Experiment: Measurement, graphing, and prediction

The essence of physics is developing methods of prediction. If a calculation does not produce experimentally verifiable results, then it is of little value. In this laboratory exercise you will become familiar with measurement techniques and the use of graphical procedures to analyze your data and make predictions. You will need to review to the "Lab Requirements" hand-out for additional information describing experimental uncertainties.

Objective(s):

1. measure the mass and diameter of a number of steel ball bearings
2. use this data to predict the mass of ball bearings if only the diameter is known
3. become familiar with the LoggerPro software

Procedure:

Use a Vernier caliper and gram scale to measure the diameters and mass of the metal spheres available to you. Everyone should make these measurements, independently. Record your measurements in the table below.

	Diameter (units)					
Sphere #	**Trial 1**	**Trial 2**	**Trial 3**	**Average**	**Uncertainty (±)**	**Mass (units)**

Question: Do your measurements agree with your partner's? What might account for any differences?

Determine the average and uncertainty (use standard deviation or min-max method) of each set of trials then record values in the data table.

Graphical analysis: Now create a plot of mass vs. average diameter of your measurements using the LoggerPro software.

1. Turn on a computer workstation and start-up the LoggerPro software.
2. Create a plot of mass (y) vs. average diameter using LoggerPro. *For better visualization, select "Point Protectors" and de-select "Connect Lines" in the Graph Options window.*
3. Measure the diameters of the unknown masses and record values in the table below.
4. Use your plot to predict the mass of these bearings. Record your predictions in the table below.

	Diameter					
Unknown mass #	**Trial 1**	**Trial 2**	**Trial 3**	**Avg ± Error**	**Predicted mass**	**% Error**

Questions

1. How did you use your data plot to make your predictions?

2. What difficulties did you have?

3. How confident are you of your predictions, i.e., what is the uncertainty in your predicted masses?

More graphical analysis: Clearly, the mass of an object rises rapidly with the diameter and this can make prediction difficult, especially when you have to extrapolate using a curved line. If your data were to lie on a straight line then extrapolation (and prediction) becomes much easier. This is why scientists often plot their data to make it look like a straight line, called *linearizing the data*. For the exercise, we can use the fact that the mass is proportional to the volume of a sphere and the volume is proportional to the cube of the diameter (*what is the actual equation that relates a sphere's volume to its diameter?* _____). Thus if you plot the mass of the known spheres vs. the cube of their diameter you should obtain a "straight line". Do it.

1. In LoggerPro, create a new "calculated" column to calculate diameter^3:

   Data→Create Calculated Column

2. When the window pops up, enter an appropriate name and unit(s).
3. Define the equation for the new column. Note: the mass and diameter columns can be selected from the "Variables" drop-down box.
4. When finished, click OK.
5. Display the graph of mass vs. diameter^3. Click on the x-axis title of the graph window then select the new calculated column you created.
6. Using the graph of mass vs. diameter^3, predict values of the unknown masses. Record your predictions in the table below.

Unknown mass #	Average Diameter^3	Predicted mass	% Error

Question: How well do the predicted values in step 6 agree with your original predictions above?

Question: Which predicted values do you think are closest to the actual values? Why?

7. Measure the mass of the unknown spheres.

Mass of Unknown #1: _____

Mass of Unknown #2: _____

8. Calculate the % Error between the all predicted and measured mass values. Record the calculations in the appropriate tables above.

Final Questions:

1. Explain why "linear" graphs easier to use.

2. How might you estimate the uncertainty in your predicted values?

3. What would your data look like if you were to plot mass vs (diameter)^2? You can use LoggerPro to verify your answer…

4. What would your data look like if you were to plot mass vs (diameter)^4? Use LoggerPro to verify your answer…