SMS-204: Integrative marine sciences.

Assignment #1

1. A. Compute the volume and densities and their uncertainties for all the rods your group measured. Divide the rods into ***two groups*** with similar densities (5pts).
   a. The uncertainty in the scale was +/-0.005gr based on its precision
   b. The uncertainty due to the caliper was is +/-0.05mm=+/-0.005cm based on its precision.

Notation: Length of rod: *H*. Diameter of rod: *D*.

Below I will assume the uncertainty in the diameter to be based on the caliper (δD=0.005cm) and similarly in the length (δH=0.005cm).

Volume (cylinder) = π width^2 × length / 4= $\pi D^2 \times H / 4$

Using the formula for propagation of errors provided to you in the lab, we can calculate of the uncertainty in the volume of a cube:

$$Volume = x \cdot y \cdot z \rightarrow \frac{dVolume}{Volume} = \sqrt{\left(\frac{dx}{x}\right)^2 + \left(\frac{dy}{y}\right)^2 + \left(\frac{dz}{z}\right)^2}$$

$$\rightarrow dVolume = Volume\sqrt{\left(\frac{dx}{x}\right)^2 + \left(\frac{dy}{y}\right)^2 + \left(\frac{dz}{z}\right)^2}$$

For a cylinder this will change to:

$$\frac{\delta Volume}{Volume} = \sqrt{\left(\frac{\delta H}{H}\right)^2 + 2\left(\frac{\delta D}{D}\right)^2}.$$

Uncertainties in density are computed from those of a ratio:

$$z = x \cdot y \rightarrow \frac{dz}{z} = \sqrt{\left(\frac{dx}{x}\right)^2 + \left(\frac{dy}{y}\right)^2}$$

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hence:

$$\frac{\delta density}{density} = \sqrt{\left(\frac{\delta Volume}{Volume}\right)^2 + \left(\frac{\delta mass}{mass}\right)^2}$$

Since the mass of *each* cylinder was different so will the uncertainty.

For example, for the 25mm long rod, with diameter of 12.7mm that weighed 3.65gr:

$$\delta density = 1.15\sqrt{\left(\frac{0.02}{3.2}\right)^2 + \left(\frac{0.005}{3.65}\right)^2} = 0.007g\ cm^{-3}$$

Rod #	1	2	3	4	5	6	7	8
Mass [g]	3.65	5.36	5.11	7.13	6.57	8.89	10.98	14.3
Length [mm]	25	30	35.1	40	45.1	50	75	80
Diameter [mm]	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7
mass	Repeat of line 1 above							
Δmass [g]	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Volume [cm^3]	3.2	3.8	4.4	5.1	5.7	6.3	9.5	10.1
Δvolume [cm^3]	0.02	0.02	0.03	0.03	0.03	0.04	0.05	0.06
Density [g cm^-3]	1.15	1.41	1.15	1.41	1.15	1.40	1.16	1.41
Δdensity [g cm^-3]	0.007	0.008	0.007	0.008	0.007	0.008	0.006	0.008

Table 1: data from the different rods measured in the lab. The yellow highlights rods with the lowest density.

B. Plot the **mass** as a function of **volume** for these ***two groups***. Use the your experience from previous classes to make a good plot (one that has: labels for each axis which includes units, tick marks on axis and a symbol to denote each datum with *no* line connecting the data and no grid lines) (10pts).

