P160 Test 2 Review

1. Find absolute zero on a scale R where water freezes at 20 degrees and boils at 220 degrees. Note: on the celsius scale, water freezes at 0 C and boils at 100 C. Absolute zero is -273 C.

$$m = \frac{220-20}{100-0} = 2$$

$$R = 2C + 20 \Rightarrow R(-273) = 2 \cdot -273 + 20 = -526\ ^oR$$

2. Suppose the linear expansion coefficient for a certain metal is $2\times10^{-6}\deg C^{-1}$. By how much does the length of a 15 meter beam made of this metal change when the temperature drops by 40 C?

$$\Delta L = \alpha L \Delta T = 2\times10^{-6}\cdot 15\cdot(-40) = -0.0012\ m$$

3. A tire heats up during a long road trip, going from 20 C to 50 C. If it expands to 5% greater volume than its original volume, what is the pressure inside the tire, if the original pressure was $3\times10^5\ pa$?

$$\frac{P_2V_2}{P_1V_1} = \frac{n_2RT_2}{n_1RT_1}$$

$$\frac{P_2 1.05V_1}{3\times10^5\cdot V_1} = \frac{T_2}{T_1} = \frac{273+50}{273+20}$$

$$P_2 = \frac{3\times10^5}{1.05}\cdot\frac{323}{293} = 315kPa$$

4. A substance has a density of $12,500\ kg/m^3$. If it's thought to be part gold and part lead, how much of the substance is gold.

$$m_{au} + m_{pb} = M_tot$$

so

$$\rho_{au}V_{au} + \rho_{pb}V_{pb} = \rho V_{tot}$$

In this equation, we can assume we have a volume of 1 m^3, just for concreteness. Then there are only two unknowns, which are the respective volumes of gold and lead. In principle, we know the densities of gold and lead.

Also, we have

$$V_{au} + V_{pb} = V_{tot}$$

This gives a second equation in the same two unknowns, so we can solve for the volumes of lead and gold, if we know the combined density.

5. A hydraulic jack must be designed so as to lift a weight of 8 metric tons when a force of 1 metric ton is applied. If the output piston has an area of 2 m^2,

what is the size of the input piston?

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$\frac{1000}{A_1} = \frac{8000}{2} \Rightarrow A_1 = 0.25\ m$$

6. How large a block of wood with density 700 kg/m^3 would be needed if a 100 kg man, standing on it, would still barely be above water level?

Let m be the mass of wood and M be the mass of the man. Then:

$$\sum F = 0 \Rightarrow F_B - mg - Mg = 0$$

$$\rho_{H_2O} V g - \rho_w V g - Mg = 0$$

Solve for V.

$$V = \frac{Mg}{\rho_{H_2O} g - \rho_w g} = \frac{M}{\rho_{H_2O} - \rho_w}$$

$$V = \frac{100}{1000 - 700} = 3.33\ m^3$$

7. A cork is placed in the mouth of an empty bottle, and the bottle is submerged in a lake. At a depth of 50 feet, the cork just begins to be pushed inwards. What is the force of friction holding the cork in place, if the cross-sectional area of the cork is 4 cm^2.

$$\Delta P = \rho g h = 1000 \cdot 9.8 \cdot 50 = 490,000\ pa$$

This is the difference in pressure between inside the bottle and the water outside at 50 meters depth. Note that the gas in the bottle is atmospheric pressure. Now:

$$\sum F = F_{fric} + \Delta P A = 0 \Rightarrow F_{fric} = -\Delta P A = 196\ N.$$

8. A horizontal pipe with cross section 10 cm^2 splits into two, each of which has cross sectional area of 2 cm^2. If the pressure in the big pipe is 2×10^5 pascals, what is the velocity of the water jetting out of the small pipes?

Use Bernouilli's equation and the equation of continuity.

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

$$A_1 v_1 = A_2 v_2$$

Solve these two equations simultaneously.

9. An airplane can lift a total of 5,000 kilograms. If the velocity of the air going under the wings is 180 m/s and over the wings is 220 m/s, what is the

area of the wings?

