DUTCHESS COMMUNITY COLLEGE

Lab Report 8: How Does Mass, Velocity, & Radius Affect an Object Spinning in a Circle

PHY121

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Purpose

To explore the relationship between centripetal force and different variables like mass, velocity, and radius that contribute to centripetal force.

Theory

Uniform circular motion is the motion of an object in a circle at a constant velocity. Although the velocity of the object is constant, the direction is constantly changing in the circle, and thus there is acceleration. This specific type of acceleration, wherein the magnitude of velocity is constant but its direction is changing, is called *centripetal acceleration* and is determined with the following equation.

$$a_c = \frac{v^2}{r}$$

$\mathbf{a_c}$: Centripetal acceleration
v : Velocity of object
r : Radius of circle

Since there is an acceleration, there must be a force, so using Newton's Second Law, the formula for the *centripetal force* is given by:

$$F_c = m\frac{v^2}{r}$$

$\mathbf{F_c}$: Centripetal force
m : Mass of object
v : Velocity of object
r : Radius of circle

Velocity is equal to displacement over time. When dealing with circles, the magnitude of displacement will equal the circumference of the circle. Based off that, the formula for velocity of an object on a circular path is given by:

$$v = \frac{2\pi r}{t}$$

v : Velocity of object
r : Radius of object
t : Time for object to complete on revolution on circular path
r : Radius of circle

Procedure

Part 1

1. Measured 20 cm of **string** between **rubber stopper** and **tubing**.
2. Clipped **alligator clip** 1 cm below **tubing**.
3. Tied **mass hanger** and 45 g of weight to **string**.
4. ** Added more **alligator clips** to **string** to prevent it from going into **tubing**.
5. ** Practiced swinging **rubber stopper** in a horizontal circle such that the bunch of **alligator clips** stopped right at **tubing**.
6. Once comfortable with speed of swing, recorded time needed for 20 cycles (complete revolutions) to pass.
7. Calculated time for 1 revolution by dividing time recorded by number of cycles timed for (20).
8. Calculated *centripetal force* using weight of hanging mass.
9. Calculated *average velocity* using *average period.*
10. Repeated steps 3 through 9 for 60 g, 70 g, and 80 g of weight.

Part 2

11. Measured mass of **rubber stopper**.
12. Calculated *expected velocity* for **rubber stopper** using its measured mass.
13. Determined *percent error* between expected and *measured period.*

Part 3

14. Placed 70 g on 5 g **mass hanger**.
15. Measured 0.1 m for length of **string** between **rubber stopper** and **tubing**.
16. Repeated steps 4-9 for 0.15 m, 0.2 m, and 0.3 m.

** **INCORRECT**: Deviated from lab instructions. The tubing string was supposed to be swung at a speed such that the alligator clips stayed 1 cm below the tubing.

Calculations & Graphs

Tangential Velocity

$$v = \frac{2\pi r}{t} \tag{1}$$

v : velocity
r : radius of circle
t : time for 1 revolution

Sample Calculation

using part 1 data with 50 g of weight

$$v = \frac{2\pi r}{t}$$

$$= \frac{2\pi(0.2 \text{ m})}{0.3426 \text{ s}}$$

$$v = \boxed{3.666 \text{ m/s}}$$

Centripetal Force

$$\mathrm{F_c} = \frac{mv^2}{r} \tag{2}$$

$\mathbf{F_c}$: centripetal force
m : mass of object
v : tangential velocity of object
r : radius of circle

Sample Calculation

using expected velocity in part 2 with 50 g

$$\mathrm{F_c} = \frac{mv^2}{r}$$
$$= \frac{(0.012 \text{ kg})(2.858 \text{ m/s})^2}{0.2 \text{ m}}$$
$$\mathrm{F_c} = \boxed{0.49\,\mathrm{N}}$$

Average Value Formula

$$\overline{a} = \frac{\text{sum of values}}{\text{total \# of values}}$$

Sample Calculation
average period using Part 1 at 50 g

$$\overline{a} = \frac{\text{sum of values}}{\text{total \# of values}}$$

$$= \frac{0.334 \text{ s} + 0.3515 \text{ s}}{2}$$

$$\overline{a} = \boxed{0.3426\,\text{s}}$$

Percent Error

$$\text{PD} = \left| \frac{\text{measured - actual}}{\text{actual}} \right| \text{ x } 100\% \tag{3}$$