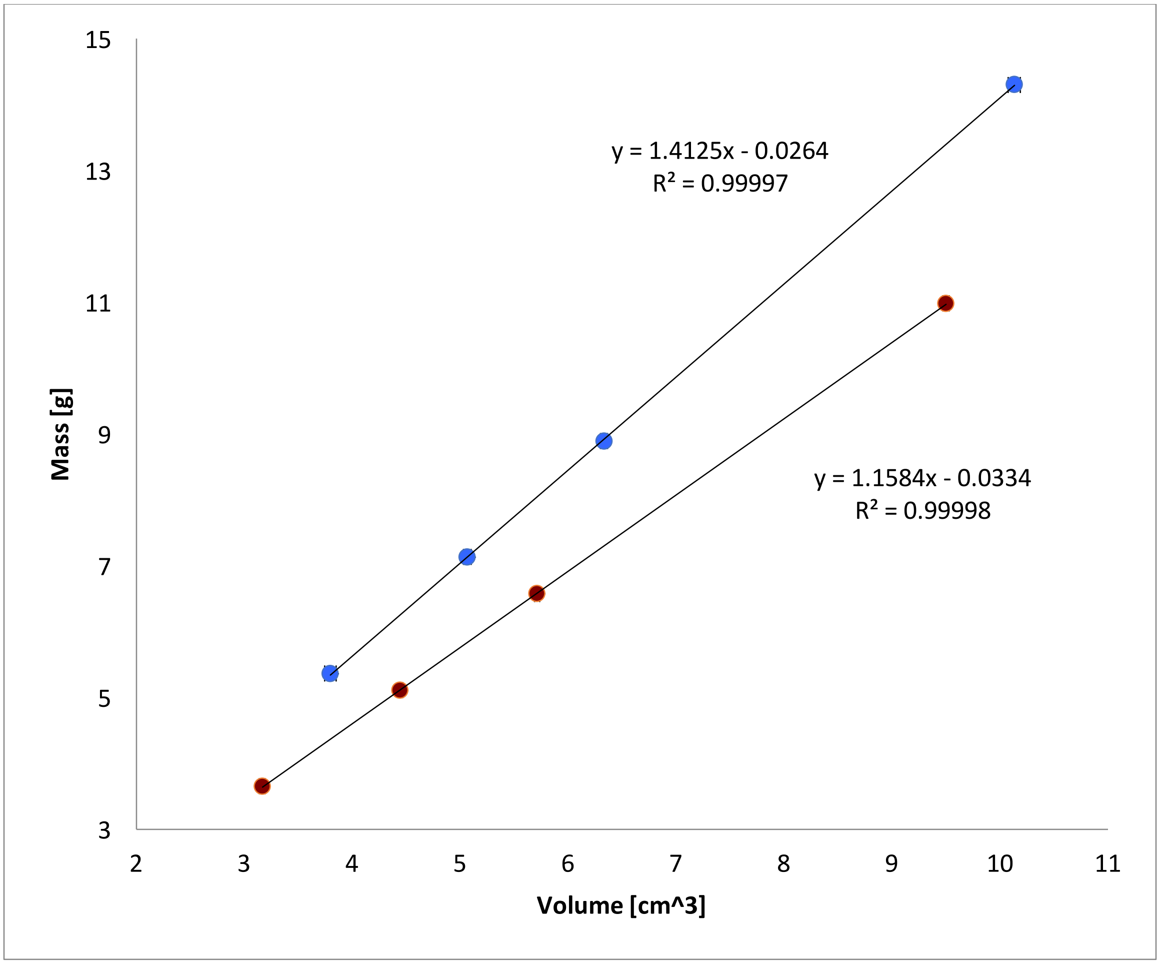

Figure 1. Rod mass as function of volume. Error bars indicate uncertainties in the measurements. The uncertainties in mass are too small to show. The lines are the linear regression fit to the two different groups of rod of similar density. The error bars are too small to be clearly seen.

Note: it may be easier for you to separate the two groups of similar density rods into separate graphs. That is OK.

C. For both groups of rods, obtain the linear regression line between Mass and volume, a (this can be done by right clicking the data points in Excel, see links below). (5 pts)

See Figure 1.

D. Display the equation and the line on the graph. You should get an equation of the type: Mass=A × Volume + B. (5pts)

See Figure 1.

E. Does there seem to be a linear relationship between Volume and Mass? (5pts)

Yes. Mass is linearly correlated with volume and a straight line fits well within the data.

F. What does the slope of the regression line represents (A in the equation in question 1D) (5pts)? What are its units (5pts)?

The slope represents the density=mass/volume. Units are [g/ml] or[g/cm^3] .

G. What are the units of the intercept (*B* in the equation in question 1D) (5pts)?

Unit is [g] as the equation is one for mass and all term in an equation should have the same units.

I. Add uncertainties (in the form of error bars, see links below) to your plot (5pts).

See Figure 1. Error bars are too small to see them clearly.

J. Explain how the uncertainties were computed (5pts).

Uncertainties in mass were assumed constant based on the rounding of values provided in the table, e.g.+/-0.0005g. Uncertainties in volume are based on propagating error associated with measurements of length and width. I assumed we measured width and length with the same caliper with uncertainty (+/-0.005cm) and propagated using:

$$\frac{\delta Volume}{Volume} = \sqrt{\left(\frac{\delta H}{H}\right)^2 + 2\left(\frac{\delta D}{D}\right)^2} \ .$$

2. A. Using an Excel spreadsheet (or another program of your choice) and the **data your whole class collected** on sinking speeds of different beads, compute for each bead the mean, median, maximum, minimum, 16th percentile, 84th percentile, and the standard deviation of the sinking speed for that bead (10pts, those program have built-in function to compute these, to learn how to use them, for example google 'how to compute percentile with excel' + some tutorial on YouTube will walk you through it).

