Report 1: Measurements

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Phys 207 Lab CD4
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1 Introduction

This lab is meant to explore the relationship between different variables, or the lack thereof.

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2 Procedure

2.1 Head Circumference and Heartbeat Time

Each group will pick one of their members to be their test subject. First, we will measure the circumference of their head by using a rope and a ruler in cm. Then, we will time between two of their heartbeats. We will enter this data onto the computer to use at the end of the lab.

2.2 Estimate π

We are meant to find the circumference and diamater of various objects, then calculate the ratio between the two using the formula:

$$\frac{C}{D} = \pi$$

The calculated value will only be an esimate of π, but it should be relatively close.

2.2.1 3 Objects

There are 3 circular objects:

1. A 500-gram mass.
2. A small circular disk.
3. A large circular disk.

For each object, we measure their circumference and diameter using a ruler, in which these values will be recorded in a Microsoft Excel spreadsheet. Then, we create a scatter plot in Excel, with the x-axis representing diameter and the y-axis representing circumfernece. Our estimate of π for this test will be the slope of the trendline of our poltted data.

2.2.2 Toothpicks

We form a circular shape using toothpicks. The circumference will be the amount of toothpicks used to form the shape and the diameter will be roughly the amount of toothpicks it takes to divide the shape in half. We then calculate our π estimate using these measurements.

2.2.3 Google Maps

We will find a circular building or geographic location. Then, using the measure distance feature of Google Maps, plot points around the circumference of the object to find the circumference and plot two points perpendicular to each other as well as the center of the object to find the diameter. We will then calculate our estimate of π using these measurements.

2.3 Calculate Uncertainty in Measurements

We will calculate the potential uncertaintiy in measuring length using the formula:

$$A \pm \delta A = (A)\left[1 \pm \frac{\delta A}{A}\right] \tag{1}$$

and density using the formula:

$$\left(\frac{A \pm \delta A}{B \pm \delta B}\right) = \left(\frac{A}{B}\right)\left[1 \pm \left(\frac{\delta A}{A} + \frac{\delta B}{B}\right)\right] \tag{2}$$

2.3.1 Measure the Fish

We will measure the length of a printed image of a fish using a ruler in centimeters. Then, we will calculate the uncertaintiy of this measurement by taking the $\pm$ difference of the ticks on the ruler nearest to our measurement and dividing the difference in half.

For example, if our measurement was 10.2 cm, and assuming our ruler measured in intervals of 0.5 cm, we would subtract the tick to the left (10.0 cm) from the tick to the right (10.5 cm), and divide that difference (0.5 cm) by 2 to get 0.25 cm. Then, since our measurement could be greater or less than the actual length, we would write our value as ± 0.25 cm.

2.3.2 Density of Wood Block

We will calculate the density of a mysterious wood block using the formula:

$$p = \frac{m}{v}$$

Where p is density, m is mass, and v is volume. We will calculate the mass in grams of the wood block using a digital scale. In order to calculate volume, we will measure the length, width, and height of the wood block in centimeters using a ruler, then multiply all three dimensions to get our volume in cm^3.

2.4 Time of Oscillations

We will measure the time it takes for a pendulum to swing back and forth, which is known as the *period of oscillation*. The pendulum will be 1.5 m long, in which it will be a rope tied to a 500-gram weight, with the length of the pendulum being the length of the rope plus the distance from the end of the rope to the center of mass of our 500-gram weight.

We will record the time it takes for this pendulum to oscillate, then reduce the length of the pendulum. We will repeat this 4 more times until we have 5 measurements. Both the length and period of oscillation in a Excel spreadsheet, then plot the values in which the period of oscillation will be a function of length.

2.5 Experiment Analysis

Going back to the first part of the procedure, we will create a table in Excel using those measurements, and then create a scatter plot the measurements. The x-axis will be heartbeat time and the y-axis will be head circumference.

