Revision 1

The Effect of the Radius of a String on the Frequency of an Object in Uniform Circular Motion

Tanner Boyle

Partner: Isaac Barbeau

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Mrs. Macintosh

SPH4U

Purpose:

The purpose of this investigation is to determine the effect of the radius of the string on the frequency of rotation for the circular motion of the attached object.

Hypothesis:

If the radius of the string from the origin of rotation increases, then the frequency will decrease because frequency has an inverse relationship to the radius.

Variables and Controls:

Independent Variable	Dependent Variable	Constants with Justification
Radius (m)	Frequency (Hz)	Mass of Rubber Stopper – The mass of the rubber stopper remained the same each trial because it affected the frequency. The force of Tension – The force of tension remained the same each trial because it affected the frequency.

Supplies and Equipment:

- 1m String
- Glass tube
- 200g mass
- Rubber stopper
- Balance
- Highlighters
- Timer

Safety Considerations:

- Wear safety glasses
- Be fragile with glass wear
- Wear closed-toed shoes
- Be aware of objects swinging around your head

Procedure:

1. All materials and equipment needed for the experiment were collected and safety equipment was put on.
2. The balance was zeroed and used to weigh the rubber stopper
3. 1m of string was measured and cut and one end was tied through the rubber stopper. The string was then fed through the glass tube
4. A loop was tied on the remaining end of the string and the 200g mass hung from it.
5. 5 Different radii were measured and marked with 5 different colors of highlighter on the rubber stopper end of the glass tube.
6. The timer was ready while the rubber stopper was swung by the glass tube in a horizontal circle at a uniform velocity at the desired radius at the top of the glass tube. When ready the timer was queued, and each revolution was counted for 30 seconds. This was done 3 times and the trials were recorded.
7. Step 6 was repeated 5 times at the different marked radii on the string.

Observations:

Quantitative Observations

Radius	Trials	Revolutions	Frequency	Avg. Frequency	Theoretical Frequency	Percentage Error
0.15m	1	95	3.17	3.26 Hz	3.32 Hz	1.8%
	2	101	3.37			
	2	97	3.23			
0.25m	1	68	2.27	2.39 Hz	2.57 Hz	7.0%
	2	71	2.37			
	3	76	2.53			
0.35m	1	62	2.07	1.99 Hz	2.17 Hz	8.3%
	2	57	1.90			
	3	60	2.00			
0.55m	1	52	1.73	1.72 Hz	1.73 Hz	0.6%
	2	53	1.77			
	3	50	1.67			
0.65m	1	43	1.43	1.47 Hz	1.59 Hz	7.5%
	2	45	1.50			
	3	44	1.47			

Qualitative Observations

- As the radius increased the rubber stopper swung slower
- The faster the rubber stopper swung the more horizontal it was, as it got slower it swung in a cone shape
- The string frayed over time and began to screech at the top of the glass tube

Calculations:

Frequency:

$$f = \frac{revolutions}{time}$$

$$f = \frac{95}{30}$$

$$f = 3.17\ Hz$$

Average Frequency:

$$f = \frac{3.17 + 3.37 + 3.23}{3}$$

$f = 3.26\ Hz$ (2.39, 1.99, 1.72, 1.47)

Percentage Error:

$$\%\ error = \frac{experimental - theoretical}{theoretical} \times 100$$

$$\%\ error = \frac{3.26 - 3.32}{3.32} \times 100$$

$\%\ error = 1.8\%$ (7.0, 8.3, 0.6, 7.5)

Theoretical Frequency:

$$f = \sqrt{\frac{F_T}{4\pi^2 m_{rs} r}}$$

$$f = \sqrt{\frac{m_w g}{4\pi^2 m_{rs} r}}$$

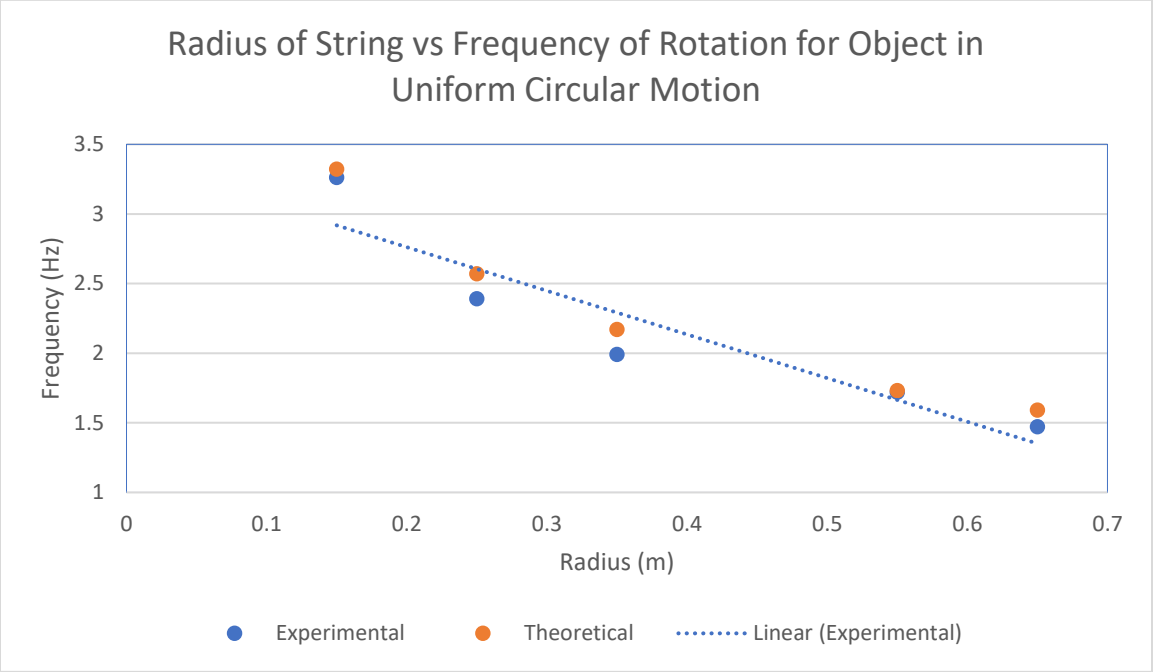
$$f = \sqrt{\frac{0.2(9.8)}{4\pi^2 (0.03)(0.15)}}$$

$$f = \sqrt{\frac{1.96}{0.177}}$$

$$f = \sqrt{11.07}$$

$$f = 3.32$$

Graph:



Conclusion:

According to the trend line in the scatter plot, the graph goes in a negative direction based on the radius of the string. There is a linear relationship between most of the variables, most data points are close to the trend line, therefore there is a strong relationship between results and the trend line.

The trend line supports the hypothesis. This is shown because when the radius of the string was increased, the frequency of rotation decreased. This is because the frequency is affected by the radius by a factor of $\frac{1}{r}$ in the equation to calculate the requency.

The results

Errors:

Error	Effect	Improvement
The velocity wasn't 100 percent uniform because of human error.	This affected the radius of the string which affected the overall frequency of trials.	Use a machine that spins objects in a uniform motion.
The string frayed and unraveled overuse.	This affected the radius of the string because it would increase it as it unraveled and prayed more.	Use tight fishing line instead of a string or weaved material like string.
The counted revolutions weren't always accurate because it was hard to read at fast speeds.	This would increase the experimental frequency of the trials.	Use a LabQuest sensor to detect the object as it was swinging, or record it in slow-motion and count it.