will use an apparatus that will allow you to measure the force acting on an object undergoing circular motion that is more uniform than you could achieve by swinging it.

PART 1 – FORCE *VS.* VELOCITY

PROCEDURE

1. Attach a Dual-Range Force Sensor and a Vernier Photogate to the Vernier Centripetal Force Apparatus (CFA), as shown in Figure 1.

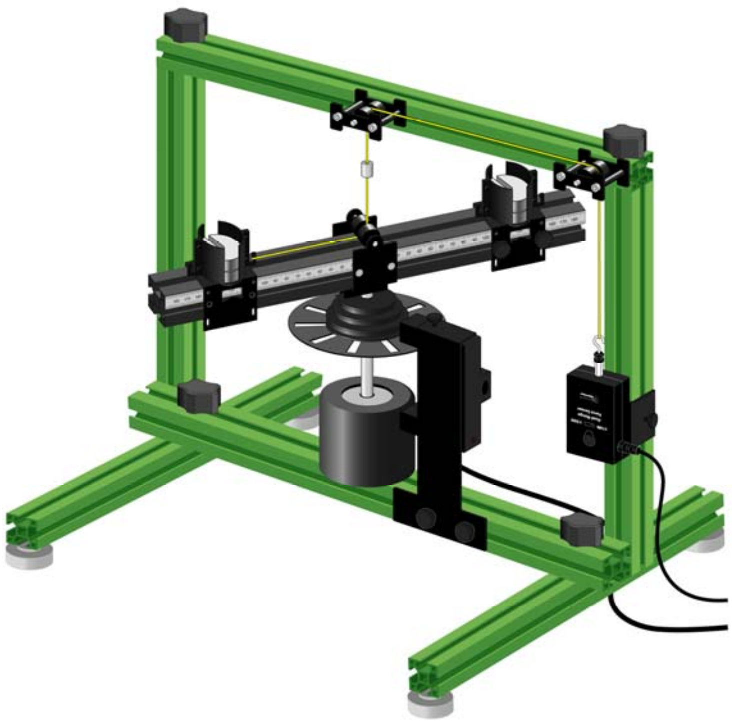

Figure 1

2. Connect the force sensor and the photogate to the interface.

3. Set up data collection.
   a. Open the experiment file 12A Centripetal Acceleration.cmbl. Data collection has been set up so that Logger *Pro* calculates the distance the carriage on the beam has travelled during its circular motion. You can examine the formula by double-clicking on the column header for Distance.
   b. Because Distance column calculation depends on the radius of the circular path, you *must* change the value of the radius parameter in Logger *Pro* whenever you move the carriage.
   c. Press the spacebar to stop collecting data when you think it is appropriate to do so.

4. Determine the mass of the sliding mass carriage. Add mass to both the sliding and fixed mass carriages as directed by your instructor. The mass of the sliding and fixed carriages should be the same so that the beam is balanced. Record the total mass of the sliding carriage and extra mass.

5. Position the fixed carriage so that its center is 10 cm from the axis of rotation. Adjust the position of the force sensor on the rail so that, when the line is taut, the center of the sliding mass carriage is also at 10 cm. Make sure that the parameter, radius, in Logger *Pro* is set to 0.10 m.

6. Zero the force sensor.

7. Spin the beam by twisting the knurled spindle of the CFA with your fingers. When the force reaches 5–8 N, begin collecting data. When you stop data-collection, use the friction between your hand and the knurled spindle to stop the beam.

EVALUATION OF DATA

1. Choose Next Page from the Page menu. Note that the vertical axis displays Force-interpolated; these are values that Logger *Pro* has interpolated from the values of force measured by the sensor.

2. Write a statement that describes the relationship between the force acting on the carriage and its tangential velocity.

3. If your graph of force *vs*. velocity is not linear, take steps to modify a column so as to obtain a linear relationship. Choose New Graph from the Insert menu, choose the new column variable for the horizontal axes, and then rearrange the graphs on the page.

4. Write the equation of the line that best fits your linearized graph. Simplify the units of your slope as much as possible. Save your Logger *Pro* file.

5. Compare the value of the slope of the linearized graph with that obtained by other groups in your class. Speculate about what might be responsible for any differences in the slopes.

PART 2 – INVESTIGATING THE EFFECT OF MASS AND RADIUS

When a quantity (in this case, force) is a function of more than one variable, it is usually the case that the slope of the graph is related to the parameters held constant during the experiment. Examine the units of the slope of your graph of F *vs.* v^2. Write an expression involving mass and radius that has the same units as that of your slope. Substitute the known values of these parameters; how closely does the value of this expression agree with that of your slope? Predict the effect of doubling the mass on the value of the slope. What effect would doubling the radius have on the slope? You can test your conclusions by varying first the mass and then the radius as follows.

PROCEDURE

1. Store your first run.

2. Change the mass on both the fixed and sliding carriages and record the value of the total mass of the sliding carriage and any extra masses. Return to Page 1 of your experiment file.

3. Re-zero the force sensor, then spin the beam as you did before. Once the force reaches 5–8 N, begin collecting data. When you stop data collection, stop the beam as you did in Part 1. Store this run.

4. Change the system mass again and record the value of the total mass of the sliding carriage and any extra masses, then repeat Step 3.

5. Return the mass on both the fixed and sliding carriages to the original value used in Part 1.

6. Decrease the radius of both the sliding and fixed mass carriages by 2–3 cm. Record the value of the radius.

7. Re-zero the force sensor, then spin the beam as you did before. Once the force reaches 5–8 N, begin collecting data. When you stop data collection, stop the beam. Store this run.

8. Now, change the radius so that it is 2–3 cm greater than your initial value. Record the value of the radius, then repeat Step 7.

EVALUATION OF DATA

1. Return to Page 2 of your Logger *Pro* file.

2. Select More on the vertical axis on the Force-interpolated *vs.* velocity graph and select the interpolated force for the three runs in which mass was varied. On the graph you should see a family of curves.

3. Now do the same for the Force-interpolated *vs.* velocity^2 (F-i *vs.* v^2) graph. Perform linear fits on all three sets of data. Record the value of the slope of each of the equations of the lines. What relationship appears to exist between the value of the slope and the total mass of the sliding carriage?

4. To study the effect of changing the radius, select More on the vertical axis of the F-i *vs.* v^2 graph. De-select Force-interpolated for the runs you examined in Step 3. Now, select it for one of the runs in which you changed the radius.

5. Because the velocity was calculated using the value of the radius, you must set this parameter to the radius used for each run you wish to examine. Perform a linear fit on the data for the desired run. Compare the value of the slope for this run to that for your first run (r = 0.10 m).

6. Repeat Steps 4 and 5 for another run in which you changed the radius. Does the change in the radius have the expected effect on the value of the slope? Compare your findings with those of other groups in class.

7. Write an equation relating the net force, mass, radius and velocity of a system undergoing circular motion.

8. Use what you have learned in Steps 3–5 of this section and Newton's second law to write an equation for the acceleration of the object undergoing circular motion. Use your text or a web resource to determine the meaning of the term "centripetal."

EXTENSION

Wikipedia warns that the centripetal force is not to be confused with centrifugal force. It describes the latter as a fictitious or inertial force. Describe an example of such a force that you have experienced and how this interaction might better be explained in terms of centripetal force.