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3 Data and Calculations

3.1 Figures and Tables

3.1.1 Pi Estimates

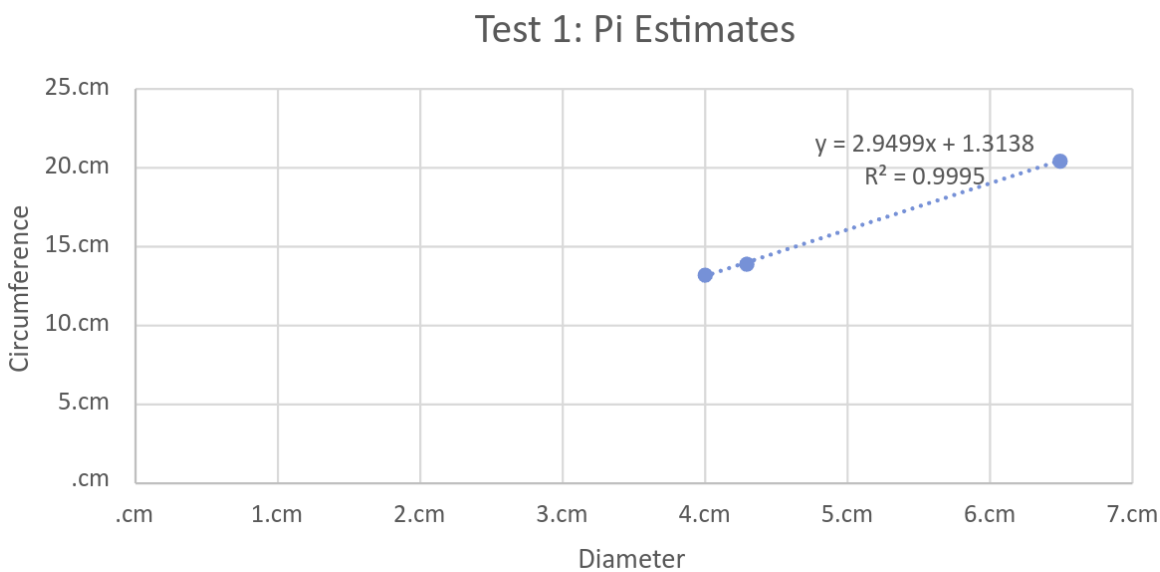

Figure 1: Circumference vs. Diamater of 3 Objects

Object #	Diamater (cm)	Circumference (cm)
1	4.0 cm	13.2 cm
2	6.5 cm	20.5 cm
3	4.3 cm	13.9 cm

