

Online Lab: Centripetal Force

Name:

Date:

Instructor:

Section:

Objective:

This experiment involves determining the relationships between the centripetal force and the affect on velocity of the stopper (Part A), the radius and the affect on velocity of the stopper (Part B), and the moving mass and the affect on velocity of the stopper (Part C).

Online Experiment Setup Instructions:

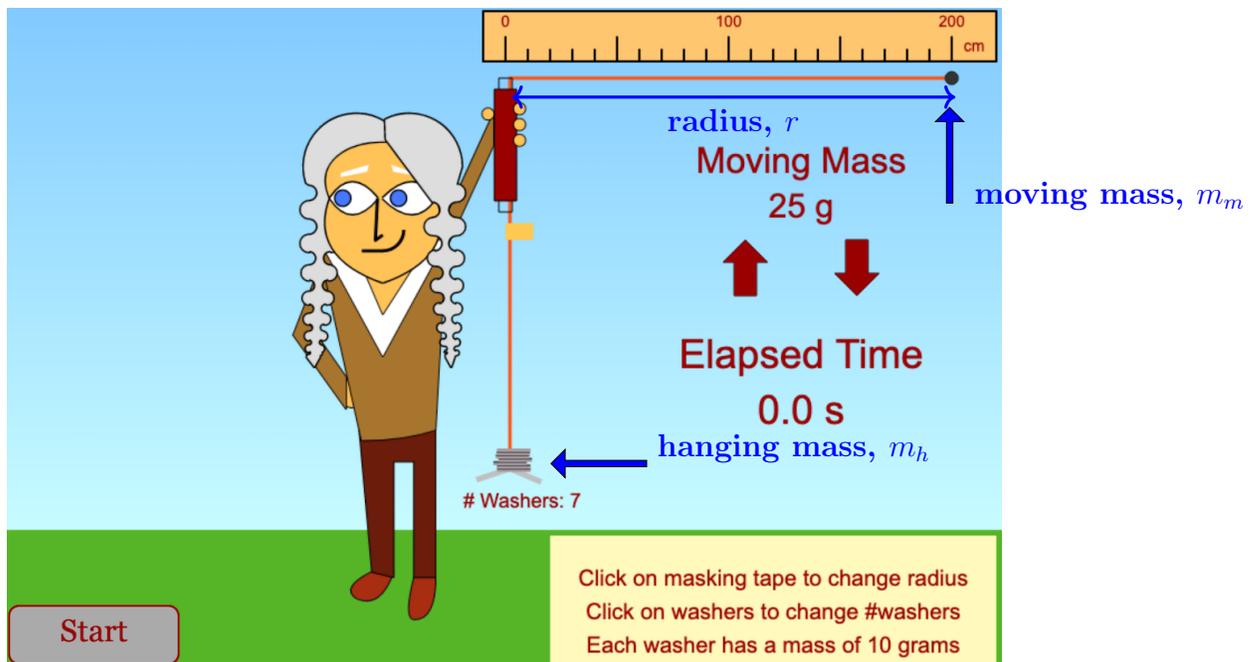
1. Today's Online Lab we are going to use one of the physicsaviary.com simulations.

Go to the following website:

<https://www.thephysicsaviary.com/Physics/Programs/Labs/ClassicCircularForceLab/index.html>

2. Click **Begin** on the bottom right of the simulation.

The figure below shows what you should see on your screen



3. Adjust the hanging mass, m_h . Click the  Icon to randomly add more washers. As indicated above, the mass of each washer is 10 grams.
4. Adjust randomly the moving mass, m_m  to increase and  to decrease.
5. The Yellow Flag  allows you to adjust randomly the radius, r .
6. Take a few minutes to CLICK on each of these to get used to how they work.

Theory:

According to Newton's First Law, an object in motion tends to stay in motion in a straight line at a constant speed if there is no external net force applied to the object. An object undergoing uniform circular motion (motion in a circle at constant speed) must be acted on by a non-zero net force called the centripetal force which must point toward the center of the circle.

