Measuring for Pi Lab (20 points)

Name: _____________________________

Physics 1 H / Pre-IB Physics

Period: _____________________________

Objectives:

1. Determine an experimental value for Pi (\(\pi\)) by measuring twelve different objects.
2. Understand the difference between random and systematic error.
3. Calculate the percent error between our experimental value(s) and the accepted value through:
   - a. standard deviation
   - b. average percent error
   - c. percent error of the mean
   - d. percent error of the slope of the graph of the data
   - e. systematic percent error

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 Physics I Honors and Pre-IB 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, when comparing experimental data to a known value is equal to the difference between the measured value and the accepted value, divided by the accepted value, multiplied by 100%.

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

1. Metal reflector (measure large end)
2. Plastic funnel (measure large end)
3. Wooden turntable
4. Wiffle ball
5. Spool of fishing line
6. Quarter
7. Blue plastic lid
8. Roll of duct tape
9. Easy button
10. Plastic bucket (measure top edge)
11. Red cup
12. Bicycle tire (measure outside of metal rim)

1. Using a measuring tape, measure the circumference and diameter of each item in millimeters and record the value in the table below.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Item #</td>
<td>Circumference (c)(mm)</td>
<td>Diameter (d)(mm)</td>
<td>(\pi' = \frac{c}{d})</td>
<td>Error</td>
<td>(\pi = \pi - \pi')</td>
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<tr>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>=B2/C2</td>
<td>B14-D2</td>
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<td>3</td>
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<tr>
<td>14</td>
<td>(\pi = 3.1415927)</td>
<td>Mean</td>
<td>=AVERAGE(D2:D13)</td>
<td>Average % Error</td>
<td>=AVERAGE(E2:E13)</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Standard Deviation</td>
<td>=STDEV(D2:D13)</td>
<td>% Error of Mean</td>
<td>=((D14-B14)/B14) x 100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>% Error of Std Dev</td>
<td>=(D15/D14) x 100</td>
<td></td>
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</tr>
</tbody>
</table>

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NOTE: You must complete the data collection above, sign the statement below, and have the teacher initial below prior to leaving the classroom. Failure to do this will require you to re-accomplish the lab individually.

This data in the table above was collected (circle one) by [myself / a team]. I participated fully and equally in the collection of this data and recorded it myself.

<table>
<thead>
<tr>
<th>Student Signature</th>
<th>Teacher Initials</th>
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</table>

2. Create a spreadsheet in Microsoft Excel like the table above. Use Excel to compute data using the equations given in bold above. Print your Excel table and attach it to this sheet.

3. 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. Print the graph and attach it to this sheet.
   a. What is the slope of this line? \((y = mx + b, m \text{ is slope})\) __________
   b. Since the slope is rise/run, for your graph the slope is circumference/diameter which is the definition of Pi. Since the best-fit line is a mathematical average of both x- and y-axes, 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.
   c. Calculate the percent error of your slope using \(\frac{(\text{slope}) - (3.1415927)}{(3.1415927)} \times 100\%\) __________

4. Thus far, you have just been dealing with random error. For systematic error, the smallest unit of measurement for the tape measure is millimeters, so the error for the tape measure is ± 1mm. The percent uncertainty for either the circumference or diameter is equal to the error divided by the average value times one hundred percent. The percent uncertainty for \(\pi\) would be equal to the sum of the percent uncertainties of the circumference and diameter.
   \[
   \left(\frac{\text{circumference} \times 100\%}{\text{avg}}\right) + \left(\frac{\text{diameter} \times 100\%}{\text{avg}}\right) = \text{ } \]

5. Answer the following questions:
   a. 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?

   b. You calculated percent error using five methods: average of individual percent errors, percent error of the mean, percent error of the standard deviation, percent error of the slope, and percent systematic error. List each of these percent errors below. Which of these methods do you believe best represents the actual uncertainty of your measurements? Why?
     average of individual percent errors __________
     percent error of the mean __________
     percent error of the standard deviation __________
     percent error of the slope __________
     percent systematic error __________

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

Student Signature

ROOM FOR IMPROVEMENT: THIS LAB CAN BE IMPROVED BY:

__________________________________________

__________________________________________

__________________________________________