Sample Calculation
percent error between theoretical period and measured period using values from part 3

$$\text{PD} = \left| \frac{\text{measured - actual}}{\text{actual}} \right| \text{ x } 100\%$$

$$\text{PD} = \left| \frac{0.3426 \text{ s - } 0.5071 \text{ s}}{0.5071 \text{ s}} \right| \text{ x } 100\%$$

$$PD = \boxed{32.41\%}$$

Tables

Table 1: Part 1

Mass (kg)	0.05	0.06	0.07	0.08
Trial 1 Period (s)	0.334	0.329	0.332	0.359
Trial 2 Period (s)	0.3515	0.353	0.354	0.3295
Average Period (s)	0.3427	0.341	0.343	0.3442
Average Velocity (m/s)	3.666	3.685	3.663	3.65
Expected F_c (N)	0.49	0.588	0.686	0.784
Actual F_c (N)	1.072	1.083	1.07	1.062

Table 2: Part 2

Mass (kg)	0.05	0.06	0.07	0.08
Theoretical Velocity (m/s)	2.478	2.715	2.932	3.135
Theoretical Period (s)	0.5069	0.4627	0.4284	0.4007
Actual Period (from part 1) (s)	0.3427	0.341	0.343	0.3442
Percent Error	32.39	26.31	19.94	14.1

Table 3: Part 3

Radius (m)	0.1	0.15	0.2	0.3
Trial 1 Period (s)	0.273	0.7	0.5015	0.5625
Trial 2 Period (s)	0.252	0.4575	0.5015	0.568
Average Period (s)	0.2625	0.5787	0.5015	0.5652
Expected Velocity (m/s)	2.146	2.629	3.035	3.718
Average Velocity (m/s)	2.393	1.628	2.505	3.335
Percent Error Velocity (%)	11.50	38.07	17.46	10.30
Expected F_c (N)	0.735	0.735	0.735	0.735
Actual F_c (N)	0.9133	0.2818	0.5004	0.5913
Percent Error F_c (%)	24.25	61.65	31.91	19.55

