Week 7 Challenge Homework

Fluid Dynamics and Simple Harmonic Oscillation

Submit a digital copy (PDF, jpg, etc.) to gradescope.com. Please use the Gradescope interface to associate each page of your submission with the corresponding question number! It makes grading much easier.

Every page should be labeled on the top left with the question number and there should be only be one solution per page. If a solution takes more than one page, be sure to label that it is a continuation of the previous page's solution. If data is needed to complete a problem, be sure to cite the source you've acquired your data from. See the course website for further details.

You will be asked to apply sense-making in some problems. Use the list below as a reference to the different sense-making techniques. More information about sense-making can be found on the BoxSand menu under Math Tools => Sense-making.

- *Sign:* Check the **sign** of each quantity makes sense.
- *Dimensionality:* Check the **dimensionality** and units of each quantity makes sense.
- *Order of Magnitude:* Check the **order of magnitude** of the final answer and other important quantities is within a a factor of 10 of what you think it should be.
- *Graphical Analysis:* Use a **graph** to see if the behavior of a solution makes sense.
- *Proportionality:* Using a symbolic solution, check the behavior of the answer when you change a given quantity on which it is dependent. Does the answer vary **proportionally** to what you expect?
- *Special Cases:* Check the behavior of a derived equation in limiting (**special**) cases makes sense, e.g. as x goes to 90 degrees in sin(x).
- *Self-consistency:* Check derived equations, functions, or values, are **self-consistent**, e.g. check that the slope of a derived position plot matches the values of the given velocity plot
- *Known Values:* Compare given or derived quantities with common well **known values**.
- *Related Quantities:* Compare the relative magnitude of two **related quantities**.

Question 1:

You are on a cruise ship to the Bahamas. **The door to your room faces the outside of the ship, and swings inwards to your room**. On a breezy day you notice that after turning the door knob, it is very difficult to pull the door open (legend has it, this happened to the mother of a friend of your instructor's cousin's dog's grand-pa's owner). The wind is blowing steadily parallel to the side of the ship. **The wind is not at all directed into the door!**

(a) What is the origin of the force preventing you from opening the door? Explain why the wind is making it difficult to open the door. Hint: if your door opened swinging outwards, it would be initially easy to open!

(b) Your door is 1.00 meters wide and 1.93 meters tall. The door handle is 87.5 cm from the door hinges. If you have to exert a force of 45 lbs to start to open the door, how fast is the wind travelling outside your door? You may assume the force discussed in part (a) acts at the center of the door. Give the speed both in m/s and m/hr.

Question 2:

In an engine, a piston oscillates with simple harmonic motion so that its position varies according to the expression $x(t) = 15.0 \cos(20.0\, t)$ where x is in centimeters and t is in seconds.

(a) What is the period of the motion?
(b) What is the amplitude of the motion?
(c) At $t = 1$ s, find the position of the piston.
(d) At $t = 1$ s, find the velocity of the piston.
(e) At $t = 1$ s, find the acceleration of the piston.
(f) Sketch a plot of the acceleration as a function of time. Scale the plot properly.