Assignment XI, PHYS 111 (General Physics I) (Last Assignment! Woo!)
Fall 2022
Due 12/2/22

This last homework only has graded problems on it related to fluids and oscillations, but we will also be doing a little bit of gravity, waves, and/or thermal physics at the very end of the semester and that material IS FAIR GAME for the final. As such, I've tried to include a variety of recommended thermal practice problems here. If you read a problem and we haven't talked about the associated ideas AT ALL by the last day of class, then you can safely assume that problems on those topics will not appear on the final.

As always, please legibly write (or type) your answers on separate paper. Incorrect answers with no work will earn nearly no credit, and consistent correct answers with no work are suspicious – many of these problems your professor can't do in his head, so it is unusual if you can. Please show all relevant work.

To help with this homework, you should read the associated sections of your text and watch the videos associated with the lectures on the course webpage: http://larsenml.people.cofc.edu/phys111_fall22.html.

(Ungraded) suggested textbook practice problems

(All problems are odd problems (that have answers in the back of the book) out of Halliday, Resnick, and Walker, 10th Ed.)

Chapter 13, Problems 1, 3, 5, 9, 13, 19, 23, 25, 29, 41, 75
Chapter 14, Problems 3, 5, 9, 27, 31, 33, 35, 37, 51, 59, 61, 63, 75, 77, 83
Chapter 15, Problems 1, 3, 5, 9, 11, 17, 19, 23, 25, 27, 29, 33, 41, 45, 47, 51, 57
Chapter 16, Problems 3, 5, 15, 19, 21
Chapter 17, Problems 1, 3, 7, 11, 15, 17, 19, 23, 51, 53, 55, 57, 61
Chapter 18, Problems 5, 7, 23, 25, 29
Chapter 19, Problems 19, 21, 29, 33, 55

Graded Homework Problems

1. Consider an ideal simple pendulum used as the timekeeping component in a pendulum clock. Throughout this problem you should assume the amplitude is small enough that $\sin\theta = \theta$ is an acceptable approximation and that there is no damping.

   a) Assume that the pendulum is designed to complete a full oscillation once every half second. How long is the pendulum arm?

   b) Since the pendulum is designed to complete two oscillations each second, this suggests that the pendulum arm should complete 172800 oscillations in each 24-hour day. If instead the pendulum completes only 172795 oscillations (e.g. the clock is "slow" by 2.5 seconds per day), then how much longer than the desired length is the pendulum? (Put another way, how much shorter would you need to make the pendulum so that it would keep proper time)?

   c) If instead you had a pendulum clock that still oscillated once every half second, but this time the pendulum arm is not a simple pendulum but rather a uniform rod, how long would that rod have to be for it to oscillate the desired 172800 times each day?

2. In class, I argued that a valid solution of the differential equation:

$$\frac{\mathrm{d}^2\theta}{\mathrm{d}t^2} + \frac{mgd}{I}\theta = 0$$

   can be expressed as

$$\theta(t) = C_1 \cos\left(\sqrt{\frac{mgd}{I}}t\right) + C_2 \sin\left(\sqrt{\frac{mgd}{I}}t\right)$$

   a) Similar to what I did in class for the mass-spring system, show that the proposed expression for $\theta(t)$ satisfies the above differential equation.

   b) If $\theta(3\text{ s}) = 0.3$ rad and $\left.\frac{\mathrm{d}\theta}{\mathrm{d}t}\right|_{t=3\text{ s}} = -0.2$ rad/s, find C_1 and C_2 if $\sqrt{\frac{mgd}{I}} = 2.7$ rad/s.

3. A little googling told me that it takes about 6.5 GPa of pressure to crush a human skull. (I'm sure I'm on a watch-list now). Some more googling told me that it takes about 300 psi to completely crush a (full) soda can. The depth of the ocean at its deepest point is about 11000 meters.

   a) If we believe the numbers above, is it possible to crush a human skull by bringing it to the bottom of the ocean? Justify your answer with an appropriate calculation.

   b) How deep would you have to place a full soda-can in the ocean so that it would be crushed?

   c) How deep would have have to go in the ocean so that the total pressure above you (atmospheric + water pressure) would equal twice standard atmospheric pressure?

4. The density of aluminum is about 2700 kg/m^3. The density of glycerol is about 1250 kg/m^3. An uniform aluminum sphere with *diameter* 4.0 cm is submerged in glycerol and dropped.

   a) What is the magnitude of the buoyant force on the aluminum sphere?

   b) What is the *net* force on the sphere of aluminum in the glycerol, assuming no drag force?

   c) In reality, there is a drag force on such a sphere falling in glycerol, and it depends on the speed of the sphere. An object is said to be falling at its "terminal velocity" if the total net force on the object is equal to 0. Let us assume the drag force on a sphere with diameter D to be $3\pi\mu Dv$ with μ equal to the viscosity of the fluid (for glycerol this is 1.412 kg/(m s)) and v the fall velocity of the sphere. The force is directed against the direction of the movement so – in this case – the drag force would point upward (against the direction of the sphere's fall). Find the terminal fall-velocity of the 4 cm diameter aluminum sphere in glycerol.

5. The density of one type of wood (ash) can vary from tree to tree, but we'll treat it as about 580 kg/m^3 . The density of gasoline is about 770 kg/m^3 . If you have a piece of ash wood floating in a pool of gasoline, what fraction of the wood would be visible above the water?

6. A long, cylindrical pipe has radius $r = 8$ cm.

   a) If this pipe has water flowing in it at a rate of 200 L/min, how fast is the water moving? (To solve this problem you should assume that the water is moving at the same speed throughout the entire cross-section of the pipe even though, in reality, that isn't true.)

   b) The pipe suddenly constricts from its initial radius of 8 cm to a smaller radius. What would the smaller radius have to be if the water now starts moving at half the speed of sound in air? (In other words, now the water will be moving at 172 m/s).

   c) If the pressure in the pipe is equal to 0.1 atm when it is at the thinner radius (your solution to part (b) above), what was the pressure in the pipe when it was at the 8 cm radius? (You can assume the pipe remains horizontal and in both cases we are talking about the pressure in the middle of the cross-section).