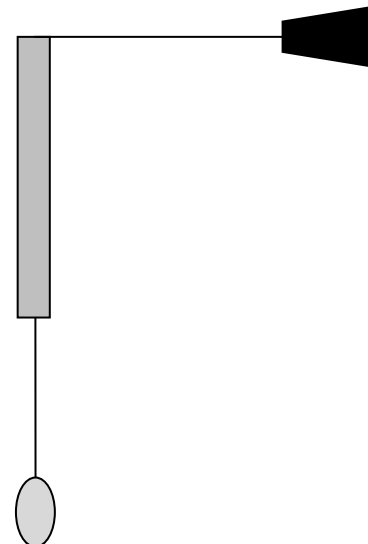


## AP Centripetal Acceleration Lab

**Note:** *Data collection will be done by table groups. Data analysis is to be done individually. Copying a data analysis from someone else or allowing someone else to copy your work will result in a zero for the assignment and a referral to the IB Coordinator for cheating.*

### Discussion:

This lab will explore centripetal acceleration using a device similar to the one in the diagram to the right. The device consists of a PVC tube, a lead weight and a rubber stopper. The weight and stopper are connected by 40lb test fishing line. The object of this exercise is to experimentally determine the velocity and centripetal acceleration of the rubber stopper and then compare it to the theoretically determined value. The stopper will be rotated at a given radius for a given period of time while the weight remains at a constant distance from the tube. The tension in the string needed to create the centripetal acceleration of the stopper is equal to the tension needed to keep the weight in a constant position. From the data collected you will compute velocity and centripetal acceleration of the stopper and then compare them to the theoretical values.



Reference the free-body diagrams below for the weight and the stopper:



If we apply Newton's Second Law to the free-body diagrams, for the weight we get,

$$F_T = F_g = m_w g$$

For the stopper we get,

$$F_T = m_s \frac{v^2}{r}$$

Combining the two equations we get,

$$m_s \frac{v^2}{r} = m_w g$$

If we then solve for the velocity of the stopper we get,

$$v^2 = \frac{m_w g r}{m_s}$$

$$v = \sqrt{\frac{m_w g r}{m_s}}$$

This gives you the theoretically determined value. Velocity is also equal to distance divided by time. For circular motion, the distance travelled is equal to the circumference and the time is the time for one revolution (the period). To minimize error, we will time for several revolutions and then divide by the number of revolutions to get an average time for one revolution.

$$v = \frac{2\pi r}{(\text{time} \div \#rev)}$$

**Materials:**

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|---|---|
| <ul style="list-style-type: none"> <li>• Safety goggles (1 per person)</li> <li>• Timer (1 per table group)</li> <li>• Meter Stick (1 per table group)</li> </ul> | <ul style="list-style-type: none"> <li>• Strip of masking tape (1 per table group)</li> <li>• Centripetal Acceleration Apparatus (1 per table group)</li> </ul> |
|---|---|

**Procedure:**

1. All table group members must don safety goggles and wear them throughout the entire experiment. There is potential for the string to break and for the stopper to strike you.
2. Pull on the stopper until you have a radius of 40cm (0.40 m) from the center of the tube to the approximate center of mass of the stopper. Have a lab partner place a small piece of masking tape on the line just below the tube on the weight side of the tube. This will act as a marker to maintain the 40 cm radius and the weight in the same position below the tube.
3. One person should practice spinning the stopper at a speed that will maintain the masking tape marker at the bottom of the tube. Be careful not to strike other students that you like.
4. When the spinner feels confident, a second person will start the timer. A third person counts the revolutions. Stop the timer after 50 revolutions and record the time *in seconds*. There will be some random error in maintaining the desired radius/weight height. However, timing for 50 revolutions should minimize this error.
5. Change job responsibilities among your table group and repeat steps 3 and 4 for a total of three trials at a 40cm radius.
6. Repeat steps 1 through 5, using a 50cm radius. Accomplish three trials for each radius.

**Data Collection (3/ \_\_\_)**

Mass of weight = 27.4g (0.0274kg)

Mass of stopper = 6.77g (0.00677kg)

Radius = 40cm:		Radius = 50cm:		Radius = 60cm:	
Trial	Time for 50 Revolutions (sec)	Trial	Time for 50 Revolutions (sec)	Trial	Time for 50 Revolutions (sec)
1		1		1	
2		2		2	
3		3		3	
Avg.		Avg.		Avg.	

**Data Analysis:**

1. Compute an average time for 50 revolutions for each of the three radii and place it in the table above.
2. Determine the circumference of the circular motion using  $C = 2\pi r$  and record it in the chart below. Do this for all three radii.
3. Determine the time per revolution by taking the average total time for all revolutions and dividing by the number of revolutions. Do this for all three radii.
4. Calculate the experimental velocity at each radius by dividing the circumference by the time per revolution. Do this for all three radii.
5. Calculate the experimental centripetal acceleration of the stopper using the experimentally determined velocity in the equation,  $a_c = \frac{v^2}{r}$  for all three radii.
6. Calculate the theoretical velocity of the stopper using,  $v = \sqrt{\frac{m_w g r}{m_s}}$  for all three radii.
7. Calculate the theoretical centripetal acceleration of the stopper using the theoretically determined velocity in the equation,  $a_c = \frac{v^2}{r}$  for all three radii.

