# M20c: Centripetal Force and Uniform Circular Motion

## Introduction:

This experiment examines properties of centripetal force and its relationship to uniform circular motion. In order for any object to experience uniform circular motion it must have some net force being exerted on it. In this case the net force becomes the centripetal force, which is required for the object to be accelerated. This acceleration is the centripetal acceleration that is responsible for continually changing the direction of the velocity. Note that although the acceleration changes the direction of the velocity it does not change the magnitude of the velocity. Since the magnitude of the velocity remains constant this leads to the expression, uniform circular motion.

The main purpose of this experiment is to examine the relationships between centripetal force, mass, radius, tangential velocity and angular velocity. Through each part of the experiment one factor will be varied and its effect on the velocity will be determined. The collected data is then graphed to demonstrate the behavior and to determine an unknown factor.

## Apparatus:

- Complete Centripetal Force Apparatus with Rotational Motor Drive
- DC Power Supply
- Computer Timing System
- Balance
- Mass Kit

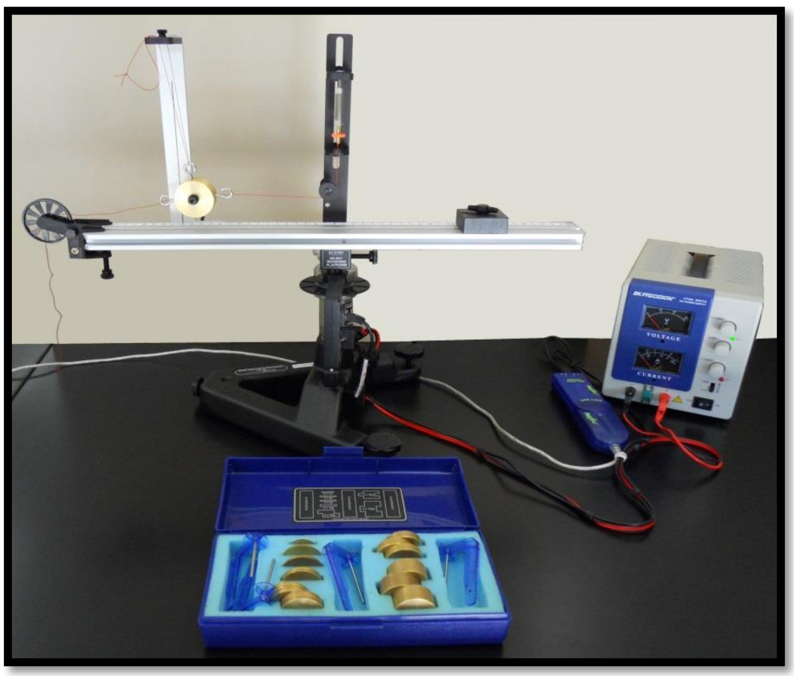


**Figure 1**

***Please see the lab instructor for a briefing on the proper setup and usage of the apparatus before beginning.***

## Discussion:

The diagram to the right is a simplified top view of this experiment. Here is a single body spinning at the end of a string. Newton's second law is applied to the moving body. In this case there is only one force on the body in the horizontal plane, the tension in the string. Thus the tension in the string is the net force on the body and is responsible for the centripetal force experienced by the body.

