

Measuring Circles

Experimental Determination of π

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Abstract—The value of the irrational constant π was determined experimentally by comparing the diameter and circumference of various circular objects. Based on gathered data, π was experimentally determined as 3.14.

I. INTRODUCTION

The Greek letter Pi (π) is traditionally used to represent the relationship between the circumference and the diameter of a circle. In this inquiry-based lab, students were asked to experimentally determine π using commonly available lab equipment.

From a pedagogical standpoint, the purpose of this lab is to introduce students to the planning, documentation, performance and analysis of an open-ended lab in the context of the *AP Physics C* course. Further, this activity provides a simple foundation upon which to develop technical lab writing skills.

II. METHODS / PROCEDURE

Pi was experimentally determined by taking the ratio of the diameter of a circle to the circle's circumference. The diameter and circumference of various-shaped circles was measured and recorded using a metric ruler and a string, and a plot of the circumference as a function of diameter was analyzed. The slope of the line provides the experimental value for Pi.

A. Materials

Standard physics lab equipment including:

- ruler
- string
- various circular objects

B. Diagram of Lab Setup

Measurements of round objects were made as shown in Fig. 1 below.

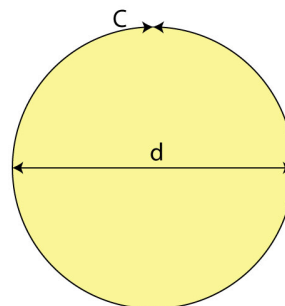


Fig. 1. Circle Measurement Setup

C. Steps Taken

Data was collected for a set of 10 different circular objects and recorded. It is expected that a larger data set would result in a more accurate final conclusion.

- 1) A string was wrapped once around the outside of the circular object at the point of its largest diameter, marking the point where the string first overlapped itself, as indicated in Figure 1.
- 2) The string was then removed from the circular object, and the length of the string from its beginning to the overlap mark was measured using a metric ruler and/or meterstick. Values were recorded.
- 3) The metric ruler was then used to measure the diameter of the circular object at its widest point, illustrated in Figure 1. This value was recorded.
- 4) A scatterplot of circumference as a function of diameter was created.
- 5) A best-fit line was determined and drawn on the graph.
- 6) The slope of the best-fit line was determined. This is the experimental value for Pi (π).

III. RESULTS / DATA

Diameter and circumference data was placed into a data file (Table 1) and analyzed using a standard linear regression, shown in Figure 2 below.

A. Data Tables

TABLE I
DIMENSIONS OF MEASURED CIRCLES

Diameter (cm)	Circumference (cm)
11.7	37.8
17.1	54
8.4	26.6
6.6	21.2
7.4	23.4
6.6	21.2
7.9	25.6
15.8	50.6
8.8	28.5
1.9	7

B. Graphs

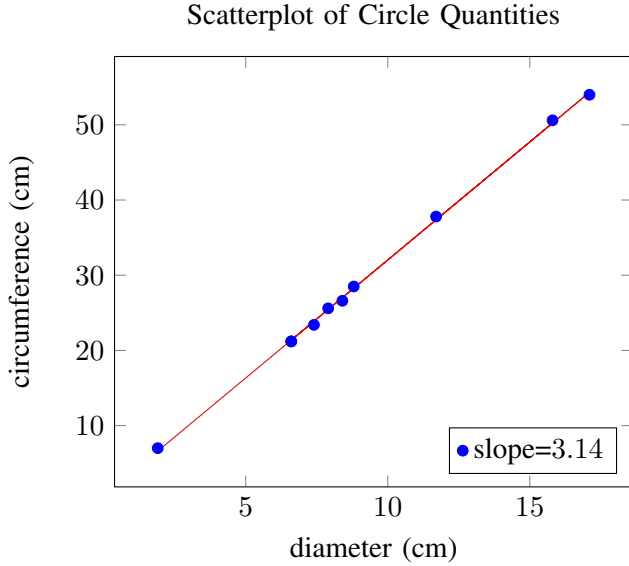


Fig. 2. Scatterplot of Circle Quantities

C. Explanations

The key relationship between the circumference of a circle and its diameter is given by the slope of the C vs. d graph, indicating a ratio of 3.14.

IV. DISCUSSION / ANALYSIS

The slope of the C vs. d graph indicates a circumference to diameter ratio of 3.14, an approximation of the irrational number π , given as 3.14159 to six significant figures. Findings, therefore, are consistent with the accepted value and with the experimenters' expectations.

The slope of the graph was determined using a linear regression algorithm. Alternately, the slope can be determined by taking two points on the best-fit line.

$$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{50.9\text{cm} - 0\text{cm}}{16.2\text{cm} - 0\text{cm}} = 3.14 \quad (1)$$

Equation (1) demonstrates that the slope of the best-fit line is 3.14, consistent with the linear regression results and the accepted value for π .

V. CONCLUSION

Students undertook a simple open-ended laboratory exercise to review measurement skills, experimental procedure, data analysis, and lab documentation techniques [1] consistent with Irondequoit High School lab report standards [2]. Exposure to the \LaTeX writing environment provided significant challenges and while opening up opportunities to develop proficiency in a powerful tool.

Potential sources of error in this experiment include accuracy limitations in utilizing the string and metric ruler / meter stick to determine the diameter and circumference of the various circles measured. As well, the objects measured may have some level of eccentricity which was not accounted for. Finally, placement of the measuring apparatus to determine the diameter holds some inherent variability and opportunity for inducing small measurement errors.

Finally, from a technical standpoint, experimenters confirmed the value of π to three significant figures as 3.14, consistent with the accepted value for π .

ACKNOWLEDGMENT

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