Jonathan Lam
Mr. Ecsedy
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# **Pendulum Lab** Report

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## Introduction

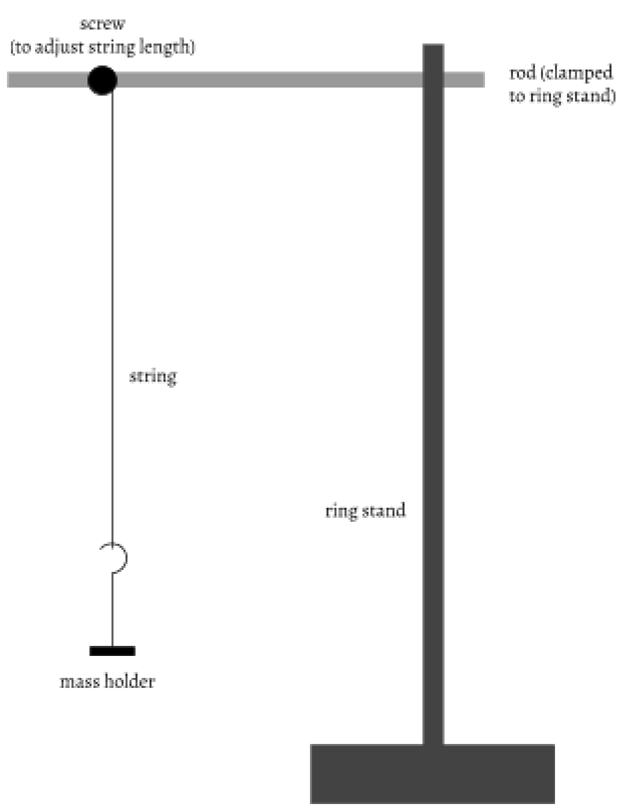
<u>Lab Partners</u>: Foster Rowberry, Nikitha Edupuganti

<u>Purpose</u>: The purpose of this lab is to determine the effect of the radius (distance from mass to axis), mass, and amplitude (initial angle) have on the period of a pendulum.

<u>Procedure</u>: We had a rod that was clamped perpendicular to a ring stand. The rod was clamped to the top of the ring stand to give maximum clearance for the pendulum. We attached the string by putting it under a screw, so that it was an adjustable length, and we attached a 50.g mass holder to the bottom of the string. The pendulum swung parallel to the ring to avoid collisions. (See illustration below).

We tested each variable by keeping the other two constant, and then running three trials at each specific variable level. The mass only considered the mass of the mass hanger and weights, not the string. The radius (distance from the axis to the mass) was measured from the screw to the approximate center of mass of the masses. The amplitude was measured using a protractor at the top of the string. We measured the time of ten periods using an iPhone timer, and then divided by ten to get an approximate period length.

<u>Experimental Setup</u>



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## Data and Observations

Notes on Data:

- Pendulum radius measured from estimated center of mass to the rotation axis.
- The mass of the string is negligible and not considered in mass measurements.
- Amplitude is measured in degrees from the vertical.
- The data rows labelled with an asterisk (*) are the same trial with the initial conditions for all three variables (mass = 0.050kg, amplitude = 10° and radius = 0.0620m).

Data for Changing Mass vs. Pendulum Period (radius = 0.6200m, amplitude = 10°)

| Mass (kg) | Ten Period Time (s) | | | Average Ten Period Time (s) | Average Period (s) |
|---|---|---|---|---|---|
| | Trial 1 | Trial 2 | Trial 3 | | |
| 0.050* | 16.16 | 14.71 | 15.05 | 15.31 | 1.531 |
| 0.100 | 15.98 | 16.08 | 15.95 | 16.00 | 1.600 |
| 0.150 | 16.18 | 16.41 | 16.20 | 16.26 | 1.626 |
| 0.200 | 16.18 | 16.31 | 16.28 | 16.26 | 1.626 |

