SAMPLE DATA SHEET
CHEM 117 LAB 1: LENGTH AND VOLUME

	Measurement of the volume with a ruler	
1.	Diameter of a polystyrene sphere using the metric ruler (in centimeters).	0.96 cm
2.	Calculate the volume of the polystyrene sphere in cm^3 from the measured diameter ($V = 4/3\pi r^2$)	0.46 cm^3
	Measurement of the volume Using a graduated cylinder (one ball)	
3.	Volume of water added to the graduated cylinder.	10.41 mL
4.	Volume of water plus one polystyrene ball.	10.84 mL
5.	Calculate volume of one polystyrene sphere: [Volume of sphere = total volume – volume of water]:	0.43 mL
	Measurement of the volume Using a graduated cylinder (ten balls)	
6.	Volume of water plus ten polystyrene balls.	14.96 mL
7.	Calculate volume of ten polystyrene spheres: [Volume of ten spheres = total volume - volume of water]:	4.55 mL
8.	Calculate average volume of spheres: [Volume of one sphere = (1/10)volume of ten spheres]:	0.455 mL

You now have three different measurements of the volume of a polystyrene sphere from #2, #5 and #8. From different members of your lab class, obtain five other values for each of the three methods. If you should find that your group completed the experiments quicker than the rest of your classmates, DON'T JUST SIT THERE WAITING FOR THEM TO FINISH. REPEAT THE EXPERIMENT and then you can use both sets of your data in Table 1.

Table 1

	#2	#5	#8
	From Ruler	From water displacement of one sphere	From water displacement of ten spheres
Your number:	0.46 cm^3	0.43 mL	0.455 mL
Labmate #1	0.52 cm^3	0.42 mL	0.437 mL
Labmate #2	0.61 cm^3	0.29 mL	0.418 mL
Labmate #3	0.47 cm^3	0.43 mL	0.442 mL
Labmate #4	0.37 cm^3	0.46 mL	0.450 mL
Labmate #5	0.42 cm^3	0.47 mL	0.460 mL

Calculate the mean for the three measurements.

$$\text{Mean} = \frac{\text{Your Volume} + \text{Labmate \#1} + \text{Labmate \#2} + \text{Labmate \#3} + \text{Labmate \#4} + \text{Labmate \#5}}{\text{number of values}}$$

Table 2 (2 pts each)

	From Ruler	From Water displacement of one sphere	From Water displacement of ten spheres
Mean	0.47_5 cm^3	0.41_7 mL	0.444 mL

The most commonly used measure of uncertainty is called the *standard deviation*. The standard deviation is a measure of the differences between the actual numbers and the mean.

$$\text{Standard Deviation} = \sqrt{\frac{(\text{Your Volume} - \text{mean})^2 + (\text{Labmate \#1} - \text{mean})^2 + (\text{Labmate \#2} - \text{mean})^2 + (\text{Labmate \#3} - \text{mean})^2 + (\text{Labmate \#4} - \text{mean})^2 + (\text{Labmate \#5} - \text{mean})^2}{(\text{number of values} - 1)}}$$

Calculating the standard deviation using this equation is easiest if you break it down into steps. The following worksheets take you though each of the individual steps.
The first step is to calculate the difference between each of the values (from Table 1) and the mean (from Table 2). Place these differences in Table 3:

Table 3

	#2 From Ruler	#5 From Water displacement of one sphere	#8 From Water displacement of ten spheres
Your number- mean:	$-0.0\underline{1}5$ cm^3	$+0.0\underline{1}3$ mL	$+0.01\underline{1}$ mL
Labmate #1- mean:	$+0.0\underline{4}5$ cm^3	$+0.0\underline{0}3$ mL	$-0.00\underline{8}$ mL
Labmate #2- mean:	$+0.1\underline{3}5$ cm^3	$-0.1\underline{2}7$ mL	$-0.02\underline{6}$ mL
Labmate #3- mean:	$-0.0\underline{0}5$ cm^3	$+0.0\underline{1}3$ mL	$-0.00\underline{2}$ mL
Labmate #4- mean:	$-0.1\underline{0}5$ cm^3	$+0.0\underline{4}3$ mL	$+0.00\underline{6}$ mL
Labmate #5- mean:	$-0.0\underline{5}5$ cm^3	$+0.0\underline{5}3$ mL	$+0.01\underline{6}$ mL

The second step is to square the each of the differences calculated in the first step (Table 3):