Note: Data were converted to the same units [cm/s] settling. Data from 'Zebra' had to be converted. Bead length data for 'Proud penguin' was clearly wrong. I kept it just so I can show you how little it affects non-parametric stats. Full data is in the appendix.

B. How do the median and mean compare? How does the standard deviation compare to (84th percentile-16th percentile)/2? We expect them to be similar for a normal distribution (5pts).

Min [cm/s]	2.83	5.90	10.10	18.97	20.30
Max [cm/s]	3.55	7.81	14.07	26.60	42.55
Mean [cm/s]	3.19	6.89	11.58	23.11	34.31
Stdandard deviation [cm/s]	0.18	0.44	0.84	1.81	4.19
Median [cm/s]	3.20	6.93	11.64	23.08	34.48
16th percentile [cm/s]	2.97	6.46	10.68	21.39	31.70
84th percentile [cm/s]	3.34	7.30	12.21	25.09	36.98
(84th-16th)/2 [cm/s]	0.19	0.42	0.77	1.85	2.64

Table 2. Summary statistics of settling data.

Mean and median are close and standard deviation compares well with (84th percentile-16th percentile)/2 suggesting the underlying distribution is likely normal. Full data is in the appendix.

C. Plot the **median** sinking speed of the beads (*y* or vertical-axis) as function of their cross-sectional area (=$\pi \times$ radius^2) (*x* or horizontal axis). (10pts)

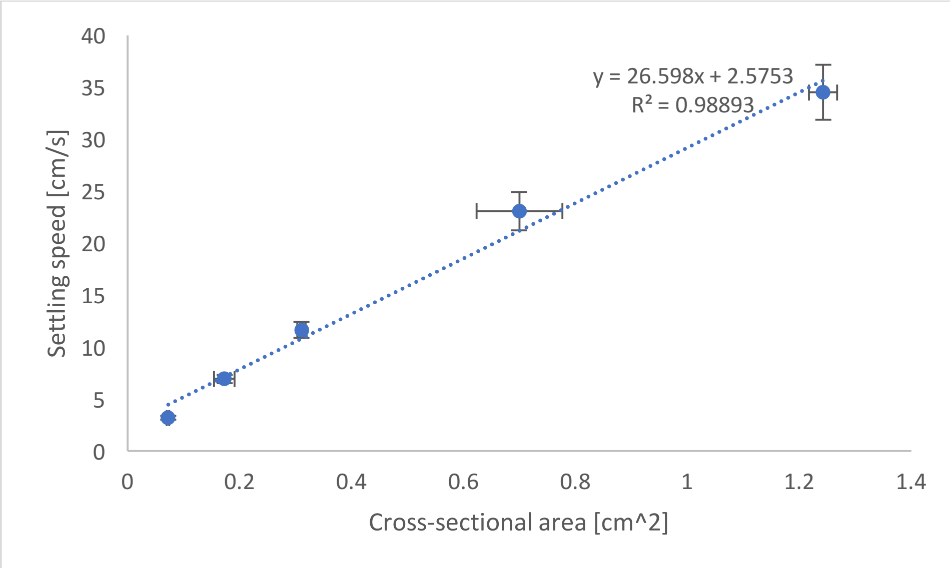

Figure 2. Settling speed as function of cross sectional area. The line is the regression line for these data

D. Does there seem to be a relationship between cross-sectional area and median sinking speed (determine a relationship by plotting the regression line and displaying its equation on the plot)? Note: When the bead reaches terminal velocity, a balance exists between the downward pool of gravity and the drag force. We will get back to these data later in the semester when we will analyze the forces acting on bodies immersed in water. (5pts)

There is a monotonic relationship though a concave curve could match data better.

E. Add the uncertainties of the data points to the graph (these are called 'error bars', see links below). Use the statistics from the whole class dataset for uncertainties. What do such uncertainties represent? How do they compare to uncertainties in individual measurements of sinking speed? (5pts)

See Fig. 2. I used the (84^{th}-16^{th} percentiles)/2 for both bead diameter uncertainty and sinking speeds. The uncertainties represent those associated with human error and are much larger than measurements uncertainties.