Data for Changing Amplitude vs. Pendulum Period (radius = 0.6200m, mass = 0.050kg)

| Amplitude (°) | Ten Period Time (s) | | | Average Ten Period Time (s) | Average Period (s) |
|---|---|---|---|---|---|
| | Trial 1 | Trial 2 | Trial 3 | | |
| 5 | 16.08 | 15.74 | 16.17 | 16.00 | 1.600 |
| 10* | 16.16 | 14.71 | 15.05 | 15.31 | 1.531 |
| 20 | 16.08 | 16.35 | 16.01 | 16.15 | 1.615 |
| 30 | 16.57 | 16.31 | 16.61 | 16.50 | 1.650 |
| 40 | 16.33 | 16.47 | 16.27 | 16.36 | 1.636 |

Data for Changing Radius vs. Pendulum Period (mass = 0.050kg, amplitude = 10°)

| Radius (m) | Ten Period Time (s) | | | Average Ten Period Time (s) | Average Period (s) |
|---|---|---|---|---|---|
| | Trial 1 | Trial 2 | Trial 3 | | |

| | | | | | |
|---|---|---|---|---|---|
| 0.2250 | 9.60 | 9.68 | 9.15 | 9.48 | 0.948 |
| 0.3800 | 12.08 | 12.24 | 12.44 | 12.25 | 1.225 |
| 0.6200* | 16.16 | 14.71 | 15.05 | 15.31 | 1.531 |
| 0.8900 | 17.97 | 17.23 | 17.57 | 17.59 | 1.759 |
| 0.9100 | 18.65 | 19.11 | 19.28 | 19.01 | 1.901 |

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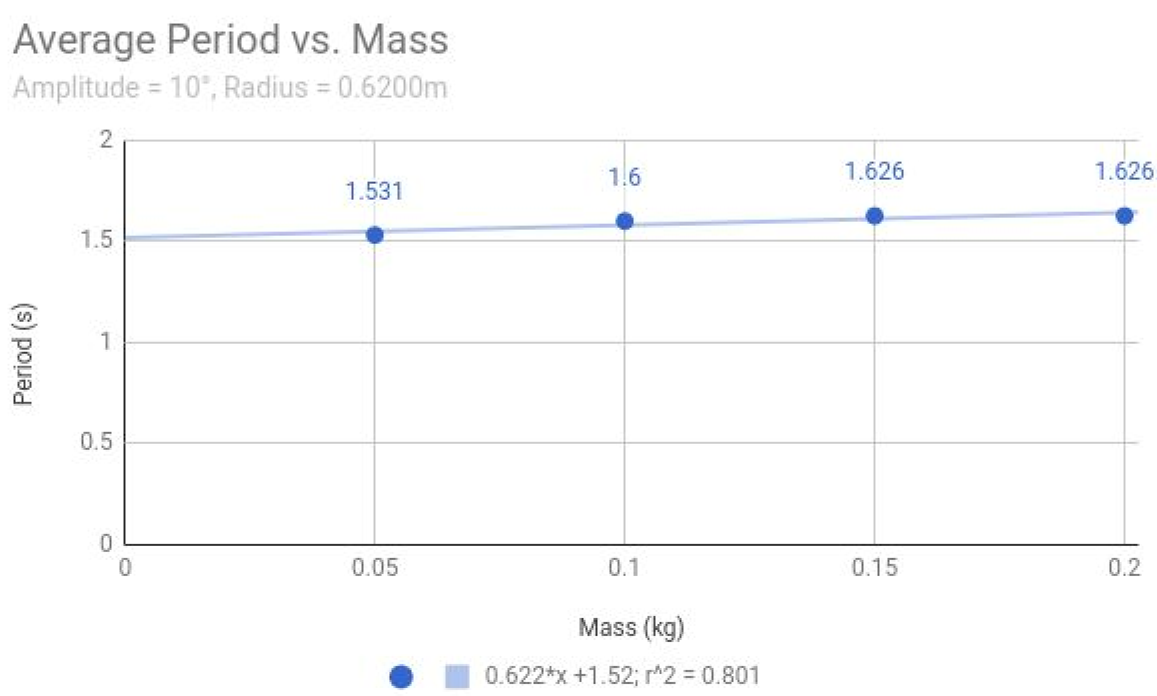
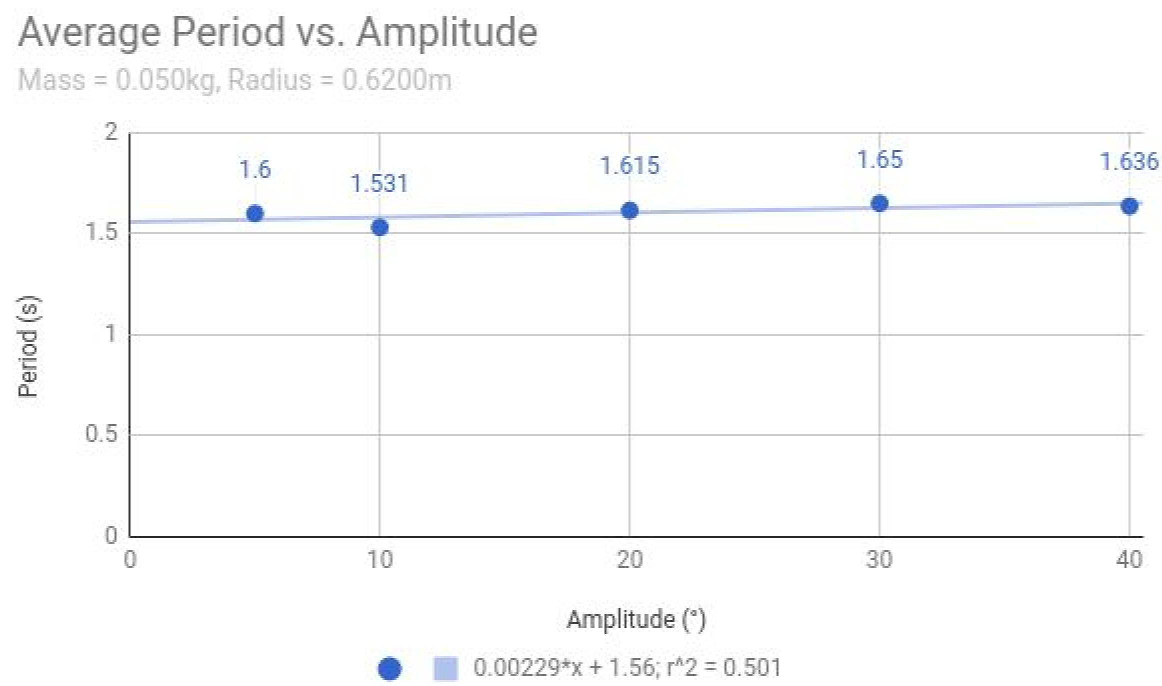
## Calculations / Graphs

