**Math 171 Group Worksheet 6**
on Chapter 5 ideas
Due Tuesday, December 4, 2018

One submission per group. Grade will be based on mathematical processes, precision, proper notation and participation. Make sure to write legibly and explain your steps.

**Problem 1. Bottle Experiment**

To do this experiment, you will need to gather some supplies. It requires:

Supplies:
- an empty plastic bottle that is mostly cylindrical in shape
- a measuring apparatus (25 ml beaker, 1/4 cup measuring cup, any small known quantity object that can be filled)
- a Sharpie marker
- metric ruler
- water
- stopwatch or digital timer (cell phone?)
- camera

Procedure:

1. Find the lowest part of the cylindrical portion of the bottle. Cut or bore a small hole (approx 1mm in diameter) into the bottle there on the side. You could use a knife or a nail heated with a lighter to make the hole.
2. Mark 1 cm increments using the Sharpie starting at the hole you created and moving vertically until you reach 11 cm above the hole. The final mark should still be within the cylindrical portion of the bottle. Estimate the radius of the bottle in centimeters.
3. You will need to fill in a chart similar to this one. You will need more spaces. The first column is to record the amount of time it will takes to go from one marked measurement on the bottle to the next. The second column has the heights above the hole that the data are being recorded for. You should fill this one out (11 10 9 ...2 1 cm) before your start the experiments. The third column is to record how long is takes to fill your apparatus (beaker or measuring cup) at each of the marked heights. It will take two runs of the experiment to completely fill in the chart.

| Time elapsed between measurements | Water height on container | Time to fill |
|---|---|---|
| $\Delta t$ (in seconds) | $h$ (in cm) | $t_f$ (in seconds) |
| 0 | Max height = 11 cm | |
| | 10 cm | |
| | 9 cm | |

4. When you are ready to start the experiment, fill the bottle up to the highest marked height. Someone will need to keep their finger on the hole until the experiment starts. Place the bottle on a flat surface where the water will not cause damage like the edge of a sink. For the first run of the experiment, you will need to record the times when the water level reaches each of the marked heights of the bottle. [Note: you can use the lapse button on a stopwatch to mark times for each height to record afterwards.] Fill in the first column of the chart with this information.
5. Once again fill the bottle to the highest marked height. This time you will need to start and stop the experiment to reset for the next calculation. You need to determine the amount of time it takes to fill your apparatus when the water level is at a marked location. You may need to add water or you may need to drain additional water to get to the next marked location after you fill the apparatus. Repeat to find the time required to fill the apparatus at the next height. This information should go into the last column of the chart.
6. Take a group selfie with all your group members and experiment setup.

Calculations:

1. Using the measurements from the chart, estimate the flow rate of the water at each level. Be sure to think about units.

$$\text{Flow rate} = \frac{dV}{dt} \approx \frac{\Delta V}{\Delta t}$$

2. Create a plot for Time (s) vs Flow rate. Does it look like a linear relation?
3. Find the best fit for the Time vs Flow rate graph. Give an explanation of what this line is telling you physically.
4. Use the equation that you found in (3) and the initial condition when $t = 0$ for a set up to an initial value problem. Solve it to determine the $V(t)$. Recall that the volume of a cylinder is given by $V = \pi r^2 h$.
5. Can you find an equation for $h(t)$? Note: You will already estimated $r$.
6. Create a plot for Time (s) vs Height (cm) using the data from the chart. Is this linear?
7. Use the equation you found in (5), to find the $h$ at the times when your experiment was at a known height. For example: You should know the time when the water was at height 3cm.
8. On a same axis, plot your data points (from the chart) for Time vs Height and the hypothesized data points (from the model) for Time vs Height. How close are they?

Wrap Up:

Be sure to include the following in your problem:

(1) data collection from experiment

(2) plots from experiments (either neatly by hand or using technology)

(3) equation of the best fit

(4) calculations of calculus ideas that are readable

(5) calculated data points with comparison graph

(6) summary statement

(7) computations are presented neatly by hand or typed

(8) selfie and names of group members

Environmental Note: Please recycle your plastic bottle when you are finished.

Grading on Problem 1 will be on the following criteria:

| Item | Criteria | Points |
|---|---|---|
| 1. | Completes data collection and present information concisely. | 4 |
| 2. | Plots are presented with clear labels and units with technology or by hand. | 4 |
| 3. | Finds best fit line for time vs flow rate. | 4 |
| 4. | Uses calculus ideas to find $V(t)$ and $h(t)$ that is easy to follow. | 4 |
| 5. | Uses model to determine comparison data points and plots results. | 4 |
| 6. | States a reasonable conclusion to accuracy to results. | 4 |
| 7. | The problem is well-organized and easy to follow. Computations and graphs are presented. | 4 |
| | Participation Multiplier (full=1, some =0.5, very little=0) | |