Table 4

	#2	#5	#8
	From Ruler	From Water displacement of one sphere	From Water displacement of ten spheres
(Your number- mean)^2:	$2.\underline{2}5\ 10^{-4}$ cm^6	$1.\underline{7}\ 10^{-4}$ mL^2	$1.2\underline{1}\ 10^{-4}$ mL^2
(Labmate #1 - mean)^2:	$2.03\ 10^{-3}$ cm^6	$9.0\ 10^{-6}$ mL^2	$6.4\ 10^{-5}$mL^2
(Labmate #2 - mean)^2:	$1.82\ 10^{-2}$ cm^6	$1.61\ 10^{-2}$ mL^2	$6.76\ 10^{-4}$ mL^2
(Labmate #3 - mean)^2:	$2.5\ 10^{-5}$ cm^6	$1.7\ 10^{-4}$ mL^2	$4.0\ 10^{-6}$ mL^2
(Labmate #4 - mean)^2:	$1.10\ 10^{-2}$ cm^6	$1.8\ 10^{-3}$ mL^2	$3.6\ 10^{-5}$ mL^2
(Labmate #5 - mean)^2:	$3.03\ 10^{-3}$ cm^6	$2.8\ 10^{-3}$ mL^2	$2.56\ 10^{-4}$ mL^2

The third step is to add together each of values in the columns of Table 4:

Table 5

	From Ruler	From water displacement of one sphere	From w ater displacement of ten spheres
Total of Squares:	$3.\underline{4}5\ 10^{-2}$ cm^6	$2.\underline{1}\ 10^{-2}$ mL^2	$1.1\underline{6}\ 10^{-3}$mL^2

The final step is to divide the numbers in Table 5 by the number of data points (5 in this case) and take the square root to get the standard deviations:

Table 6

	From Ruler	From Water displacement of one sphere	From Water displacement of ten spheres
Standard Deviation:	$0.0\underline{8}3$ cm^3	$0.0\underline{6}5$ mL	$0.01\underline{5}$ mL

Often we report our result as the mean ± standard deviation. It is intended to represent a range of possible "values" based on the precision of our measurement.

Table 7

	From Ruler	From Water displacement of one sphere	From Water displacement of ten spheres
Overall Result	0.47 ± 0.08 cm^3	0.42 ± 0.07 Ml	0.444 ± 0.015 mL

SAMPLE LAB REPORT

Name:
Lab Section:
Date:

CHEM 117 LAB 1: LENGTH AND VOLUME

Abstract: Three methods for measuring the volume of a small polystyrene ball were investigated and the precisions of these methods were compared. The most precise method measured the volume of water displaced by ten balls using a graduate cylinder. The volume of the sphere was estimated to be 0.44 ± 0.02 mL by this method.

Introduction: The concepts of precision, accuracy, significant figures and volume were explored. The precision of a measurement depends on both the tools used to make the measurement and the strategy employed in the procedure, which is highlighted in this experiment by the comparison of theses three sets of measurements.

Experimental Methods: In the first method a ruler was used to estimate the diameter of a polystyrene ball. The volume sphere was then calculated from $V = \pi(d/2)^2$. The other methods used a graduated cylinder to measure the volume of water displaced by one ball and ten balls, respectively, using a 25 mL graduated cylinder

Data:

	Measurement of the volume with a ruler	
1.	Diameter of a polystyrene sphere using the metric ruler (in centimeters).	0.96 cm
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	Measurement of the volume Using a graduated cylinder (one ball)	
3.	Volume of water added to the graduated cylinder.	10.41 mL
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6.	Volume of water plus ten polystyrene balls.	14.96 mL
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8.	Calculate average volume of spheres: [Volume of one sphere = (1/10)volume of ten spheres]:	0.455 mL

Table 1: Class Data for the volume of a polystyrene sphere

	#2 From Ruler	#5 From water displacement of one sphere	#8 From water displacement of ten spheres
Your number:	0.46 cm^3	0.43 mL	0.455 mL
Labmate #1	0.52 cm^3	0.42 mL	0.437 mL
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Labmate #3	0.47 cm^3	0.43 mL	0.442 mL
Labmate #4	0.37 cm^3	0.46 mL	0.450 mL
Labmate #5	0.42 cm^3	0.47 mL	0.460 mL

Table 2: Average volume of a polystyrene sphere

	From Ruler	From Water displacement of one sphere	From Water displacement of ten spheres
Overall Result	0.47 ± 0.08 cm^3	0.42 ± 0.07 mL	0.444 ± 0.015 mL

Discussion: The water displacement method using the 25 mL graduated cylinder is more precise than using the small ruler. However, the volume of an average ball can be estimated more precisely by measuring the water displacement that occurs from adding ten balls than by measuring the water displacement that occurs from the addition of one ball. This result was expected. The volume displaced by ten balls is ten times greater than the volume displaced by one ball, which results in one more significant figure in the volume measurement (0.445 mL vs. 0.43 mL). Because the true value for the average volume of the sphere is not known, it is difficult to determine which method is more accurate. However, the accuracy of the 25.00 mL graduate cylinder is ±0.1 mL. Thus the accuracy can be expected to be at least 1.3 % and the measurement should be fairly accurate. If the true value is 0.446 mL, then the method using the water displacement obtained from the addition of ten balls is also the most accurate method, as the difference between the average and the true value is 0.002 mL.