Graphs

Figure 1: Part 1: Actual F_c vs Actual Average Velocity

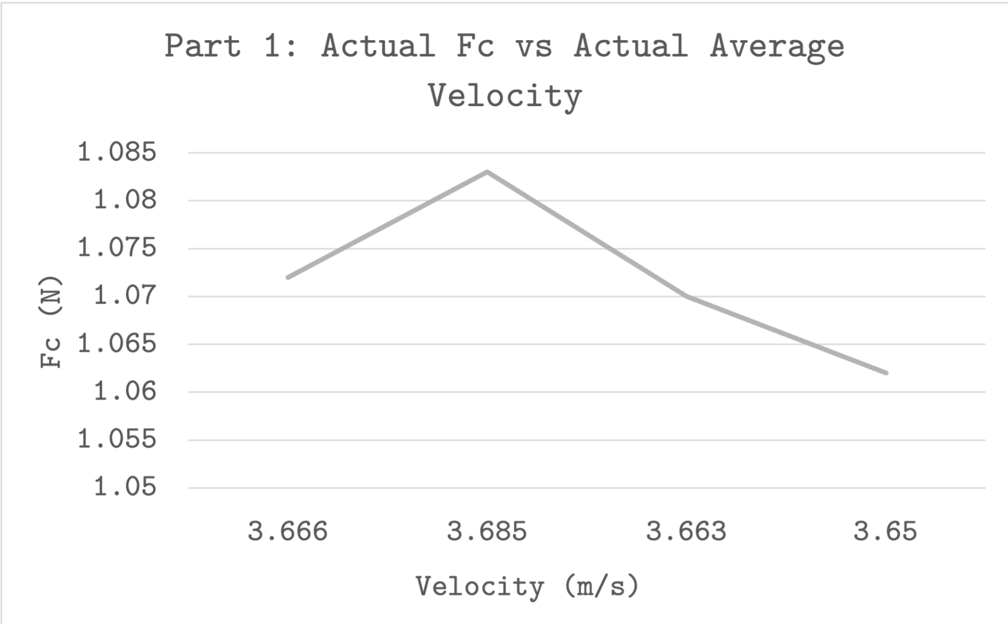


Figure 2: Part 1: Expected F_c vs Expected Velocity

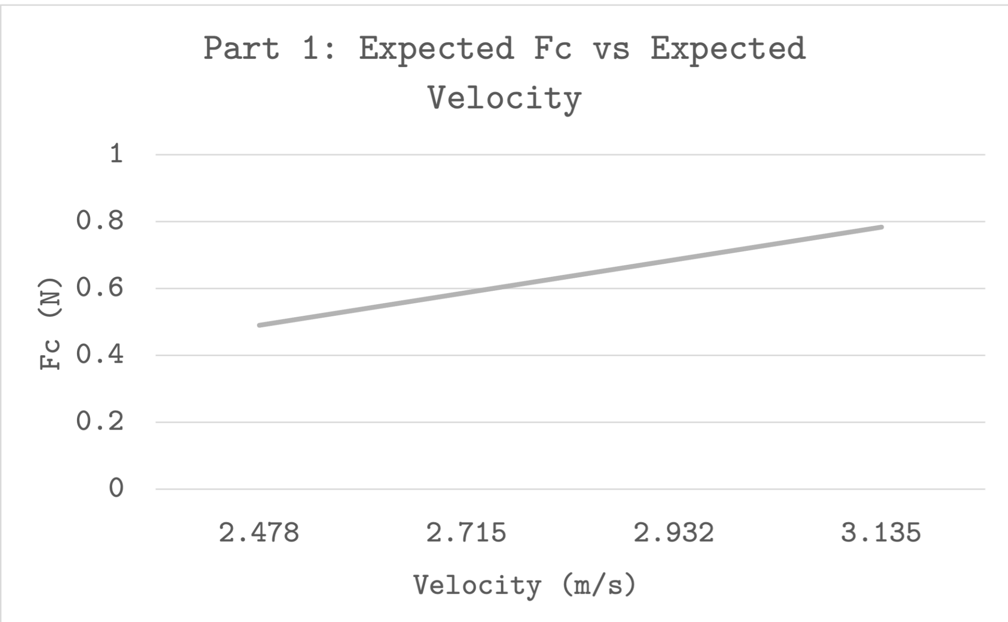


Figure 3: Part 3: Radius vs Actual Average Velocity

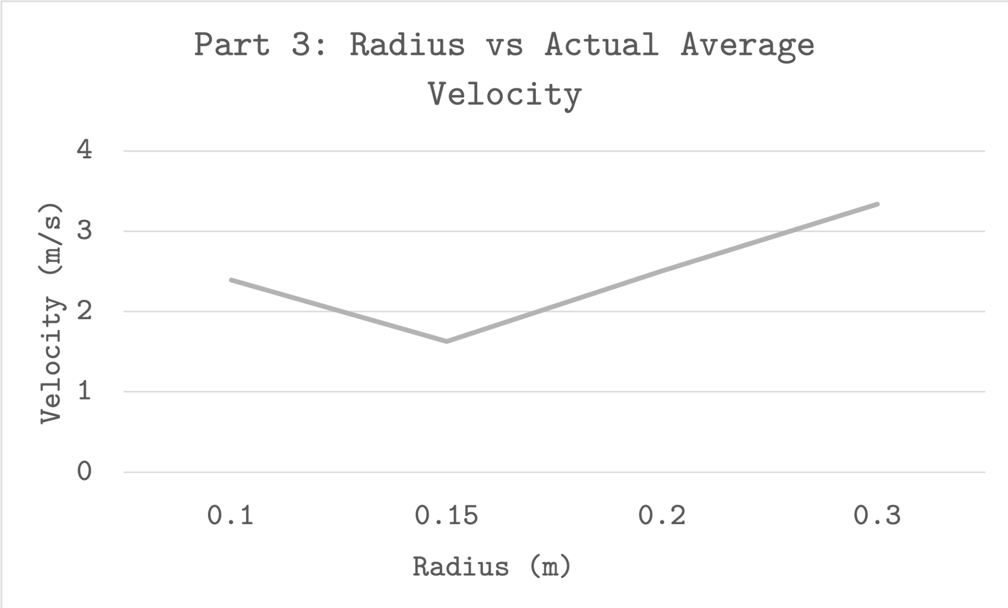
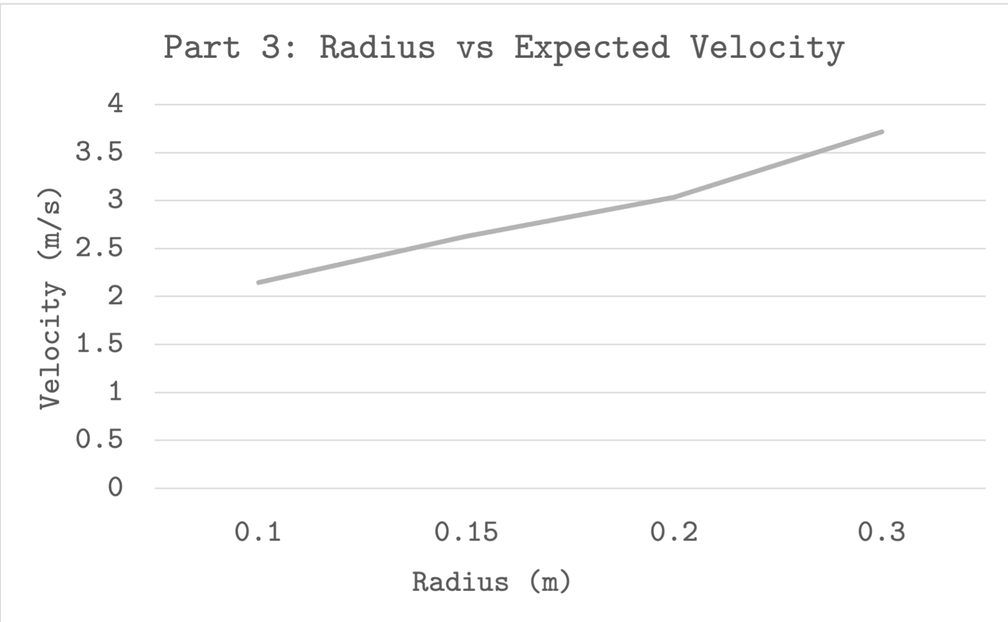


Figure 4: Part 3: Radius vs Expected Velocity



Questions

1. **Which trials in part 1 did you seem to have the most difficulty with? Was it the heavier masses or the lighter masses?**

   We had more trouble with the lighter masses.