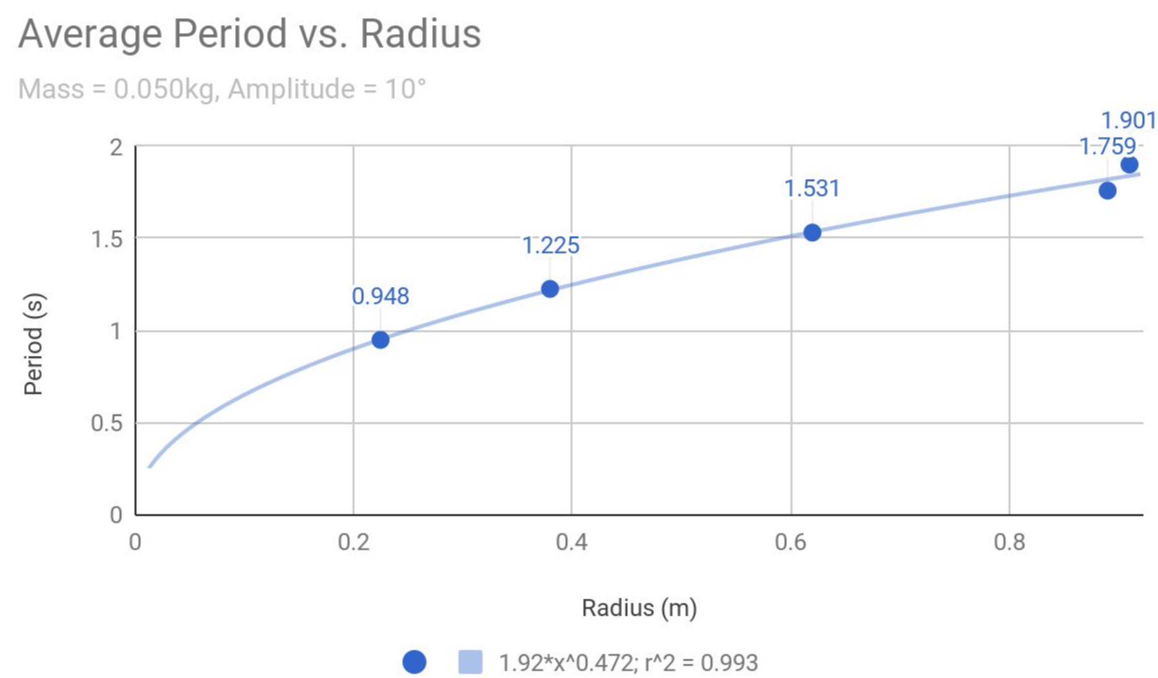
### Calculations

Average period = Average ten period time / 10

### Graphs



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Results and Conclusion

<u>Data Analysis</u>

We observed a very slight positive linear correlation (almost constant linear graphs) in the period-mass and period-amplitude graphs. Their respective slopes are 0.622s/kg and 0.00229s/degree, respectively, meaning that there is almost no change in period if the mass (kg) or amplitude (degrees) change. This makes sense, because increasing either the mass or amplitude (which increases the height) increases the gravitational potential energy of the mass (as gravitational potential energy = mgh). If we set h=0 at the equilibrium point, this means that all of the gravitational potential energy is converted to the kinetic energy by the bottom of the swing, meaning that: $mgh = \frac{1}{2}mv^2 \Rightarrow gh = \frac{1}{2}mv^2 \Rightarrow v^2 = \frac{2g}{m}h \Rightarrow v^2 \propto h$. This means that changing the mass of a pendulum will not affect its velocity and period, and increasing or decreasing its height will also increase or decrease its velocity so that the period is the same. Thus, this data and this calculation show that there is no effect of the amplitude or mass of the pendulum on its period. (The slight positive slopes of these two graphs can be accounted for under the "potential errors" section below.) At a radius of 0.6200m, the period is roughly 1.54s, independent of amplitude or mass.

When radius is changed, there is a clearer positive correlation. I ran a linear, polynomial, exponential, and power regression on the data, and it seems that a power regression with an equation of $period = 1.92 \times radius^{0{,}472}$ fit best, with a correlation coefficient $r^2 = 0.993$. (Because the power is very close to 0.5, we can approximate it as a square-root correlation.) This makes sense, because as the radius gets closer to zero, the period should also approach zero. A linear or exponential correlation would not make sense because they would give a positive period for a zero-radius pendulum, and a logarithmic correlation would not make sense because it would give a negative period for a positive radius close to zero.

By these reasonings, the period of this pendulum can be roughly modelled by the equation $period = 2sm^{-0.5} \times \sqrt{radius}$, where period is measured in seconds and radius is measured in meters.

<u>Potential Errors</u>

We had one potential outlier in our data: the first trial that we conducted. This was the asterisk-marked trial, and its values seem low and cause both the period-mass and period-amplitude graphs to have a little slant, when it makes sense that they should not (see above in data analysis). This single trial included the only two time measurements that were below 15.7s, in both of these tables, when all of the other values were in the low- to mid-16s region. Unfortunately, because this trial included all of the "initial conditions" of the variables we were conducting, it appears in all three data tables. This is probably because we were not used to measuring the period yet and stopped the time before the pendulum reached the top again. Re-measuring this one trial would probably correct the slightly-positive slopes in both of the first two graphs.

Another possible source of error is with the unaccounted friction and mass of the string. We assumed that the pendulum is roughly frictionless, but as the amplitude (and thus the speed) of the pendulum mass increases, or as we add masses and increase the surface area of the object, there is a slight increase in air resistance. This may cause slightly longer period times for the trials with higher amplitudes or masses (which may be the source of the slight positive slopes in either of these graphs). Similarly, we assumed the string was massless, but its mass may slightly increase the overall mass of the pendulum and change the center of mass of the pendulum, especially if the added masses are small, causing unexpected results. We can avoid this by using larger masses, so that the mass of the string is more negligible.

## Conclusion

We learned that changing the amplitude and mass of a (frictionless) pendulum will have no effect on its period, but that changing the radius has a square-root correlation with the period length.