Lab 8 - Centripetal Force

Name ____

Partner's Name ____

I. Introduction/Theory

When a body is caused to revolve in a circle with uniform velocity, the resultant inward force on the body is called *centripetal force*. The centripetal force produces an inward radial acceleration, **a**, given by Newton's Second Law:

$$\mathbf{F} = m\mathbf{a} \qquad (1)$$

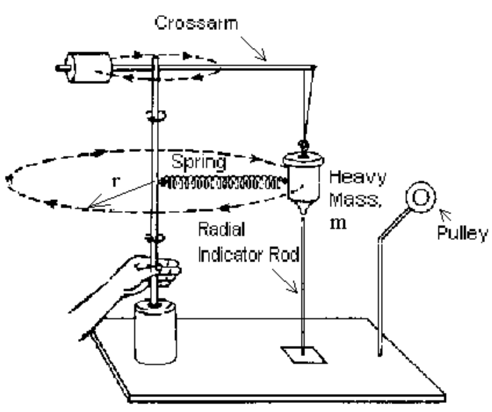
in which m is the mass of the revolving object.

Since $a = v^2/r$,

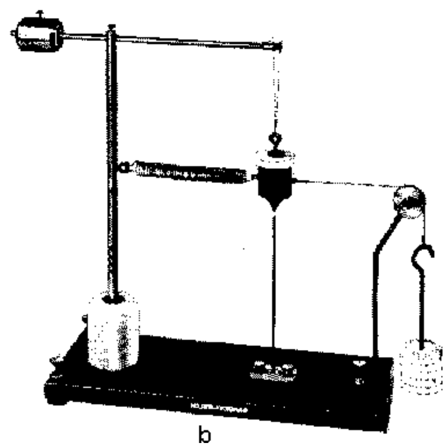
$$F = m\,v^2/r \qquad (2)$$

where r is the radius of the circular path and v is the speed, $v = 2\pi r/T$ with T being the period of one revolution.

Equation (2) is the working equation for this experiment. If m is in kilograms and r is in meters, F will be in Newtons.



a



b

Figure 1

II. Equipment

Centripetal Force Apparatus, WL0930
Slotted Mass Set
Vernier caliper
Stopwatch
Ruler
Scale (500 g capacity)

III. Procedure/Data

The object of this experiment if to verify equation 2 for several values (~5) of r and m by comparing the computed value of the centripetal force using equation 2 with the static displacement force, F_{disp}, required to displace the heavy mass, m, to the same radial position. While the method of accomplishing this is outlined later, the following suggestions may be helpful in familiarizing yourself with this experiment:

Notes:

A. In any given trial, the position of the crossarm and radial indicator rod must be such that the heavy mass, m, hangs freely exactly over the indicator when the spring is detached. Therefore, when changing the radius of rotation, both indicator and crossarm must be moved correspondingly. It will be observed that the location of the counterbalance on the crossarm is not critical.

B. The radius of rotation is the distance from the center of the top of the radius indicator to the axis of the vertical shaft. To obtain this value, add one-half the diameter of the shaft - as measured with a vernier caliper - to the distance from the shaft to the center of the top of the indicator - as measured with the ruler.

C. Determine the mass of the revolving object (heavy mass, m) with a scale balance. To change this value, add or remove slotted masses. Place these weights on the heavy mass, m, with the open end of the slot outward and secure in place with the knurled nut. Up to 100 g may be added.

D. Rotate the system by applying torque with the fingers on the knurled portion of the shaft. With a little practice, the rotation rate can be adjusted to keep the heavy mass, m, passing directly over the indicator.

E. For an accurate determination of the rotational period, T, the time of ~10 complete revolutions should be measured with a stopwatch. The time of one rotation (rotational period), T, is then the time of ten rotations divided by ten.

Trial 1 (m-minimum, r-minimum)

1. Determine the mass of the heavy mass, m, with a scale balance. There should be no slotted weights on the heavy mass, m. Record heavy mass, m, in Table 1.
2. Adjust the radius of rotation to a minimum distance, such that the retaining spring will be stretched ~2 cm when the heavy mass, m, hangs vertically down. Record the radius, r, in Table 1, see Notes A & B. Adjust the radial indicator rod to be vertically under the heavy mass, m. Connect/verify the spring is connected to the heavy mass, m, and the knurled screw on top of the vertical shaft is tightened.
3. Connect hanger to heavy mass, m, via a string over the pulley (see Figure 1b). Add mass to hanger until the radial indicator rod is aligned vertically with the heavy mass, m. Record this displacement mass, m_{disp} (mass of hanger and added mass), and displacement force ($F_{disp} = m_{disp}g$) in Table 1. Remove hanger, masses, and string from the heavy mass, m.
4. Before rotating the system, verify/adjust that when the heavy mass, m, is hanging vertically, the spring is horizontal. This geometry is critical for valid data. Consult your instructor if there are any questions.
5. Rotate the system by applying torque with the fingers on the knurled portion of the shaft, see Note D. Adjust as need to get the heavy mass, m, passing directly over the radial indicator (see Figure 1a). Record the rotational period, T, in Table 1, see Note E.