2. **Describe some ways that error was present in your lab today.**

   The biggest source of error in the lab was not following directions properly. Instead of swinging the rubber stopper such that the alligator clip remained 1 cm below the tubing, we attached MORE alligator clips and swung the stopper such that the centripetal force exceeded the weight of the stopper below. Our measured velocity ended up being way higher and consistent than it should have been.

3. **Which experiment (part 1, 2, etc.) did you have the most difficulty with, why do you think that was the case?**

   Since we didn't follow directions properly in part 1, part 3 ended up being the most difficult. I think this was the case because as the radius increased, we needed to find the right speed to balance the weight of the hanging mass at the bottom. We got close but the results would have aligned with our expectations more if we practiced doing the experiment properly the first time.

4. **From what you saw today, in the data you collected and the graphs you made, what type of relationship exists between centripetal force and the velocity?**

   The data shows that the centripetal force increased as the velocity increased, so they're directly related to each other.

Conclusion

The purpose of this lab was to explore the relationship between centripetal force and different variables like mass, velocity, and radius that contribute to centripetal force. To do so, we tied a rubber stopper to a string, and the other end of the string through a tube, to a hanging mass with a weight placed on it. By clipping an alligator clip 1 cm below the tube, and then spinning the rubber stopper at such a speed that the alligator clip stayed in place, we could explore the relationships between centripetal force and different variables.

Unfortunately, we did not initially conduct the experiment as described above. Instead of swinging the rubber stopper at just the right speed sch that the alligator clip would remain 1 cm below the tubing, we swuing it much faster, increasing the centripetal force more than necessary, and completely negating the weight of the hanging mass. The result of this error can be seen in our data. Taking a look at Table 1 and Figure 1, our values for the velocity of the rubber stopper were incredibly consistent for every 10 g of weight we added to the hanging mass. This should not have been the case: instead of our velocity, and in turn, the centripetal force, increasing alongside the weight of the hanging mass, it stayed mostly the same through out (see Table 1 and Figure 1). Because the weight of the hanging mass increased, to keep the alligator clip 1 cm below the tubing, balancing the centripetal force and weight of the hanging mass, we would need to increase the velocity of the rubber stopper by swinging it faster, as Figure 2 shows. Table 2 shows what the actual velocity of the rubber stopper should have been for the centripetal force to equal the weight of the hanging mass.Our own results for velocity were off by as much as 30% (see Table 2). This experiment would need to be recreated again, with the directions followed more closely, to get data that better aligns with expectations.

In part 3 we observed the relationship between radius, velocity, and centripetal force. Since we were increasing the radius between each trial, based off equation 2 we'd expect the velocity to increase along with the radius to equal the weight of the hanging mass. While we managed to follow instructions more closely, we did not sufficiently practice our swings, so our values are still quite far from expectations. For example, while overall the velocity increased between trials, when the radius was 0.15 m, we ended up with a velocity of more than 35% difference with expected values (see Table 3 and Figure 3). Once again, we'd need to repeat this experiment to get values that align more with expectations. Since the weight of the hanging mass did not change between trials, we'd expect the centripetal force to be about the same throughout. Since velocity is directly linked to centripetal force, the percent difference between our actual and expected values for centripetal force are all more than 10%, reaching as high as 60% (see Table 3).

We were not able to directly confirm out hypotheses based on the results of our experiments, due to incorrectly following instructions. However, using equations 1 and 2, we determined expected values (see Figure 2 and Figure 4). Considering our results, there are a few things I would do differently besides just following directions properly.

The biggest source of error in this lab was undoubtedly human error. We incorrectly followed instructions leading to results that deviated a great deal from expectations. To prevent this mistake from happening in the future, we need to confirm with the lab instructor early on that we're conducting the experiment correctly. We interpreted the instructions in the lab differently than intended, so confirming with the lab instructor our interpretation would have prevented us from making such a mistake. Additionally, we could have checked in with other lab groups to see if their data followed similar trends as ours. For instance, in part 1 of the lab, had we checked with other groups and seen that all their velocities were increasing, we would know immediately that we were doing something incorrect.