The magnitude of the centripetal force required to keep an object in a circular path depends on the inertia (or mass) and the acceleration of the object, as you know from the second law ($F = ma$). The acceleration of an object moving in uniform circular motion is $a = \frac{v^2}{r}$, so the magnitude of the centripetal force of an object can be found from

$$F_c = \frac{mv^2}{r} \quad (1)$$

Where (m) is the mass of the object moving in a circle in a circular orbit of radius (r) with a tangential velocity (v). The distance (circumference) around a circle is $2\pi r$. The velocity of an object moving in a circular path can be found from $v = \frac{d}{t}$. For uniform circular motion, the tangential speed is given by:

$$v = \frac{2\pi r}{T} \quad (2)$$

where $2\pi r$ is the distance around one complete circle and T is the period (time) required to make one revolution. Now if we substitute for v into Equation (1) yields:

$$F_c = \frac{mv^2}{r} = \frac{4\pi^2 mr^2}{T^2 r} = \frac{4\pi^2 mr^2}{T^2 r} \Rightarrow \boxed{F_c = \frac{4\pi^2 m_m r}{T^2}} \quad (3)$$

For this experiment, mass m_m is the mass of the moving mass moving at a constant tangential speed of v_t at the end of a string of length r . The centripetal force will be supplied by a hanging mass m_h that is attached to the bottom of the string. See the figure on page 1. The weight of this hanging mass is determined by the equation:

$$F_w = m_h \cdot g \quad (4)$$

Therefore, the weight of the hanging mass is the centripetal force applied to mass m_m , keeping it in a horizontal circular orbit. $F_c = F_w$ or:

$$m_m \frac{v_t^2}{r} = m_h g \quad (5)$$

Thus the calculated tangential velocity $v_{t_{calc}}$ required to keep this system in equilibrium, will be:

$$v_{t_{calc}} = \sqrt{\frac{m_h}{m_m} r g} \quad (6)$$

The measured tangential velocity $v_{t_{meas}}$ is determined by:

$v_{t_{meas}} = \omega \cdot r$ where (ω) is the angular velocity given by $\omega = \frac{2\pi/rev}{T/rev}$ in rad/sec.

Part A - Relationship Between Force and Velocity

1. Place a small number of washers (~ 8) on the end of the string. Record your exact hanging mass, (m_h) which is the # of washers $\times 10\text{g}$ in Row 1, Column 1 of Table 1.
2. **SET** a radius of ($\sim 200\text{ cm}$) and mass of the moving mass, m_m to a value in the range of 60-90 g. Record your exact values in meters (m) and kilograms (kg) in the space provided.
3. Click Start for 10 complete revolutions. Hit Pause. Record the time under the t_1 column of Table 1. Click Reset. Repeat 2 more times. **Calculate** and Record the average t_{avg} .
4. Click on the washers 1-2 times to add more mass. Record the exact (m_h) value in Table 1. Repeat Step 3. Then do this step 3 more times to complete Table 1.

Table 1: Data - Relationship Between Force and Velocity

Run	m_h (kg)	t_1 (s)	t_2 (s)	t_3 (s)	t_{avg} (s)
1					
2					
3					
4					
5					

$$m_m = \quad (\text{kg}) \quad r = \quad (\text{m})$$

Data Analysis:

1. **Calculate** the Period, T for each run. Record your result in the Analysis Table.
2. **Calculate** the angular velocity, ω for each run. Record your result in the Analysis Table.
3. **Calculate** the measured tangential velocity, $v_{t_{meas}} = \omega r$ for each run. Record your result in the Analysis Table.
4. **Calculate** the theoretical tangential velocity, $v_{t_{calc}}$ for each run using Equation 6. Record your result in the Analysis Table.
5. **Calculate** the Centripetal Force, F_c for each run. Record your result in the Analysis Table.

Table 2: Analysis - Relationship Between Force and Velocity

Run	$T = \frac{t_{avg}}{10}$ T (s)	$\omega = \frac{2\pi}{T}$ ω (rad/s)	$v_{t_{meas}}$ (m/s)	$v_{t_{calc}}$ (m/s)	$F_c = m_h \mathbf{g}$ F_c (N)	$\%_{error}$
1						
2						
3						
4						
5						

Part B - Relationship Between Radius and Velocity

1. **SET** the radius to ~ 30 cm. Record your exact radius, (r) in Row 1, Column 1 of Table 3.
2. **SET** the hanging mass, m_h to (~ 150 g) and the moving mass, m_m to (~ 50 g).
Record your exact values in meters (m) and kilograms (kg) in the space provided.
3. Click Start for 10 complete revolutions. Hit Pause. Record the time under the t_1 column of Table 1. Click Reset. Repeat 2 more times. **Calculate** and Record the average t_{avg} .
4. Click on the yellow tab 1-2 times to increase the radius. Record the exact (r) value in Table 1. Repeat Step 3. Then do this step 3 more times to complete Table 1.

