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Evidence and Experimental Outcomes

I.Developing an Experimental Model

a. Determine IVs not to include in the mathematical model and provide evidence for decision

i. Tested IVs should not be included: mass, angle of release

ii.

- Angle: The period is not impacted by the angle of release

Control Variables (CV):

- mass: 70 g
- length: 32 cm

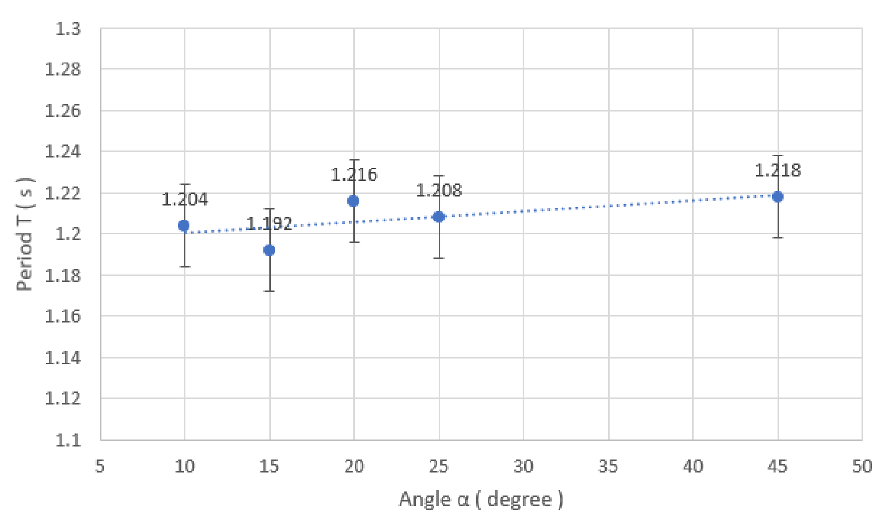


Fig 1: The effect of angle on period

- Mass: The period is not impacted by the mass

Control Variables (CV):