Table 1: Diamater and Circumference of 3 Objects

3.1.2 Oscillation and Pendulum Length

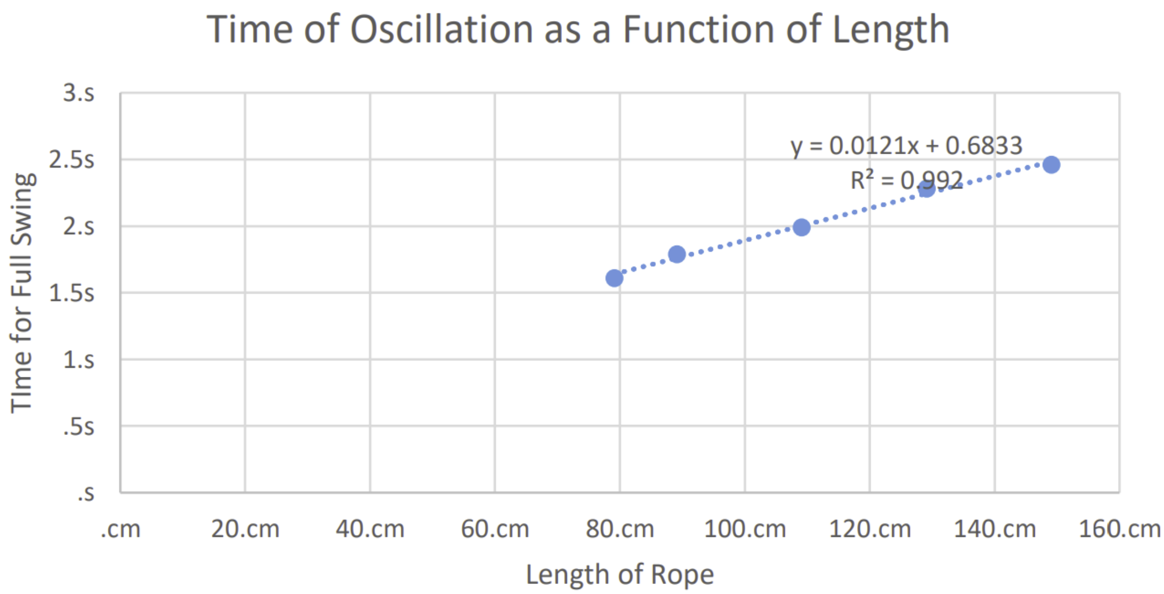

Figure 2: Period of Oscillation vs. Pendulum Length

Rope Length (cm)	Period of Oscillation (s)
149.1 cm	2.46 s
129.1 cm	2.28 s
109.1 cm	1.99 s
89.1 cm	1.79 s
79.1 cm	1.61 s

Table 2: Rope Length vs. Period of Oscillation

3.1.3 Density of Wood

Mass (g)	Volume (cm^3)	Density (g/cm^3)
72.3 g	122.14 cm^3	0.59 g/cm^3

Table 3: Mass, Volume, and Density of Wood Block

3.1.4 Time Between Heartbeats vs Head Circumference

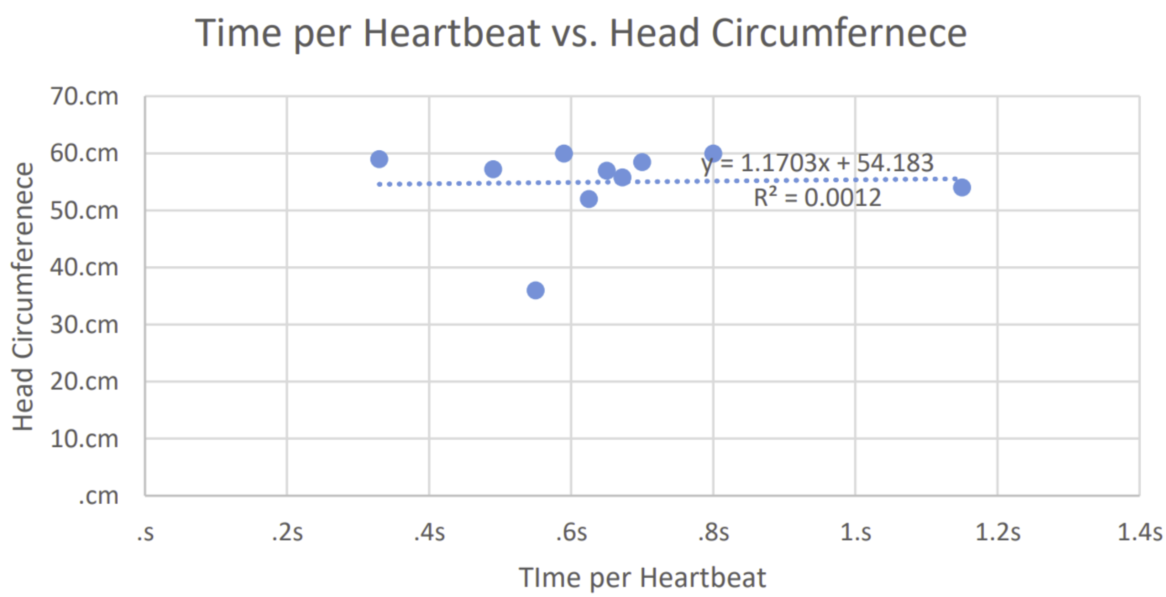

Figure 3: Heart Pulse vs. Head Circumference

Time Between Heartbeats (s)	Head Circumference (cm)
0.8 s	60.0 cm
0.59 s	60.0 cm
0.33 s	59.0 cm
0.7 s	58.5 cm
0.49 s	57.2 cm
0.65 s	57.0 cm
0.67 s	55.8 cm
1.15 s	54.0 cm
0.63 s	52.0 cm
0.55 s	36.0 cm