Table 3: Data - Relationship Between Radius and Velocity

Run	r (m)	t_1 (s)	t_2 (s)	t_3 (s)	t_{avg} (s)
1					
2					
3					
4					
5					

$$m_h = \quad \quad \quad (\text{kg}) \quad \quad m_m = \quad \quad \quad (\text{kg})$$

Data Analysis:

1. **Calculate** the Period, T for each run. Record your result in the Analysis Table.
2. **Calculate** the angular velocity, ω for each run. Record your result in the Analysis Table.
3. **Calculate** the tangential velocity, v_t for each run.
Record your result in the Analysis Table.
4. **Calculate** the Centripetal Force, F_c for each run. Record your result in the Analysis Table.

Table 4: Analysis - Relationship Between Radius and Velocity

Run	r (m)	$\mathbf{T} = \frac{t_{avg}}{10}$ \mathbf{T} (s)	$\omega = \frac{2\pi}{T}$ ω (rad/s)	$v_t = \omega r$ v_t (m/s)	$F_c = m_h g$ F_c (N)
1					
2					
3					
4					
5					

Part C - Relationship Between Mass and Velocity

1. **SET** the moving mass to ~ 25 (g). Record the exact value in Row 1, Column 1 of Table 5.
2. **SET** the hanging mass, m_h to ~ 150 g and the radius, r to ~ 180 cm.
Record your exact values in kilograms (kg) and meters (m) in the space provided.
3. Click Start for 10 complete revolutions. Hit Pause. Record the time under the t_1 column of Table 1. Click Reset. Repeat 2 more times. **Calculate** and Record the average t_{avg} .
4. Click on the **UP** arrow to increase the moving mass. Record the exact (m_m) value in Table 1. Repeat Step 3. Then do this step 3 more times to complete Table 1.

Table 5: Data - Relationship Between Mass and Velocity

Run	m_m (kg)	t_1 (s)	t_2 (s)	t_3 (s)	t_{avg} (s)
1					
2					
3					
4					
5					

$m_h =$

$r =$

Data Analysis:

1. **Calculate** the Period, T for each run. Record your result in the Analysis Table.
2. **Calculate** the angular velocity, ω for each run. Record your result in the Analysis Table.
3. **Calculate** the tangential velocity, v_t for each run.
Record your result in the Analysis Table.
4. **Calculate** the Centripetal Force, F_c for each run. Record your result in the Analysis Table.

Table 6: Analysis - Relationship Between Mass and Velocity

Run	m_m (kg)	$T = \frac{t_{avg}}{10}$ T (s)	$\omega = \frac{2\pi}{T}$ ω (rad/s)	$v_t = \omega r$ v_t (m/s)	$F_c = m_h g$ F_c (N)
1					
2					
3					
4					
5					

Conclusions

1. As centripetal force increases, the velocity (increases / decreases) .
2. As the radius increases, the velocity (increases / decreases) .
3. As the mass of the moving mass increases, the velocity (increases / decreases) .
4. **Use your analysis results in Table 2 to create a graph of the Centripetal Force F_c versus the measured tangential velocity v_t^2 .**
Upload it with this Lab Report in D2L. Comment on the graph.
5. **Use your analysis results in Table 4 to create a graph of r versus v_t .**
Upload it with this Lab Report in D2L. Comment on the graph.
6. **Use your analysis results in Table 6 to create a graph of m_m versus v_t .**
Upload it with this Lab Report in D2L. Comment on the graph.
7. Discuss how well your measured v_t values ($v_{t_{meas}}$) compared to the theoretical v_t values ($v_{t_{calc}}$) from Table 2. Compare the measured values with the theoretical values using the equation below. Record your results in Column 7 of Table 2.

$$\%Error = \left(\frac{v_{t_{meas}} - v_{t_{calc}}}{v_{t_{calc}}} \right) \times 100 \quad (7)$$

8. **Take a photo or scan a copy showing ALL calculations performed during this lab and upload it with this Lab Report in D2L.**