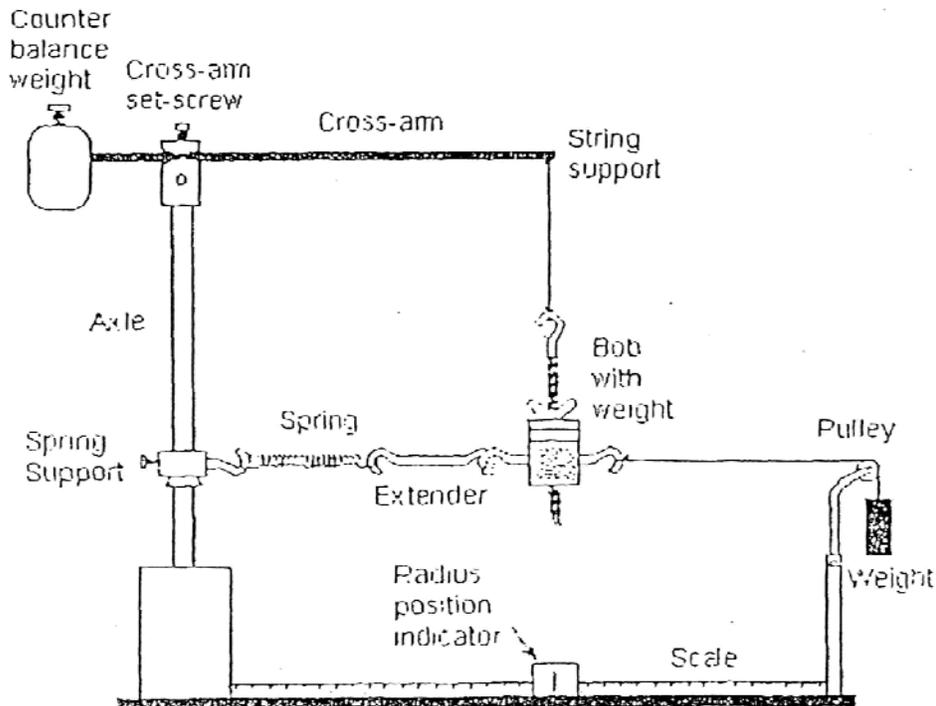


Lab 3. Centripetal Force

Introduction

Those of you who have tied an object to a string and whirled it in a horizontal circle above your head no doubt have recognized that you have to pull on the string and therefore on the object in a direction toward the center of the circle if you wish to have circular motion. This pull or force is called a centripetal force (F_c). You may also have noticed that a more massive (m) item requires more effort in your swing. The length of the string (or radius, r , of the circle), and the speed (velocity, v) with which object is traveling will also change. In this laboratory you will complete an investigation which will allow you to determine empirically what the relationship is between F_c , m , r , and v for uniform motion in a circle.

Whenever an object moves in a circular path, the object is accelerating because the velocity is constantly changing direction. All accelerations are caused by the net force acting on an object. In the case of an object moving in a circular path, the net force is a special force called the centripetal force (not centrifugal!). Centripetal is Latin for "center seeking." So a centripetal force is a center seeking force which means that the force is always directed toward the center of the circle. Without this force, an object will simply continue moving in straight line motion.



Procedure:

Equipment

hand-operated centripetal force apparatus with cylindrical bob
slotted weights
weight hanger
metric ruler
laboratory balance

Materials

data sheets
string.

The apparatus is depicted in the figure on the previous page. This figure shows the apparatus as set up to measure the spring force (F_c). This is the procedure to obtain the direct measurement of the centripetal (F_c). The other measurements are taken by removing the hanging weight from the bob and rotating the apparatus such that the spring is stretched by the same amount as by the hanging weight.

As shown, the cylindrical bob is suspended by means of a string supported by a cross arm. The cross arm is supported by a freely turning axle. The distance r (radius) of the bob from the axis of rotation is adjustable by means of the cross arm set screw. An adjustable counterweight is provided to balance the system and reduce wobble. The centripetal force is provided by a spring connected between the axle and bob by means of hooks.

Part 1: Comparing experimental value with actual value.