Experimental Data (1/4 point each, total = 5/___)							Theoretical Data	
Radius	m <sub>weight</sub> (kg)	M <sub>stopper</sub> (kg)	Circumference (m)	Time/Rev	v (m/s)	a <sub>c</sub> (m/s <sup>2</sup> )	v (m/s)	a <sub>c</sub> (m/s <sup>2</sup> )
0.40 m	0.0274	0.00677						
0.50 m	0.0274	0.00677						
0.60 m	0.0274	0.00677						

8. (6/\_\_\_) Calculate the percent difference between the theoretical and the experimental values using  $\left(\frac{\text{Experimental} - \text{Theoretical}}{\text{Theoretical}}\right) \times 100\%$  and record your answers in the chart below.

	Velocity % Diff.	Centripetal Accl. % Diff.
40 cm		
50 cm		
60 cm		

9. (1/\_\_\_) Were your experimental values generally higher or lower than the theoretical values? Explain why you think this is so.

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The value you used for the radius in your calculations was based on the measured distance from the center of the tube to the center of the stopper. This would be true if the stopper was rotating horizontally. This cannot happen because there would be no vertical component of the tension force to support the weight of the stopper. You can see from the drawing that the actual radius (distance from the stopper to the axis of rotation) is slightly less. You can find the actual radius by using the equations below:

$$F_{T-y} = F_{g-s} = m_s g$$

$$\sin\theta = \frac{m_s g}{m_w g} = \frac{m_s}{m_w}$$

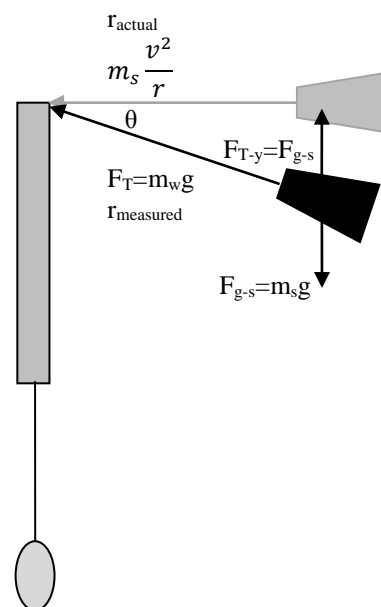
$$F_{T-x} = m_s \frac{v^2}{r}$$

$$\theta = \sin^{-1} \frac{m_s}{m_w}$$

$$F_T = m_w g$$

$$\cos\theta = \frac{r_{actual}}{r_{measured}}$$

$$r_{measured} \cos\theta = r_{actual}$$



For experimental data, the actual angle between the rotating stopper and horizontal should be measured, but for this experiment it is impractical.

- Calculate the angle  $\theta$  and actual radius using the equations above and find the circumference based on this new radius.
- Re-calculate the experimental *and* theoretical velocity and centripetal acceleration as you did before, but this time use the "actual" radius as calculated above.

Experimental Data (1/4 point each, total = 6/___)									Theoretical Data	
$r_{measured}$	$M_{stopper}$ (kg)	$m_{weight}$ (kg)	$\theta$	$r_{actual}$	"New" Circumference (m)	Time/Rev (unchanged)	$v$ (m/s)	$a_c$ (m/s <sup>2</sup> )	$v$ (m/s)	$a_c$ (m/s <sup>2</sup> )
0.40 m	0.00677	0.0274								
0.50 m	0.00677	0.0274								
0.60 m	0.00677	0.0274								

- (6/\_\_\_) Calculate the percent difference between the theoretical and the experimental values using  $\left(\frac{Experimental - Theoretical}{Theoretical}\right) \times 100\%$  and record your answers in the chart below.

	Velocity % Diff.	Centripetal Accl. % Diff.
40 cm		
50 cm		
60 cm		

- (1/\_\_\_) Did the percent differences between experimental and theoretical increase or decrease? \_\_\_

14. (1/\_\_\_) Were your new experimental values generally higher, lower or just about the same as the theoretical values? Explain why you think this is so.

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15. (3/\_\_\_) List three potential sources of error in this experiment:

- a. 

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- b. 

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- c. 

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16. (3/\_\_\_) List three ways in which the accuracy of this experiment could be improved:

- a. 

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- b. 

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- c. 

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**This data was collected (circle one) by myself / a team. I participated fully and equally in the collection of this data and recorded it myself. The answers on this lab are a product of my own work and effort. Though I may have received some help in understanding the concepts and/or requirements, I did the work myself.**

\_\_\_\_\_  
**Student Signature (for electronic submission, type student number in lieu of signature)**

**ROOM FOR IMPROVEMENT**

**APPLICABILITY:** This lab is best suited for (check all that apply):

- Pre-DP Physics     IB Physics 2     IB Physics 3     None of These

**IMPROVEMENT:** This lab can be improved by: