

Name: \_\_\_\_\_

Period: \_\_\_\_\_ Date: \_\_\_\_\_

## Measuring for Pi Lab (10 points)

Data collection will be a group effort due to limited resources. Data analysis is an individual effort. *You must create your own spreadsheet and your own graph and you must answer the questions individually. Collusion is tantamount to cheating.*

### Objectives:

1. Determine if there is a relationship between circumference and radius in round objects. If there is a relationship, determine the constant of variation
2. Understand the difference between random and systematic error.
3. Determine the following:
  - a. percent error of standard deviation
  - b. average percent systematic error
  - c. average percent random error
  - d. percent error of the mean
  - e. percent error of the slope of the graph of the data

**Discussion:** The majority of the error you will experience in this lab will be the *random error* of humans trying to take measurements with fairly rudimentary tools. Here, the random error is mostly due to human error, but random error exists anytime the environment can't be completely controlled and thus has an impact on your experimental outcomes. *Systematic error* comes from the precision of the tools you are working with. The Giancoli textbook for AP Physics defines systematic error as plus or minus the smallest measurement on the instrument. The Tsokos textbook for IB Physics uses this same definition for electronic tools (digital readout of measurement), but uses plus or minus half of the lowest measurement for mechanical tools (observer must read from a scale). We will use the Tsokos method. *Percent uncertainty*. The percent uncertainty caused by a known or estimated error is equal to the error divided by the measured value multiplied by 100%.  $\left[\frac{\text{error}}{\text{measure}}\right] \times 100\%$ .

**Procedure:** The following numbered items can be found on the lab counter and side tables.

- |  |   |  |
|--|---|--|
| <ol style="list-style-type: none"> <li>1. Large blue plastic lid</li> <li>2. Metal reflector (large dia)</li> <li>3. Small blue plastic lid</li> <li>4. Wiffle ball</li> </ol> | <ol style="list-style-type: none"> <li>5. Easy button (base)</li> <li>6. 500g mass</li> <li>7. 100g mass</li> <li>8. Quarter</li> </ol> | <ol style="list-style-type: none"> <li>9. Plastic bucket (top)</li> <li>10. Red cup (top)</li> <li>11. Wooden turntable</li> <li>12. Bicycle tire rim</li> </ol> |
|--|---|--|
1. Using a measuring tape, ruler and meter stick, measure the circumference and diameter of each item in millimeters and record the value in the table below. When there are multiple circles on an item, choose the one that is easiest for you to measure.
  2. Record the total systematic (tool/reading) error for both circumference and diameter.
  3. Estimate a value for random (human) error for both circumference and diameter.
  4. Add the systematic and random error for both circumference and diameter.
  5. Be sure to record all qualitative observations as you take your measurements

# DATA COLLECTION

| Item # | Circumference (c)(mm) | Read Error (mm) | Random Error (mm) | Circumference Total Error (mm) | Diameter (d)(mm) | Read Error (mm) | Random Error (mm) | Diameter Total Error (mm) |
|--------|-----------------------|-----------------|-------------------|--------------------------------|------------------|-----------------|-------------------|---------------------------|
| 1      |                       |                 |                   |                                |                  |                 |                   |                           |
| 2      |                       |                 |                   |                                |                  |                 |                   |                           |
| 3      |                       |                 |                   |                                |                  |                 |                   |                           |
| 4      |                       |                 |                   |                                |                  |                 |                   |                           |
| 5      |                       |                 |                   |                                |                  |                 |                   |                           |
| 6      |                       |                 |                   |                                |                  |                 |                   |                           |
| 7      |                       |                 |                   |                                |                  |                 |                   |                           |
| 8      |                       |                 |                   |                                |                  |                 |                   |                           |
| 9      |                       |                 |                   |                                |                  |                 |                   |                           |
| 10     |                       |                 |                   |                                |                  |                 |                   |                           |
| 11     |                       |                 |                   |                                |                  |                 |                   |                           |
| 12     |                       |                 |                   |                                |                  |                 |                   |                           |

### Qualitative Observations:

Write down any qualitative observations below. Specifically, you want to record anything that could affect the accuracy of your measurements.

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## DATA PROCESSING

Create a spreadsheet in Microsoft Excel like the table below. Use Excel to compute data in the shaded columns by using the equations given in bold italics. We will do this together in class.

|    | A      | B                     | C                | D                      | E            | F                | G                      | H                                   | I                               |
|----|--------|-----------------------|------------------|------------------------|--------------|------------------|------------------------|-------------------------------------|---------------------------------|
| 1  | Item # | Circumference (c)(mm) | Total Error (mm) | Fractional Error       | Dia (d) (mm) | Total Error (mm) | Fractional Error       | Computed value $\pi' = \frac{c}{d}$ | Total Absolute Error            |
| 2  | 1      |                       |                  | <b><i>=(C2/B2)</i></b> |              |                  | <b><i>=(F2/E2)</i></b> | <b><i>=B2/E2</i></b>                | <b><i>=(D2+G2)xH2</i></b>       |
| 3  | 2      |                       |                  |                        |              |                  |                        |                                     |                                 |
| 4  | 3      |                       |                  |                        |              |                  |                        |                                     |                                 |
| 5  | 4      |                       |                  |                        |              |                  |                        |                                     |                                 |
| 6  | 5      |                       |                  |                        |              |                  |                        |                                     |                                 |
| 7  | 6      |                       |                  |                        |              |                  |                        |                                     |                                 |
| 8  | 7      |                       |                  |                        |              |                  |                        |                                     |                                 |
| 9  | 8      |                       |                  |                        |              |                  |                        |                                     |                                 |
| 10 | 9      |                       |                  |                        |              |                  |                        |                                     |                                 |
| 11 | 10     |                       |                  |                        |              |                  |                        |                                     |                                 |
| 12 | 11     |                       |                  |                        |              |                  |                        |                                     |                                 |
| 13 | 12     |                       |                  |                        |              |                  |                        |                                     |                                 |
| 14 |        |                       |                  |                        |              |                  | Mean                   | <b><i>=AVERAGE (H2:H13)</i></b>     | <b><i>=AVERAGE (I2:I13)</i></b> |
| 15 |        |                       |                  |                        |              |                  | Standard Deviation     | <b><i>=STDEV (H2:H13)</i></b>       |                                 |

## ANALYSIS

- What is
  - your average measured value of  $\pi$ ? \_\_\_\_\_
  - the standard deviation of your measured value of  $\pi$ ? \_\_\_\_\_
  - the average absolute error of your measured value of  $\pi$ ? \_\_\_\_\_
  - the highest absolute error of your measured value of  $\pi$ ? \_\_\_\_\_
  - the  $\frac{\text{min}+\text{max}}{2}$  of the absolute error of your measured value of  $\pi$ ? \_\_\_\_\_
- Considering just the tabulated data, which value of uncertainty from #1 above best represents the uncertainty of your data? Give a reason for your choice. \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_
- Using Excel, create a graph of your data with circumference on the y-axis and diameter on the x-axis. Use Excel to draw a line of best fit, and show the equation for this line (as computed by Excel) on your graph. Be sure to give your graph a title and label each axis and include units.
  - What is the equation of this line? \_\_\_\_\_
  - What is the slope of this line? ( $y = mx + b$ , m is slope) \_\_\_\_\_
  - What is the y-intercept of this line? ( $y = mx + b$ , b is y-intercept) \_\_\_\_\_
  - Since the slope is rise/run, the slope of your graph is circumference/diameter which is the definition of Pi. Since the best-fit line is a mathematical average of both x- and y-values, it is the best approximation of the

relationship between circumference and diameter (i.e., Pi) for your data. This method is an excellent means of determining the relationship between two variables for experimental data.

4. Format your data table and graph so that they can be printed on one sheet each. Print your data table and graph and attach it to this report.

5. What is

a. your average measured value of  $\pi$  from the table? \_\_\_\_\_

b. your average measured value of  $\pi$  from the slope of your graph? \_\_\_\_\_

c. your chosen value of uncertainty for your measured value of  $\pi$ ? \_\_\_\_\_

6. You came up with two different values for pi: one as the average of your computed values and one as the slope of your graph. Which do you feel is a more analytically accurate representation of your data and why? **Note: do not use comparison to the actual value as a rationale.**

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7. Calculate:

a. the absolute percent error of your slope using your chosen value of uncertainty from 5.c. above by using the formula  $\frac{(\text{uncertainty})}{(\text{avg measured } \pi)} \times 100\%$  \_\_\_\_\_

b. the difference between your measured value of  $\pi$  and the actual value of  $\pi$  by using the formula  $\frac{(\text{value}) - (3.1415927)}{(3.1415927)} \times 100\%$  (note: a negative value will indicate your measured value was less than the actual and a positive value will indicate your measured value was higher than actual) \_\_\_\_\_

c. Which of the two above was higher and by how much? What does this tell you? ("that Newton was a really smart cookie" is not an acceptable answer) \_\_\_\_\_

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2. Was there any difference in error between calculations of  $\pi$  when measuring items with smaller diameter/circumference as compared to items with higher diameter/circumference? What can you infer from this?

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3. Looking at your graph, how could you improve the distribution of your sample sizes?

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4. State three ways in which you could *reasonably* improve the collection of data for this experiment.

a. \_\_\_\_\_  
\_\_\_\_\_

b. \_\_\_\_\_

\_\_\_\_\_

c. \_\_\_\_\_

\_\_\_\_\_

**The answers on this lab are a product of my own work and effort. Though I may have received some help in taking/recording measurements and understanding the concepts and/or requirements, I did the work myself.**

\_\_\_\_\_  
**Student Signature**