- length: 32 cm
- angle: 25 degrees

d. Insert error bars

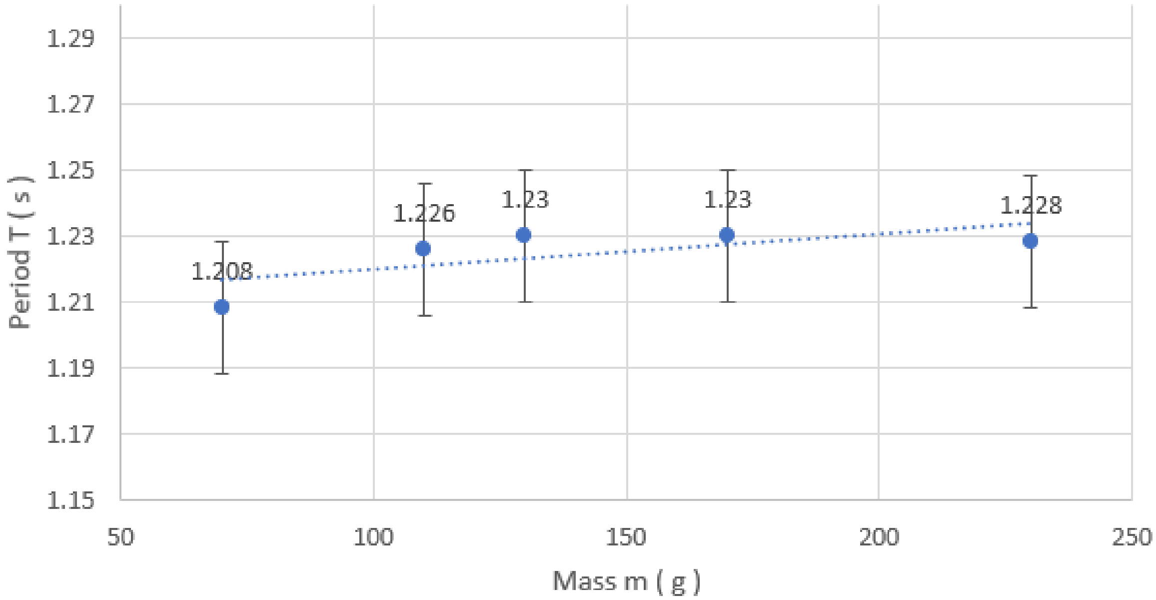


Fig 2: The effect of mass on period

- The error bars are too small to be seen

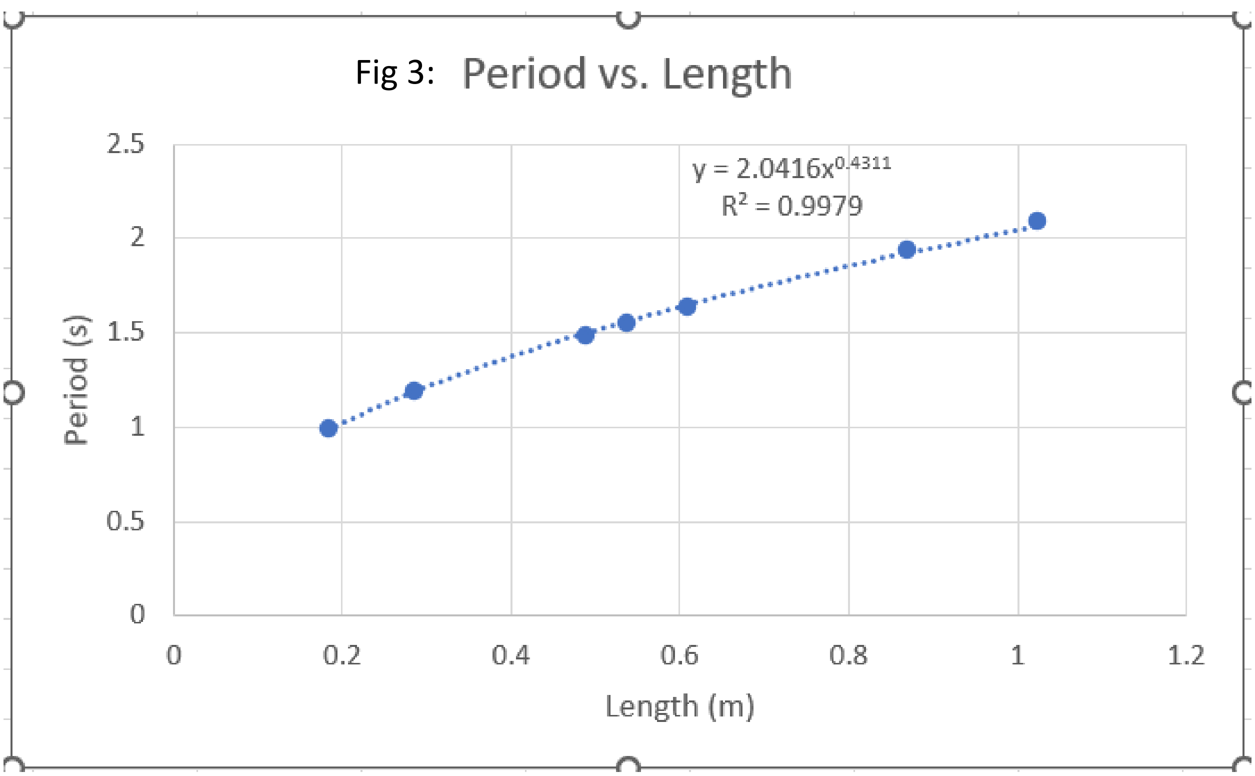


Fig 3: Period vs. Length

e. Determine the relationship between the IV and DV

1. Look at the plotted points.

- Is the relationship between the period (DV) and IV linear or non-linear? Does a line or curve best fit the data? Consult the chart of common graphs on Canvas if suggestions are needed.

→ The relationship between the period (DV) and length (IV) is non-linear. The trendline power curve best fits the data with the R^2=0.9979 close to 1

3.

T = 2.0416 (s/m) * L (m)0.4311

e. Compare your experimental mathematical model with the established scientific model.

In your lab records, describe what is similar between your experimental model and the scientific

model (T = 2πsqrt/(l/g)

. Here are some ideas to consider:

i. Are the same variables included in both models? If so, is the mathematical relationship between

these variables the same in both models?

- the variables included in both models are the same. y is T, x is l, and the constant in experimental model (2.0416) is approximately (2pi/sqrt(g) with g=9.8 m/s^2). This is after the sample model (T=(2pi)sqrt(l/g) has been converted into (T=((2pi/sqrt(g)/l^0.5)

ii. Are the same variables (IVs) excluded from both models suggesting "no correlation" exists?