$$\sum F = T = F_{net}$$

$$F_{net} = F_{centripetd} = ma_{centripetd}$$

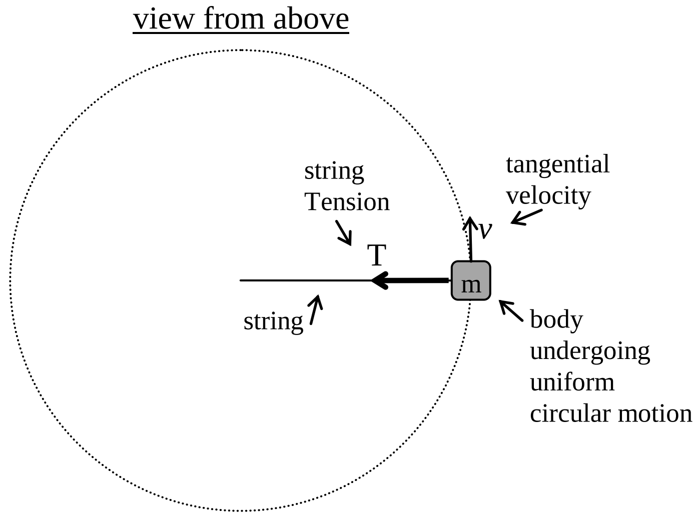



**Figure 2**

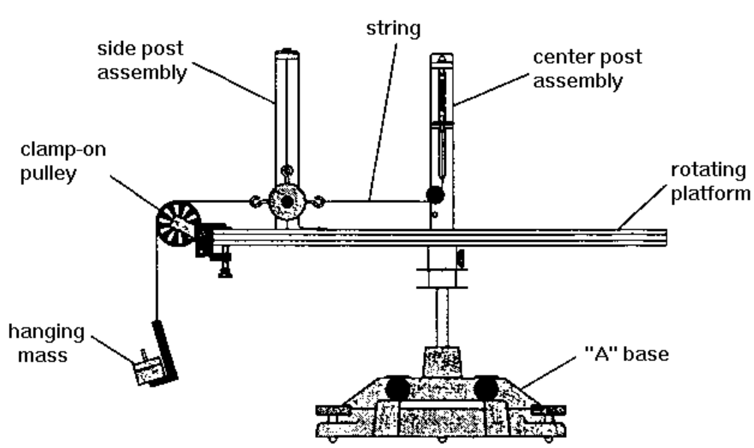
The centripetal force produces a centripetal acceleration on the body. Centripetal acceleration is related to the tangential velocity or the angular velocity by the following expression. Note that here *v* is the tangential velocity, ω is the angular velocity and *r* is the radius of the circle.

$$a_{centripetd} = \frac{v^2}{r} = \omega^2 r \qquad \text{where: } \frac{v}{r} = \omega$$

Combining this with the force equation provides the expressions being studied in this experiment.

$$F_{centripetd} = m\frac{v^2}{r} = m\omega^2 r$$

Remember that in this case the centripetal force is equal to the tension in the string.




**Centripetal Force Apparatus**

**Figure 3**

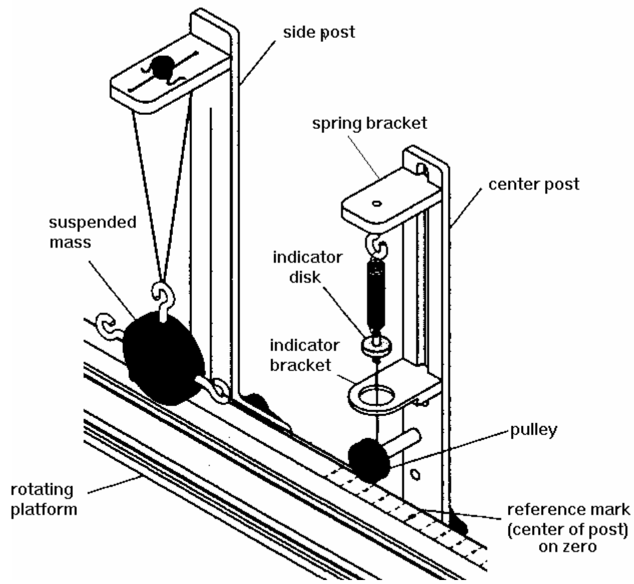


**Figure 4**

## Procedures:

### Part 1: Varying the Centripetal Force

The radius of rotation and the mass of the body will remain constant for this set of procedures.

1. Adjust the side post assembly along the track for the rotational radius specified in Table 1. Make certain the side post is exactly perpendicular to the track. Record this radius value.
2. Hang the suspended mass, with the two auxiliary masses attached, on the side post assembly.
3. Connect the suspended mass to the spring, on the center post, using a string. The string must go through the indicator bracket and around the pulley.
4. If necessary, attach the clamp-on pulley to the end of the track closest to the side post assembly.
5. Select a light weight mass hanger from the mass kit and place the first mass on it as specified in Table 1. Measure the combined mass and hanger using the balance and record the value.
6. Connect the mass hanger, with a string placed over the clamp-on pulley, to the suspended mass hanging from the side post.
7. Adjust the height of the suspended mass, on the side post assembly, until the string is parallel to the track. Adjust the clamp-on pulley until the connecting string is parallel to the track.
8. Adjust the spring bracket, on the center post, up or down until the suspended mass is hanging from the side post exactly perpendicular to the track.
9. Adjust the indicator bracket, on the center post, up or down until it aligns with the orange indicator disk attached to the spring.
10. Once everything is aligned, remove the clamp-on pulley and hanging mass from the string.
11. Follow the provided computer instructions to begin the computer data collection.
12. Turn on the power to the DC power supply. The voltage dial is used to control the rotation rate of the platform. Slowly increase the voltage, while watching the orange indicator disk, until the disk is aligned with the indicator bracket. Continue adjusting as necessary until a steady-state alignment between the orange indicator disk and the indicator bracket is reached.