3. (15pts): Watch the movie "Introduction of the Study of Fluid Motion" https://www.youtube.com/watch?v=EIuU9Q8CGDk, and answer the following questions (note: there is no need to use more than 4 sentences to answer each part correctly):

a. Find in the movie 4 natural phenomena that are relevant to Oceanography or marine Biology.

Waves, winds, Gulf Streams and other currents, swimming by marine animals, rivers flowing into the ocean.

b. What are the fundamental dimensions in physics? Give example of their units.

Dimensions: Length, time, mass (or force) and possibly temperature. Units: Meter, second and kilogram (or Newton), Kelvin.

c. In order to build a model that is similar in behavior in fluid to the real life object in water, what needs to be done?

Non-dimentional ratios of fluid properties and object properties (such as the Euler number, Froud number, Reynolds number and Mach number) need to be similar in the model experiment as in real life, for the model to mimic the full size object (Dynamical similarity).

Appendix: data from settling experiment.

bead 1	bead 2	bead3	bead4	bead5
sinking apeed [cm/s]	sinking apeed [cm/s]	sinking apeed [cm/s]	sinking apeed [cm/s]	sinking apeed
2.90	5.90	10.23	21.10	21.00
2.95	6.15	10.47	21.28	29.90
2.97	6.17	10.59	21.70	31.90
2.99	6.42	10.60	22.00	29.93
3.07	6.46	10.68	22.31	31.00
3.12	6.73	10.80	22.47	32.79
3.18	6.90	10.93	22.79	33.28
3.19	6.99	11.10	22.86	33.59
3.20	6.99	11.48	23.08	34.22
3.23	6.99	11.53	23.33	34.48
3.25	7.06	11.64	23.39	34.90
3.26	7.07	11.70	24.20	35.78
3.31	7.10	12.08	24.20	35.96
3.32	7.13	12.10	24.38	36.15
3.37	7.41	12.12	25.48	36.89
3.43	7.42	12.50	25.75	37.38
3.47	7.81	13.29	26.60	40.29
2.95	6.04	12.61	23.00	40.78
2.88	6.47	12.70	20.77	42.55
2.96	6.89	10.75	21.40	32.59
3.08	6.29	10.10	20.75	35.00
3.10	6.47	10.58	22.81	33.61
3.03	6.71	11.10	21.39	32.48
3.23	7.10	11.33	24.70	28.67
3.24	7.23	10.60	21.62	34.22
3.21	6.79	11.69	24.81	36.70
3.11	7.12	11.87	26.42	33.04
3.20	7.38	11.44	22.47	35.45
3.38	7.42	11.70	25.33	36.98
3.20	6.80	12.08	23.90	36.15
3.20	6.78	11.85	23.49	33.85
3.33	6.78	14.07	24.10	34.78
3.34	7.63	12.65	24.78	34.87
3.49	7.78	11.80	26.43	33.60
2.83	6.20	11.40	22.40	42.55
2.90	6.61	12.08	19.91	31.88
2.90	6.43	10.59	21.10	31.70
3.07	6.80	10.70	18.97	20.30
3.06	6.62	10.76	21.60	29.00
3.14	6.63	11.20	21.39	31.39
3.27	7.17	10.84	23.60	34.22
3.22	6.87	11.20	19.42	32.79
3.24	6.68	12.03	21.81	36.89
3.26	6.99	12.05	25.30	35.78
3.19	7.30	11.44	23.39	35.63
3.28	7.09	11.69	23.03	38.25
3.27	7.04	12.70	24.36	34.55
3.27	6.93	11.89	23.49	33.61
3.50	7.03	11.80	23.26	36.73
3.42	6.96	12.21	25.09	40.78
3.55	7.62	13.17	25.15	38.83

Bead diameter [mm]				
bead 1	bead 2	bead3	bead4	bead5
0.20	0.40	0.60	0.80	1.00
3.10	4.26	6.19	6.82	11.70
2.88	4.26	6.20	8.54	12.40
2.93	4.27	6.20	9.18	12.54
2.96	4.50	6.21	9.32	12.55
2.97	4.60	6.26	9.39	12.56
3.00	4.62	6.27	9.40	12.57
3.02	4.68	6.27	9.41	12.58
3.03	4.69	6.29	9.44	12.58
3.03	4.69	6.29	9.45	12.60
3.04	4.71	6.29	9.46	12.60
3.04	4.72	6.30	9.46	12.60
3.06	4.72	6.30	9.48	12.61
3.06	4.72	6.31	9.49	12.61
3.08	4.75	6.31	9.50	12.61
3.09	4.75	6.32	9.50	12.63
3.11	4.75	6.34	9.50	12.63