1. Remove the bob and determine its mass using a laboratory balance.
2. Adjust the position of the radius position indicator to the smallest radius. Measure this distance and record on data sheet.
3. Reattach the bob and with the bob hanging freely, adjust the support arm so that the bob is suspended directly over the pointer. Reattach the spring to the bob.
4. Determine the speed of the bob necessary for circular motion at the smallest radius. Obtain the necessary data by rotating the axle clockwise as viewed from the top using your thumb and forefinger. With a little practice you may rotate the axle at a constant rate with the bob hanging vertically so that its point swings directly over the radius position indicator.
5. The person rotating the axle of the apparatus will need to indicate when to start and stop the time. Multiple observers reduce error. Count out loud. This helps!
6. Time 20 revolutions of the bob and then record this data in the table. Repeat this procedure two more times. If the three measurements agree within a slight margin, average them. If not, perform additional measurements so that if you have an obviously bad measurement you may discard it. Remember: the revolution count is zero, not one, at the instant the timer is started.

7. Attach a string to the bob opposite the spring and suspend a weight hanger over the pulley. Add sufficient weights to the hanger until the bob is directly over the pointer. Record this mass on the data sheet.
8. Follow the data sheet for part one to determine the values needed. Write down the formula each time before you calculate a value. Show your work! Each person should figure the values independently in order to understand the process. You can help one another; just remember you will be responsible for the use of the formulas on the midterm and final exams.
9. Calculate the T (period) by dividing the number of seconds by the number of revolutions. Round off the number to the third place to the right of the decimal.
10. To calculate the "computed value of centripetal force," use the following formula. The value for π we will use is 3.14.

$$24. F_c = \frac{4 \pi^2 r m}{T^2}$$

11. To calculate the direct measure of (F_c), use $F_c = ma$. The acceleration for this formula is the acceleration due to gravity (g). Therefore the formula should be written $F_c = mg$, ($g = 9.8 \text{ m/s}^2$).
12. Compute the percent error by using the direct measure of (F_c) as the accepted value.

$$\%Error = \left| \frac{\text{experimental value} - \text{accepted value}}{\text{accepted value}} \right| \times 100$$

Part 2: Variation of mass

1. Place a 50 g mass on the top of the bob.
2. Repeat steps (4 - 12).
3. Reminder: The overall mass of the bob changed. Make sure the data sheet reflects this change.

Part 3: Variation of radius

1. Remove the extra mass from the bob.
2. Adjust the position of the radius indicator to the largest radius. Measure this distance and record on data sheet.
3. Repeat steps (4- 12).

Remember to write the formulas each time you use them. Show work!!

Data Sheet: Comparing experimental value with actual value

Mass of bob: _____ Kg

Radius of path: _____ m

Time in seconds	_____ sec	_____ sec	_____ sec
Number of revolutions	_____ rev	_____ rev	_____ rev
#seconds per #revolutions	_____	_____	_____
T (period)	_____ sec/rev	_____ sec/rev	_____ sec/rev

Average T: _____ (sec/rev)

Computed value of centripetal force: _____ N

Mass from direct measure: _____ Kg

Direct measurement of centripetal force: _____ N

Percent error: _____

Your computations (show work):

Data Sheet: Variation of mass

Mass of bob: _____ Kg

Radius of path: _____ m

Time in seconds	_____ sec	_____ sec	_____ sec
Number of revolutions	_____ rev	_____ rev	_____ rev
#seconds per #revolutions	_____	_____	_____
T (period)	_____ sec/rev	_____ sec/rev	_____ sec/rev

Average T: _____ (sec/rev)

Computed value of centripetal force: _____ N

Mass from direct measure: _____ Kg

Direct measurement of centripetal force: _____ N

Percent error: _____

Your computations (show work):

Data Sheet: Variation of radius

Mass of bob: _____ Kg

Radius of path: _____ m

Time in seconds	_____ sec	_____ sec	_____ sec
Number of revolutions	_____ rev	_____ rev	_____ rev
#seconds per #revolutions	_____	_____	_____
T (period)	_____ sec/rev	_____ sec/rev	_____ sec/rev

Average T: _____ (sec/rev)

Computed value of centripetal force: _____ N

Mass from direct measure: _____ Kg

Direct measurement of centripetal force: _____ N

Percent error: _____

Your computations (show work):

5. Confer with the others in the class. Write down the following measurements:
- a) The class maximum averaged time for experiment 1:
 - b) The class minimum averaged time for experiment 1:
 - c) The class maximum averaged number of rotations for experiment 1:
 - d) The class minimum averaged number of rotations for experiment 1:
 - e) The class maximum averaged T for experiment 1:
 - f) The class minimum averaged T for experiment 1:
 - g) The class maximum % error for experiment 1:
 - h) The class minimum % error for experiment 1:
 - i) Which values varied the most (% variation = $100 \times (\text{maximum} - \text{minimum}) / \text{maximum}$)? Provide a reasonable explanation for the variation.