## Procedures (cont.):

13. Once a steady-state condition is reached, allow the computer to collect approximately twenty seconds of measurements related to this rotation rate and then stop the collection process.
14. Turn the voltage dial, on the power supply, back to zero.
15. Follow the provided computer instructions to obtain the analyses of the data collected by the computer for this trial.

**Repeatable Steps**

1. Select the next mass from the mass kit as specified in Table 1 and add it to the mass hanger. Measure the total mass & hanger combination on the balance and record the value.
2. If necessary, attach the clamp-on pulley to the track and connect the mass hanger to the suspended mass with the string.
3. Adjust the spring bracket, on the center post, up or down until the suspended mass is hanging from the side post exactly perpendicular to the track.
4. Adjust the indicator bracket, on the center post, up or down until it aligns with the orange indicator disk.
5. Remove the clamp-on pulley and hanging mass.
6. Follow the provided computer instructions to begin the computer data collection.
7. Slowly increase the voltage, on the power supply, while watching the orange indicator disk. Adjust until the disk is aligned with the indicator bracket and a stead-state condition is reached.
8. Once a steady-state condition is reach, allow the computer to collect approximately twenty seconds of measurements related to this rotation rate and then stop the collection process.
9. Turn the voltage dial, on the power supply, back to zero.
10. Follow the provided computer instructions to obtain the analyses of the data collected by the computer for this trial.
11. Repeat these steps (1-11) each time increasing the hanging mass as specified in Table 1

### Part 2: Varying the Radius of Rotation

The centripetal force and the mass of the body will remain constant for this set of procedures.

1. Adjust the side post assembly along the track for a rotational radius as specified in Table 1. Make certain the side post is exactly perpendicular to the track. Record this radius value.
2. Hang the suspended mass, with the two auxiliary masses attached, on the side post assembly.
3. Connect the suspended mass to the spring, on the center post, using a string. The string must go through the indicator bracket and around the pulley.
4. If necessary, attach the clamp-on pulley to the end of the track closest to the side post assembly.
5. Using the specification in Table 1 select a mass hanger and masses from the mass kit. Measure the combined mass and hanger using the balance and record the value.
6. Connect the mass hanger, with a string placed over the clamp-on pulley, to the suspended mass hanging from the side post.
7. Adjust the height of the suspended mass, on the side post assembly, until the string is parallel to the track. Adjust the clamp-on pulley until the connecting string is parallel to the track.
8. Adjust the spring bracket, on the center post, up or down until the suspended mass is hanging from the side post exactly perpendicular to the track.

## Procedures (cont.):

9. Adjust the indicator bracket, on the center post, up or down until it aligns with the orange indicator disk attached to the spring.
10. Remove the clamp-on pulley and hanging mass attached by the string.
11. Follow the provided computer instructions to begin the computer data collection.
12. Turn on the power to the DC power supply. The voltage dial is used to control the rotation rate of the platform. Slowly increase the voltage, while watching the orange indicator disk, until the disk is aligned with the indicator bracket. Continue adjusting as necessary until a steady-state alignment between the orange indicator disk and the indicator bracket is reached.
13. Once a steady-state condition is reached, allow the computer to collect approximately twenty seconds of measurements related to this rotation rate and then stop the collection process.
14. Turn the voltage dial, on the power supply, back to zero.
15. Follow the provided computer instructions to obtain the analyses of the data collected by the computer for this trial.
16. Repeat these steps (1-15) each time increasing the radius as specified in Table 1.

### Part 3: Varying the Mass of the Rotating Body

The centripetal force and the radius of rotation will remain constant for this set of procedures.

