STEM coding Data Science

Air Pressure! (designed by Prof. Chris Orban, Ohio State U.)

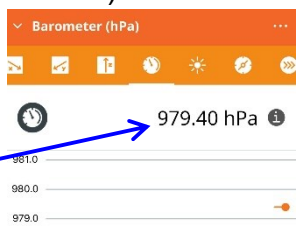
It turns out nearly all smartphones (iPhones and Android models) and nearly all iPads have air pressure sensors (a.k.a. barometers). There are a couple of apps you can use to get a pressure reading but the one that seems to work best on all platforms is the Arduino Science Journal app.

Step 0. Download the Arduino Science Journal app onto your device.

Note: It doesn't make a big difference if you use a smartphone or a tablet/iPad for this lab. But if you do have an iPad, please go ahead and use that.

Step 1. Open the app. Press "+" to open a new experiment. Click on this symbol:  in the lower right corner to edit the new experiment. Then click the "Sensors" symbol:  at the bottom of the screen to bring up the various sensors.

Step 2. Click on this symbol  (fourth sensor from the left) to select the barometer. At this point your screen should look something like this:



You may have a different number here:

Step 3. In this course we typically assume 100 kPa for atmospheric pressure. The pressure reading on your device may fluctuate by a small amount, but go ahead and take a reading by clicking on the "Snapshot" symbol at the bottom () and calculate by what percentage it is different from 100 kPa. (Hint: h = hecto, google it to get the value). Would you say using 100 kPa is a good or bad approximation?

$$\% = 100 \times \frac{|\qquad - 100\ \text{kPa}|}{100\ \text{kPa}} =$$

Step 4. Without getting out of your seat, what do you think will happen if you increase your height above the ground? Will the pressure go up or down? Why?

Step 5. Go to a stairwell and measure the pressure with the device on the floor on the ground level. Use a meter stick to estimate the distance between floors, and take readings at each level until you reach the highest floor.

Estimated Height (m)	P_{meas} (hPa)	P_{meas} (Pa)
0 m		

Step 6. The pressure vs height should (at least roughly) obey this formula:

$$P_{meas} = -\rho g h + P_{ground}$$

where P_{meas} and P_{ground} are in Pa units, g = 9.8 m/s^2 , ρ is the density of air in kg/m^3 units and h is the height above the ground in meters. Use your measurements to create a pressure vs. height scatter plot in Excel or Google Sheets. Does the plot look how you would expect it to, considering the formula above?

Step 7. Using this scatter plot and the formula above, we can estimate other interesting quantities, like the density of air and the height of the edge of the atmosphere. To do this, you first need to perform a *linear regression* on the plot of your data. A linear regression will model the relationship between height and pressure measurements with a linear equation (which should be a good fit for your roughly linear data). A simple way to do this is by fitting a linear trendline to your data. See the **Linear Regression Instructions** document if you are unsure how to do this.

Record the equation of the linear trendline here: $y =$ _____ $x +$ _____

Step 8. Notice that both the trendline equation and the formula from Step 6 are in slope-intercept form ($y = mx + b$). In the formula from Step 6, what are the x and y variables? What are the slope and y-intercept? Estimate air density, ρ, using this information.

Formula from Step 6:	Linear trendline equation:
$P_{meas} = -\rho g h + P_{ground}$	$y =$ _____$x +$ _____

$$\rho =$$

Step 9. Hypothetically, what kind of experiment could you do to measure the density of air that wouldn't involve a barometer? (Hint: it may require a parachute!)

Step 10. It is hard to say exactly where the earth's atmosphere ends and space begins, but a reasonable way of doing it is to estimate the height above the ground where the atmospheric pressure would be zero ($P_{meas} = 0$). Use the formula from Step 6 and your value for air density (ρ) found in Step 8 to estimate the height of the edge of the atmosphere, h_{space}.

$$\mathrm{P_{meas}} = -\rho \mathrm{g h_{space}} + \mathrm{P_{ground}} = 0$$

$$\rightarrow \mathrm{h_{space}} =$$

Step 11. How could you use the scatter plot and linear trendline equation directly to estimate h_{space} instead of using the formula from Step 6?

$$\mathrm{h_{space}} =$$

Step 12. Explain why our estimations of the edge of the earth's atmosphere is a low estimate at best. What crucial assumptions are we making here? Which one is to blame? (Hint: can you explain why it's not gravity's fault?)

Step 13. In a sentence or two, how would you improve your estimate for the edge of space?