Table 4: Time Between Heartbeats vs. Head Circumference

3.2 Calculations

3.2.1 Density of Wood Block

The dimensions of the wood block were:

$$l = 23.8\,\text{cm} \quad w = 5.448\,\text{cm} \quad h = 0.942\,\text{cm}$$

Thus the volume was:

$$v = l \cdot w \cdot h = 23.8\,\text{cm} \cdot 5.448\,\text{cm} \cdot 0.942\,\text{cm} \approx 122.14\,\text{cm}^3$$

The mass of the wood block was $m = 72.3$ g, thus the density was:

$$p = \frac{m}{v} = \frac{72.3\,\mathrm{g}}{122.14\,\mathrm{cm}^3} \approx 0.59\,\mathrm{g/cm}^3$$

3.2.2 Uncertainty in Density of Wood Block

Since the density p consists of two quantities: mass m, which was measured using a scale measuring in increments of 0.01 grams, and volume v, which was calculated using the product of the 3 measured dimensions l, w, and h, all measured using a caliper measuring in increments of 0.001 centimeters.

The error propagation of the mass, which will be the δA of formula (2), can be calculated by dividing the increment of measurement by 2:

$$\delta A = \pm\frac{0.01\,\mathrm{g}}{2} = \pm 0.05\,\mathrm{g}$$

The error propagation of the volume δB will require us to calculate the relative uncertainties of all 3 measured dimensions.
The relative uncertainty of length l:

$$\delta l = \pm\frac{0.001\,\mathrm{cm}}{l}\cdot 100 = \pm\frac{0.001\,\mathrm{cm}}{23.8\,\mathrm{cm}}\cdot 100 \approx \pm 0.0042017\,\%$$

The relative uncertainty of length w:

$$\delta w = \pm\frac{0.001\,\mathrm{cm}}{w}\cdot 100 = \pm\frac{0.001\,\mathrm{cm}}{5.448\,\mathrm{cm}}\cdot 100 \approx \pm 0.0183554\,\%$$

The relative uncertainty of length h:

$$\delta h = \pm\frac{0.001\,\mathrm{cm}}{h}\cdot 100 = \pm\frac{0.001\,\mathrm{cm}}{0.942\,\mathrm{cm}}\cdot 100 \approx \pm 0.1061571\,\%$$

When we multiply all 3 dimensions, we will add the uncertainties:

$$v = (l \pm \delta l)(w \pm \delta w)(h \pm \delta h) = lwh \pm (\delta l + \delta w + \delta h)$$

When we substitue in our measurements, we get:

$$v = 122.14\,\mathrm{cm}^3 \pm 0.1287142\,\%$$

and converting to absolute uncertainty:

$$v = 122.14 \pm 15.72\,\mathrm{cm}^3$$

Using formula (2), we find that our uncertainty is:

$$p = \frac{72.3 \pm 0.05\,\mathrm{g}}{122.14 \pm 15.72\,\mathrm{cm}^3}$$

4 Questions

4.1 Discuss the limitations of these methods for calculating π. Which method was the best? The worst? Are there improvements to be made?

The best method for estimating π was taking the slope of the linear trendline from the plotted diameters and circumferences of the three objects. This is so because the value obtained from the slope had the least difference from π compared to the other methods.

Using Google Maps to calculate π turned out to be the worst method since the calculated value had the biggest difference from π compared to the other methods.

We could improve the first method of calculation by measuring more than just 3 objects. Perhaps 6 or 9 would give us a more accurate value. The second method of calculation, in which we used tooth picks to form a circular shape, would benefit from the use of more toothpicks in forming the circumference. It might also benefit from forming multiple circular shapes from different amounts of toothpicks, then taking the average of the calculated π estimates. The third and final method could benefit from plotting more points along the circumference of the circular object.

4.2 Try to match your piece of wood with a known tree. Discuss whether you can be certain of your identification.

4.3 Based only on your experimental data, can you say how the time for one swing relates to the length of the pendulum? Is there a clear functional dependance? What could you do to make the experiment better?

Based on my experimental data, the time for one swing seems to have a linear relationship to the length of the pendulum. Thus, it is clear that the period of oscillation depends on the length of the pendulum. The experiment would benefit from recording more than 5 data points as well as specifying a specific interval of rope length between data points.

4.4 Is there a correlation between the circumference of someone's head and the time between heartbeats? Would you expect there to be one?

5 Conclusion