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

Neglect the gravitational contributions.

$$\Delta P = P_1 - P_2 = \frac{1}{2}\rho\left(v_2^2 - v_1^2\right)$$

$$\Delta P = \frac{1}{2}\cdot 1.3 \cdot \left(190^2 - 189^2\right)$$

Newton's second law gives

$$\sum F = 0 = -mg + A\Delta P \Rightarrow A = \frac{mg}{\Delta P} = 13.24\ m^2$$

10. Two violins play notes simultaneously. A beat frequency of 3 Hz is heard. By how much does the tension in the string differ, if the linear density of the strings are 10 grams/m? Assume the fundamental is 800 Hz.

Use the tension equation and take the differential.

$$v = \sqrt{\frac{T}{\mu}}$$

Also, from the frequency of the fundamentals for strings tied at both ends, obtain

$$f = \frac{v}{2L} \Rightarrow v = 2fL$$

so

$$2fL = \sqrt{\frac{T}{\mu}}$$

Take the differential:

$$2ldf = \frac{1}{2}\left(\frac{T}{\mu}\right)^{-1/2}\frac{dT}{\mu}$$

df is the difference in frequencies, while dT is the difference in tensions. Assume the linear densities are the same, and plug in the numbers.

11. A jet cranks up its engine. If the noise level is 120 db at a distance of ten meters, what is the noise level at 20 meters?

$$120 = 10\log\left(\frac{I}{10^{-12}}\right)$$

Use this to obtain the intensity at 10 meters. Multiply by $4\pi r^2$ to get the total power output, true at any distance. Divide by the area of the greater sphere, 20 meters in radius, to get the intensity at 20 meters, and plug back into the decibel equation.

12. A string fixed at both ends makes a sound with wavelength 0.5 meters when plucked. If this corresponds to the fundamental frequency, and the string is 0.7 meters long, what is the velocity of the wave on the string? Take the speed of sound to be 340 m/s.

13. A sinusoidal wave on a string has wavelength 5 meters. If at t=x=0 $y = 0.2\ m$ and $v_y = -0.1\ m/s$, and the speed of the wave is 500 m/s, find the equation describing the wave. Also, find the wave number, angular wave number, frequency, angular frequency, period, and amplitude.

14. A horizontal string is attached to the wall, a mass of 50 kg hanging over a pulley. If the string has a linear density of 20 gm/m, find the speed of vibrations on the string.

15. Two trains are approaching each other at a station, travelling at the same speed. Find the speed, if a horn blasting at 700 Hz on one train is heard by passengers to be 750 Hz on the other train.

$$\frac{f_L}{v \pm v_L} = \frac{f_s}{v \pm v_s}$$

16. A taut rope has a mass of 0.3 kg and length of 4 meters. Find the power necessary to create sinusoidal waves with amplitude of 0.2 meters, wavelength of 0.7 meters, and travelling at 50 m/s.

17. Speakers face each other, 10 meters apart, putting out sound waves in phase and with frequency 500 hz. Find the points of destructive interference between the two speakers.

18. A string tied at both ends has second harmonic of 800 Hz. Find the speed of waves on the string, if the length is 0.7 meters. What is the tension in the string, if the linear density is 5 gm/m? Finally, what wavelength sound is produced, assuming the speed of sound is 340 m/s?

19. An organ pipe open at both ends is 0.8 meters long. What is the fundamental and first harmonic? If a cap goes over the top, what is the first harmonic and first overtone?

$$f_n = n\frac{v}{2L}$$

So

$$f_1 = 1 \cdot \frac{340}{2 \cdot 0.8} = 212.5\ Hz$$

$$f_2 = 2f_1 = 425\ Hz$$

For the pipe open at one end, we have

$$f_n = n\frac{v}{4L}$$

which is good n=1,3,5... Plug in:

$$f_1 = \frac{340}{3.2} = 106.25\ Hz$$

$$f_3 = 3\frac{340}{3.2} = 318.75\ Hz$$