This is a follow-up from the density lab, to give you practice working with statistics in experimental data. You will be given each lab group's measurements (with uncertainty) for the density of rubber and cork.

1 Numerical

For each material, find:

- The mean density of the material $\overline{\rho}$
- The difference between each group's results and the mean $(\rho_i - \overline{\rho})$
- The difference squared $(\rho_i - \overline{\rho})^2$
- The standard deviation

$$\sigma_\rho = \sqrt{\frac{\sum_{i=1}^{N}(\rho_i - \overline{\rho})^2}{N-1}}$$

  where N is the total number of results

Include the results of each step in your report, organized in data tables.

All calculations are to be done by hand for one of the materials. Yes, this is tedious. Yes, are computer programs that *could* do this for you. However, there is no better way to develop an intuition for what the equations tell you than to sit down and repeatedly do the work yourself.

When working with large data sets, where it is beneficial to apply statistics like this, the result is reported as

$$\rho = \overline{\rho} \pm \sigma_\rho$$

2 Visual

Make a visual representation of the data for each material: display each group's results on a plot with error bars given by measurement uncertainty. Draw dashed lines representing the mean, and the mean plus or minus one standard deviation. See figure 1 for an example.

Again, one plot is to be done by hand. Yes, it is tedious. Yes, there are computer programs that could do it for you. But as with the calculations, there is no better way to develop intuition than to make the graph yourself.

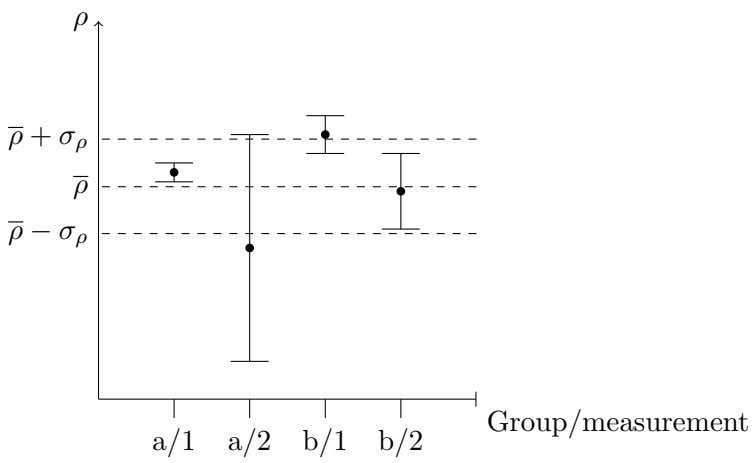

Figure 1: Plot of two group's results for cork, with mean and standard deviation shown. Error bars are each group's measurement uncertainty.

3 Analysis

1. Are there any outliers in the aggregate data set? What do they tell you, if anything?
2. Did you exclude any measurements from your analysis? If so, justify your decision.
3. What is the density of each material? Include conclusions (with uncertainty) from your measurements alone, as well as from the aggregate data set. How do the results from the aggregate data set compare to the results you found with your particular experiments? What can this tell you, if anything?
4. If you were asked to report on the density of rubber and cork, what would you say based on these findings? Would you be comfortable reporting a value (including uncertainty)? Would you ask for more time to perform more and/or different tests?

On the following page(s) are the class's results from the density lab, *as reported* by each group—I have not edited them for any inconsistencies with significant figures, units, incorrect calculations, etc. You may decide some results are unreliable for one reason or another. If you exclude data points from your analysis you *must* be able to justify the exclusion.

Please note that not every group followed the same procedure for each measurement. For example, "measurement 1" from group 1 could have been a different procedure than "measurement 1" for group 2. Because of this, you must work with each table as one single data set, and you cannot draw conclusions about different methods.

Groups have intentionally been left anonymous. Individuals may decide to re-do calculations (including error analysis, rounding for significant figures, unit conversions, etc.) before turning in their report.

Measurement 1				Measurement 2		
Group	Density	Uncertainty	Units	Density	Uncertainty	Units
1	0.25	0.1	g/cm^3		Not reported	
2	0.12	0.02	g/mL	0.16	0.8	g/mL
3	0.183	0.03	g/mL	0.17	0.08	g/mL
4	0.15	0.01	g/mL	0.16	0.4	g/mL
5	0.509	0.02	g/mL		Not reported	
6	0.18	0.7	g/mL	0.15	0.02	g/mL
7	0.2	0.08	g/mL	0.17	0.02	g/mL
8	0.17	0.008	g/mL	0.2	0.02	g/mL
9	0.285	0.003	g/cm^3	0.25	0.03	g/cm^3
10	0.18	0.02	g/mL	0.18	0.02	g/mL
11	380	78.6	kg/m^3	347	62.1	kg/m^3
12	0.183	0.00646	g/mL	0.17	0.00106	g/cm^3
13	0.179	0.014	g/cm^3	0.204	0.108	g/cm^3
14	0.2	0.5	g/mL	0.15	0.03	g/mL
15	0.215	0.02261	g/mL $\pm$ mL/g	0.221	0.01699	g/mL $\pm$ mL/g
16	0.177	0.018	g/cm^3	0.188	0.021	g/cm^3

Table 1: Cork

Measurement 1				Measurement 2		
Group	Density	Uncertainty	Units	Density	Uncertainty	Units
1	1.32	0.1	g/cm^3		Not reported	
2a	1.37	0.02	g/mL	1.53	0.9	g/mL
2b	1.4	0.01	g/mL	1.4	0.9	g/mL
3	1.27	0.1	g/mL	1.32	0.01	g/mL
4	1.3	0.1	g/mL	1.4	0.4	g/mL
5	1.167	7.19	g/mL		Not reported	
6	1.3	0.7	g/mL	1.4	0.2	g/mL
7	1.2	0.08	g/mL	1.2	0.1	g/cm^3
8	1.3	0.02	g/mL	1.15	0.08	g/mL
9	1.3	0.1	g/cm^3	1.36	0.02	g/cm^3
10	1.2	0.03	g/mL	1.3	0.1	g/mL
11	1300	110	kg/m^3	1425	244	kg/m^3
12	1.27	0.00779	g/mL	1.32	0.00829	g/cm^3
13	1.2130	0.0925	g/cm^3	1.26	0.65	g/cm^3
14	1.3	0.2	g/mL	1.2	0.3	g/mL
15	1.26	0.09825	g/mL $\pm$ mL/g	1.27	0.09793	g/mL $\pm$ mL/g
16	1.25	0.9527	g/cm^3	1.29	0.01066	g/cm^3

Table 2: Rubber; note that group 2 reported two sets of calculations