AP Physics 1
Lab Journal Guidelines
Calculating the value of *Pi*
Example
2015 – 2016[1] [2]

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Lab Journal Guidelines

(I) **Purpose of Lab**

- Lab Question: The purpose of this lab is to demonstrate that $\pi = 3.1416$ is the ratio of the object's circumference, C, and the diameter, d, for any size circular object.

(II) **Lab Investigation Question/Hypothesis/Prediction**

- Lab Question: How can you determine the value of π by measuring various circular objects?

- Hypothesis: The value of π can be determined for any circular object, irrespective of its size, by calculating the ratio of a circle's circumference, C, to its diameter, d.

- Prediction: If the value of π can be determined for an circular object, irrespective of its size, by calculating the ratio of a circle's circumference, C, to its diameter, d, then if I measure the circumference of any circle and its diameter, I should be able to calculate the value of π by dividing the object's circumference by its diameter: $^{C}/_{d}$.

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[1] Adapted from Dolores Gende & College Board
[2] Last Modified: 2015/09/14 at 8:31pm

(III) Equipment & Equipment Setup

Equipment

- Pennies
- Nickels
- Dimes
- Quarters
- Various other circular objects
- Meter stick
- Ruler
- String
- Scissors

Equipment Setup

- A detailed and labeled diagram to illustrate the configuration of the equipment. This will vary, of course, for each student/group.

(IV) Step-by-Step Procedure

1. We estimated the widest part of the circular object.
2. We placed a segment of string across this distance.
3. Finally, we measured the length of this segment of string with a ruler. We did this by roughly estimating where the widest part of the plate was, placing a string across that distance, then measuring the length of the string with a ruler. This allowed us to determine the diameter, d.
4. We wrapped a segment of string one full turn around the circular object.
5. We measured the length of this segment of string with a ruler. This allowed us to determine the circumference of the object, C.

Variables

- <u>INDEPENDENT VARIABLE(S)</u>: different-sized circular objects. This was controlled by using a variety of different types of circular objects.
- <u>DEPENDENT VARIABLE(S)</u>: circumference & diameter

(V) **Data**

What Data Needs to be Taken?

1. We will measure the circumference, C, and the diameter, d, of each circular object. Both of these are *measured quantities*.

NB: You will only report your measurements in this section. Your calculations will be shown in the next section

How many trials will be included?

- We will have five trials for each circular object. (You should do at least three for each experiment.)

How will you report your data?

- We will report our data in a data-table.

Table 1: Diameter and circumference measurements of the circular plate

Trial	Diameter, d (cm)	Circumference, C $(cm)^2$
1	7.85	24.59
2	7.75	24.63
3	7.90	24.65
4	7.78	24.61
5	7.85	24.66
average	7.83	24.63

(VI) **Data Analysis**

What are your calculations?

1. We will take the average of each of these *measured quantities*. This is a *calculated quantity*.
2. We will then calculate the ratio of the object's circumference, C, and the diameter, d, to determine the value of π. This is a *calculated quantity*.
3. Calculate our percent error
4. We will then plot and graph the circumference, C, and the diameter, d, making sure to draw a best-fit line.
5. We will then calculate the ratio of the object's circumference, C, and the diameter, d, to determine the value of π by determining the slope of our graph. This is a *calculated quantity*.
6. We will calculate our percent error for this calculated value of π.
7. Lastly, we will calculate our percent difference.

Calculations

- **Mean for diameter, d**

$$\begin{aligned} \bar{x} &= \frac{1}{n}\sum_{i=1}^{n} x_1 = \frac{x_i + x_2 + x_2 + \ldots}{n} \\ \bar{x} &= \frac{\sum_{i=1}^{5} x_i}{5} = \frac{7.85 + 7.75 + 7.90 + 7.78 + 7.85}{5} = \boxed{7.83\ cm} \end{aligned} \tag{1}$$

- **Mean for circumference, C**

$$\begin{aligned} \bar{x} &= \frac{1}{n}\sum_{i=1}^{n} x_1 = \frac{x_i + x_2 + x_2 + \ldots}{n} \\ \bar{x} &= \frac{\sum_{i=1}^{5} x_i}{5} = \frac{24.59 + 24.63 + 24.65 + 24.61 + 24.66}{5} = \boxed{24.63\ cm} \end{aligned} \tag{2}$$

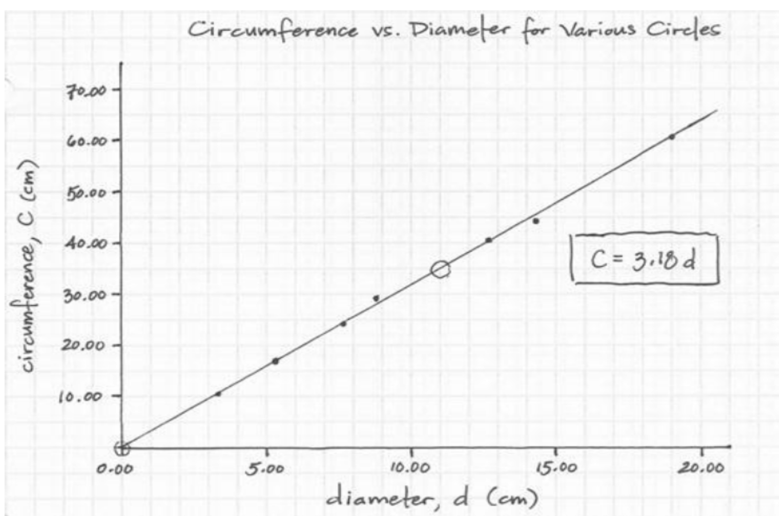
- **The ratio of the object's circumference, C, and the diameter, d, to determine the value of π**

$$\begin{aligned} \pi &= \frac{C}{d} \\ &= \frac{24.63 \cancel{cm}}{7.83 \cancel{cm}} \\ &= \boxed{3.15} \end{aligned} \tag{3}$$

- **Calculate percent error**

$$\begin{aligned} percent\ error &= \left|\frac{measured\ value - expected\ value}{expected\ value}\right| \times 100 \\ &= \left|\frac{3.15 - 3.1416}{3.1416}\right| \times 100 \\ &= \boxed{0.267\%} \end{aligned} \tag{4}$$

- **A graph of the circumference, C, and the diameter, d, with a best-fit line**



[3]

- **CALCULATE SLOPE OF LINE. THE SLOPE OF THIS LINE IS π.**

$$\begin{aligned} slope\ of\ graph &= \frac{\Delta y}{\Delta x} = \frac{C}{d} = \pi \\ &= \frac{35.00\ \cancel{cm}}{11.00\ \cancel{cm}} \\ &= \boxed{3.18} \end{aligned} \tag{5}$$

- **CALCULATE PERCENT ERROR**

$$\begin{aligned} percent\ error &= \left|\frac{measured\ value - expected\ value}{expected\ value}\right| \times 100 \\ &= \left|\frac{3.18 - 3.1416}{3.1416}\right| \times 100 \\ &= \boxed{1.22\%} \end{aligned} \tag{6}$$

- **CALCULATE PERCENT DIFFERENCE BETWEEN TWO METHODS**

$$\begin{aligned} percent\ difference &= \left|\frac{value\ 1 - value\ 2}{\frac{1}{2}(value\ 1 + value\ 2)}\right| \times 100 \\ &= \left|\frac{3.15 - 3.18}{\frac{1}{2}(3.15 + 3.18)}\right| \times 100 \\ &= \boxed{0.9\%} \end{aligned} \tag{7}$$

(VII) Conclusions

The graph shows a direct linear relationship between diameter and circumference. The bigger the diameter of a circle, the bigger its circumference is by the same constant factor π. By plotting circumference measurements on the *y-axis* and diameter measurements on the *x-axis*, it was expected that the best-fit line would have a constant slope equal to π. It was also expected that the best-fit line would pass through the origin, since a circle with a diameter of 0 cm should have a circumference of 0 cm as well. The best-fit line of this graph has a slope of 3.18, which is 1.22% off of the accepted value of 3.14. The results of our data was calculated in two different ways, first by using the mean of C and d, and second by finding the slope when they were graphed. The percent difference between our two methods was 0.9%, thereby increasing our level of confidence that our data is correct.

Although the differences between the experimental and accepted values of π in this lab were minimal, a few possible sources of error may have led to these discrepancies. First, there may have been some error in the measurement of the diameters, since these measurements were based on the experimenter's best judgment of the center line locations. The diameter is the widest part of a circle, so misjudgment in either direction from the center line would have resulted in a slightly smaller value for the diameter, which would have led to the slightly larger value of pi that was observed in both parts of the experiment. Second, there may have been some error in the circumference measurements because of slight stretching in the string as it was wrapped around the circular objects. This would have produced circumference measurements slightly smaller than the actual values, which would have yielded a smaller experimental value of π; since the experimental π values in both parts were larger than the accepted value, this particular error probably was not responsible for the discrepancies observed. Lastly, since the best-fit line on the graph was drawn based on human judgment, it may have been steeper than the true best-fit line, which would account for a larger experimental value of π.