- the variables (m/angle) in the experimental model are excluded as they didn't show any significant fluctuation in the results. This is also true in sample model as the equation didn't include mass and angle

iii. Is the coefficient the same in both models? In order to answer this, you will need to calculate the

numerical coefficient in the scientific model for pendulums on earth, where g = 9.80 m/s2. Discuss

how this calculated value in the scientific model compares to the coefficient in your model. If

there are large differences, discuss what may account for these differences.

- The coefficient calculated in the sample model after taking 2pi/sqrt(g) is 2.007, and the coefficient model constant is 2.0416. This is not significant difference, when taken into account other factors like human errors

II. Making sense of your experimental model

Group's Experimental Model (including conditions): T = 2.0416*(L^0.4311) angle held constant 10 degrees

pendulum length L

Experimental relationship from group: $T = 2.0416(L^{0.4311})$

The scientifically established relationship:

$$T = 2\pi\sqrt{\frac{L}{g}}$$

Physical explanation for why relationship makes sense: The longer the Length of the rope is, the more the bob must travel to complete one period, which would increase the time for each period.

mass of bob M

Experimental relationship from group: no correlation

The scientifically established relationship: no correlation.

Physical explanation for why relationship makes sense: since an object's falling velocity is only dependent on the gravitational constant, and not its mass, it makes sense that the time for the period to not be affected.

angle of release θ

Experimental relationship from group: $not\ correlated\ (\theta < 15)$.

The scientifically established relationship: $not\ correlated\ (\theta < 15)$

Physical explanation (done for you): The equation, $T = 2\pi\sqrt{\frac{L}{g}}$, is derived from Newton's 2nd Law of Rotation and holds only when the pendulum undergoes simple harmonic motion, which occurs for $\theta < 15^o$. This simulation compares the motion of the pendulum for small and large angles.

acceleration due to gravity g

Experimental relationship from group: Group was not able to test this IV.

The scientifically established relationship: $T \propto \frac{1}{\sqrt{g}}$ when L is constant and $\theta < 15^o$

Physical explanation (done for you): When g is smaller, such as on the moon, the bob will accelerate downward at a smaller rate, taking longer to complete one oscillation for the same angle of release θ and pendulum length L. It makes sense then that g should be in the denominator.

Period of Pendulum (T)

III. Final Wrap-up Question

a.

1. The measurement collected when testing each IVs can be trusted. Since we record many periods with each case so the period collected is guaranteed the same when reproduction of the experiment is made, and the uncertainty of the photogate was 0.001s, which mean each period measured was not overlapped with the other so we can conclude that the result was good. Each of the point on the graph is close to the trendline as well.
2. The equation is relatively trustable since the graphed line is close to each point on the graph, the R^2=0.9979 which is high, indicates that the trendline can be trusted. The range of IV tested is from 0.2m to 1.2m which is wide and can test different values. The equation that the Excel gave was relatively close to the established equation and comparing to other groups, we also have a close-numbered factors in the equation. All of this guarantees the level of trust in our equation.

b. Limitations

- Range of test: our tested range was only 0.2m to 1.2m so our conclusion does not apply to the extended range.
- Values chosen for CVs were listed as angle: 25 deg; mass: 70g. So, the conclusion can only be applied to these set of values

Discussion and Conclusion

a. Research question

The question for the lab is to figure out what impacts the period of pendulum. To address this question, length of the string, mass, and angle were tested.

b. How did your group answer the research question?

1. In the fig 1 and fig 2, the plot and error bar show that the period seems to be the same for each change in the angle or mass because the range of uncertainty overlap. As a results, the angle and mass are not related to the period of pendulum. In the fig 3, however, the period increases when the length of the string increases. With the very small error bar, the range of uncertainty does not overlap. So that, the length of the string is related to the period of pendulum.

2. Experimental model:

$T = 2.0416(s/m) \times L^{0.4311}$

Condition model is known to hold:

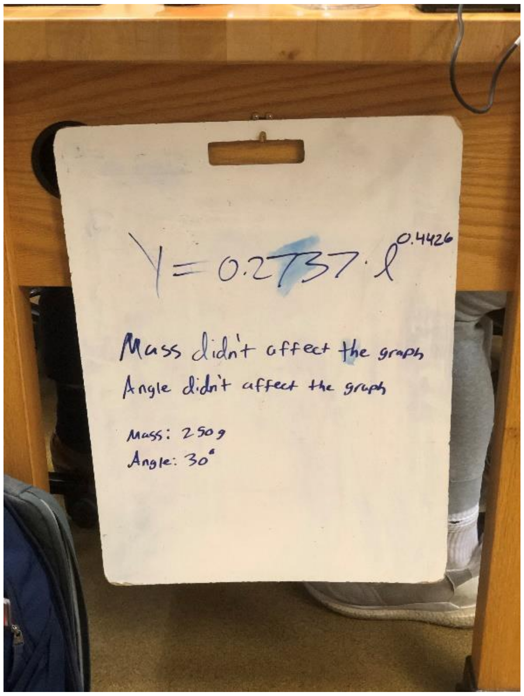
Mass: 210g

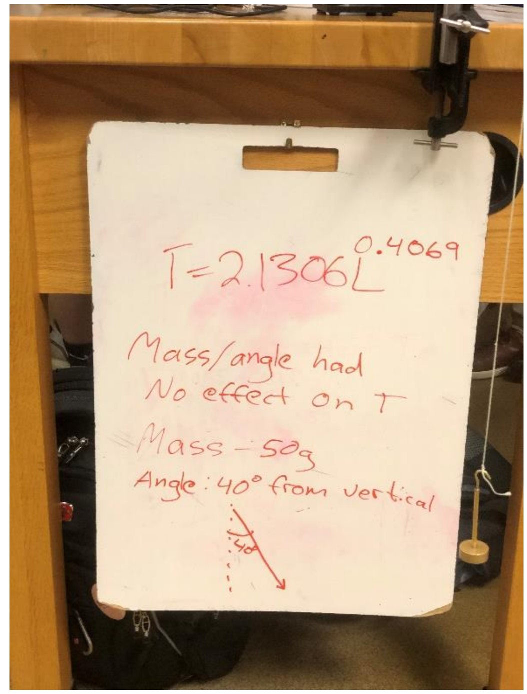
Angle: 30 degrees

c. Should a reader trust your answer to the research question?

1. The data collected in each experiment should be trusted. For the change in angle and mass, the experiment was conducted with significant different angle and mass for 5 times. However, the data point overlaps each other show that the angle and mass are not related to the period. In the experiment with the change in length of string, the uncertainty error bar is so small and the data plots do not overlap show that the change in length of string is related to the period of pendulum.

2. The equation determined by Excel should be trusted for presenting the true relationship between L and T because the power trendline almost go through data plots with the $R^2 = 0.9979$, which is closet to 1 comparing to other kinds of trendline.

3. 



(Team a) (Team b)

+ For team a data, the constant is different from our data. That value is not equivalent to $2pi/g^{1/2}$. It might because they haven't converted the unit of length into m

+ For team b data, their formula looks quite same as us which means our result would be correct.

4. Scientifically established model: $T = 2\pi\sqrt{\frac{L}{g}}$, constant: 2π

- Experimental model: $T = 2.0416 \times L^{0.4311}$, constant: 2.0416

- Both formulas do not include mass or angle. This indicates that the period of pendulum is not affected by those factors

d. Do your experimental outcomes make sense in physical sense?

Since the equation $T = 2\pi\sqrt{\frac{L}{g}}$ show that mass is not involved to calculate period, in physic, mass would rather affect the amplitude than the period. For the angle variable, small angle will not affect the period which is determined by length and gravity. And for the length, since the length is involved in the formula, the change in length will directly cause the change in period.

e. What are the limitations of your finding?

Because the length of the string can not be larger than the height of the room which is 333cm and the gravity is always about 9.8 m/s^2. The period of the pendulum can not exceed the range between 0 and 5 second regardless of the mass and angle proved above. So that if we got the value for period that is higher than 5 seconds, it might be an outliner

f. What are some suggestions for further investigation?

1. How we measure the length of the string might cause the random uncertainty due to the factor like parallax. Systematic uncertainty might occur when we have a bad set up for the position of the period measuring machine and how we release the pendulum.

2. The random uncertainty, which is resulted from measuring the length, might affect the claim in case there is any data point overlap each other. And systematic uncertainty due to experiment set up will result in outliner which make people hard to state the claim

3. To reduce the random uncertainty due to measuring the length, we should have a precise tool that help us to measure the length of the string. And for the systematic uncertainty due to the experimental set up, we can prevent it from occurring by ensure every equipment is placed at the correct place and the people who conduct the experiment release the pendulum vertically to make sure it completely go through the period measuring machine without touching anything on the path.

d. Did you proofread your report and include possible citation?

Yes