Trial 2 (m-maximum, r-minimum)

6. Increase the heavy mass, m, by 50 or 100 grams, see Note C. Record heavy mass (include slotted mass), m, in Table 1.
7. Before rotating the system again, verify/adjust that when the heavy mass, m, is hanging vertically, the spring is horizontal. This geometry is critical for valid data. Consult your instructor if there are any questions.
8. Rotate the system by applying torque with the fingers on the knurled portion of the shaft, see Note D. Adjust as need to get the heavy mass, m, passing directly over the radial indicator (see Figure 1a). Record the rotational period, T, in Table 1, see Note E.

Trial 3 (m-minimum, r-middle)

9. Remove the 50 or 100 grams of extra mass from the heavy mass, m. Adjust the radius of rotation such that the radius is increased by 2 to 3 cm, see Notes A & B. Record the radius of rotation, r, and heavy mass, m, in Table 1. Adjust the radial indicator rod to be vertically under the heavy mass, m. Connect/verify the spring is connected to the heavy mass, m, and the knurled screw on top of the vertical shaft is tightened.
10. Connect hanger to heavy mass, m, via a string over the pulley (see Figure 1b). Add mass to hanger until the radial indicator rod is aligned vertically with the heavy mass, m. Record this displacement mass, m_{disp} (mass of hanger and added mass), and displacement force ($F_{disp} = m_{disp}g$) in Table 1. Remove hanger, masses, and string from the heavy mass, m.
11. Before rotating the system again, verify/adjust that when the heavy mass, m, is hanging vertically, the spring is horizontal. This geometry is critical for valid data. Consult your instructor if there are any questions.
12. Rotate the system by applying torque with the fingers on the knurled portion of the shaft, see Note D. Adjust as need to get the heavy mass, m, passing directly over the radial indicator (see Figure 1a). Record the rotational period, T, in Table 1, see Note E.

Trial 4 (m-minimum, r-maximum)

13. Adjust the radius of rotation such that the radius is increased by an additional 2 to 3 cm, see Notes A & B. Record the radius of rotation, r, and heavy mass, m, in Table 1. Adjust the radial indicator rod to be vertically under the heavy mass, m. Connect/verify the spring is connected to the heavy mass, m, and the knurled screw on top of the vertical shaft is tightened.
14. Connect hanger to heavy mass, m, via a string over the pulley (see Figure 1b). Add mass to hanger until the radial indicator rod is aligned vertically with the heavy mass, m. Record this displacement mass, m_{disp} (mass of hanger and added mass), and displacement force ($F_{disp} = m_{disp}g$) in Table 1. Remove hanger, masses, and string from the heavy mass, m.
15. Before rotating the system again, verify/adjust that when the heavy mass, m, is hanging vertically, the spring is horizontal. This geometry is critical for valid data. Consult your instructor if there are any questions.
16. Rotate the system by applying torque with the fingers on the knurled portion of the shaft, see Note D. Adjust as need to get the heavy mass, m, passing directly over the radial indicator (see Figure 1a). Record the rotational period, T, in Table 1, see Note E.

Trial 5 (m-maximum, r-maximum)

17. Increase the heavy mass, m, by 50 or 100 grams. Record heavy mass, m (include slotted mass), in Table 1.
18. Before rotating the system again, verify/adjust that when the heavy mass, m, is hanging vertically, the spring is horizontal. This geometry is critical for valid data. Consult your instructor if there are any questions.
19. Rotate the system by applying torque with the fingers on the knurled portion of the shaft, see Note D. Adjust as need to get the heavy mass, m, passing directly over the radial indicator (see Figure 1a). Record the rotational period, T, in Table 1, see Note E.

IV. Analysis

1. For each trial calculate and record in Table 1 the force from equation 2. Also, calculate and record the percent difference between the force from equation 2 and the displacement force.
2. Comment on the data and results from Table 1.

Trial No.	1 m-min, r-min	2 m-max, r-min	3 m-min, r-mid	4 m-min, r-max	5 m-max, r-max
Radius of Rotation (meters) , r					
Displacement Mass (kg), m_{disp}					
Displacement Force (N), $F_{dis\ p}$ ($=m_{disp}g$)					
Total Heavy Mass (kg), m					
Rotational Period (s), T					
Speed (m/s), v ($=2\pi r/T$)					
Force Eq'n (2) (N), F ($=mv^2/r$)					
% Difference, ($\|F-F_{disp}\|/F$) x 100%					

Table 1

V. Conclusions (include physical concepts and principles investigated in this lab, independent of your experiments success, and summarize without going into the details of the procedure.)