1. Adjust the side post assembly along the track for a rotational radius as specified in Table 1. Record this radius value.
2. Also select the specified mass and hanger from the mass kit for the hanging mass. Measure the combined mass and hanger using the balance and record the value.
3. Remove both auxiliary masses from the suspended mass. Measure the value of the single suspended mass using the balance and record the value.
4. Hang the suspended mass from the side post assembly and connect it to the center post spring using the attached string.
5. If necessary, attach the clamp-on pulley to the track and connect the hanging mass to the suspended mass with the string.
6. Adjust the spring bracket, on the center post, up or down until the suspended mass is hanging from the side post exactly perpendicular to the track.
7. Adjust the indicator bracket, on the center post, up or down until it aligns with the orange indicator disk.
8. Remove the clamp-on pulley and the hanging mass attached by the string.
9. Follow the provided computer instructions to begin the computer data collection.
10. Slowly increase the voltage, on the power supply, while watching the orange indicator disk. Adjust until the disk is aligned with the indicator bracket and a steady-state condition is reached.
11. Once a steady-state condition is reached, allow the computer to collect approximately ten seconds of measurements related to this rotation rate and then stop the collection process.
12. Turn the voltage dial, on the power supply, back to zero.
13. Follow the provided computer instructions to obtain the analyses of the data collected by the computer for this trial.
14. Repeat these steps (1-13) each time increasing the mass of the rotating body as specified in Table 1.

## Table 1

| Varying the Centripetal Force | |
|---|---|
| Suspended Mass = 200 (grams) Radius of Rotations = .140 (meters) | |
| Trial # | Hanging Mass (grams) |
| 1 | 25 |
| 2 | 45 |
| 3 | 65 |
| 4 | 85 |
| 5 | 105 |
| **Varying the Radius of Rotation** | |
| Suspended Mass = 200 (grams) Hanging Mass = 50 (grams) | |
| Trial # | Radius of Rotations (meters) |
| 1 | .130 |
| 2 | .140 |
| 3 | .150 |
| 4 | .160 |
| 5 | .170 |
| **Varying the Mass of the Rotating Body** | |
| Hanging Mass = 50 (grams) Radius of Rotations = .140 (meters) | |
| Trial # | Suspended Mass (grams) |
| 1 | 100 (original mass) |
| 2 | 125 (combine 2 10gram and 1 5gram + original mass) |
| 3 | 150 (combine 1 auxiliary + original mass) |
| 4 | 175 (combine 2 10gram and 1 5gram + 1 auxiliary + original mass) |
| 5 | 200 (combine 2 auxiliary mass + original mass) |

## Data Analyses:

The following calculations and subsequent graphs will help demonstrate and explain the relationships being studied in this experiment.

1. Calculate the tension in the string originally set-up for each trial (using the hanging mass).
2. Calculate the centripetal force experienced by the suspended mass for each trial.

Part 1:

3. Graph the tangential velocity as a function of centripetal force (using the hanging mass string tension as the centripetal force).
4. Fit the graph with the appropriate type of trendline in excel including the equation and statistics.

Part 2:

5. Graph the angular velocity as a function of the radius of rotation.
6. Calculate the tangential velocity for each trial, in *meters per second*.
7. Graph the tangential velocity as a function of radius.
8. Fit each of the graphs with the appropriate type of trendline in excel including the equation and statistics.

Part 3:

9. Graph the tangential velocity as a function of the suspended mass.
10. Fit the graph with the appropriate type of trendline in excel including the equation and statistics.

**Experiment M20c: Centripetal Force and Uniform Circular Motion**

Student Name________________________________________

*Lab Partner Name*________________________________________

*Lab Partner Name*________________________________________

Physics Course________________________________________

Physics Professor________________________________________

Experiment Start Date__________________________________

| *Lab Assistant Name* | *Date* | *Time In* | *Time Out* |
|---|---|---|---|
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Experiment Stamped Completed

## Data Sheets: M20c: Part 1: Varying the Centripetal Force

**NAME: ____________________________** **DATE: _________________**

Radius (m): ________________________

Suspended Mass (kg): ________________________

| Trial# | Hanging Mass | Tension in String | Tangential Velocity | Standard deviation | Centripetal Force |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |

**Data Sheets: M20c: Part 2: Varying the Radius of Rotation**

**NAME: ____________________________ DATE: _________________**

Suspended Mass (kg): ________________________

Hanging Mass (kg): ________________________

Tension in String (N):________________________

| Trial# | Radius | Angular Velocity | Standard deviation | Tangential Velocity | Centripetal Force |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |

## Data Sheets: M20c: Part 3: Varying the Mass of the Rotating Body

**NAME: ______________________________ DATE: __________________**

Radius (m): __________________________

Hanging Mass (kg): __________________________

Tension in String (N): __________________________

| Trial# | Suspended Mass | Tangential Velocity | Standard deviation | Centripetal Force |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |