“Heat Waves” (50,000 points) Multiple-Guess-Pick-The-Best-Answer-Fill-In-The-Bubbles

1.) (a) A good can of beans hisses as air rushes in if the absolute pressure inside is ________ the outside.
   A = Less Than B = Same As C = More Than D = None of these
   The pressure inside the can must be lower.

(b) A putrid can of beans hisses as air rushes out if the gauge pressure (inside - outside) is ________ zero.
   A = Less Than B = Same As C = More Than D = None of these
   The pressure inside the can must be higher.

(c) A boat of mass 150. kg has dimensions 1.0 m × 0.50 m × 1.5 m. What is the maximum load that can be carefully placed in this boat before it sinks?
   A = 150. kg B = 500. kg C = 600. kg D = 750. kg E = 1000. kg
   F = None of these
   \[ V = 0.750 m^3, \text{ so } m_{\text{max}} = 750. kg. \] Subtract 150. kg for boat, 600. kg for load.

(d) A 9” diameter pipe narrows to 1” diameter. Water flowing in the wide pipe is ________ as fast as the narrow pipe.
   A = 1/3rd    B = 1/9th  C = just D = 3 times E = 9 times
   F = None of these
   Use Continuity Equation. \( 9^2 = 81. \)

In parts (e)-(g), select which of the laws and definitions of Thermodynamics is best used to solve or describe the problem.

(e) If you had an engine with a Second Law Efficiency equal to 100%, you would violate ________.
   A = Thermo 1st law B = Thermo 2nd law C = Entropy
   D = Actual Efficiency E = Carnot Efficiency F = None of these
   QC cannot be zero, so 2nd Law Efficiency is never 100%.

(f) If you had an engine with a Second Law Efficiency equal to 110%, you would violate ________.
   A = Thermo 1st law B = Thermo 2nd law C = Entropy
   D = Actual Efficiency E = Carnot Efficiency F = None of these
   At 110%, you're getting more Work than QH put in.

(g) Monitoring the temperature of the hot and cold reservoirs allows you to find the ________.
   A = Thermo 1st law B = Thermo 2nd law C = Entropy
   D = Actual Efficiency E = Carnot Efficiency F = None of these
   Definition of Carnot Efficiency

Fred blows into a musical instrument and it sounds with a frequency \( f = 500. \text{ Hz}. \) He blows harder and it sounds with a frequency \( f = 1500. \text{ Hz}. \) The speed of sound in air is 343 m/s. Use \( v = f \lambda \)

(h) The wavelength of the 500. Hz tone is __________.
   A = 0.229 m B = 0.343 m C = 0.500 m
   D = 0.686 m E = 0.916 m F = None of these

(i) For the 1500. Hz tone, \( \lambda = \) __________.
   A = 0.229 m B = 0.343 m C = 0.500 m
   D = 0.686 m E = 0.916 m F = None of these

(j) If one of these standing waves is the Fundamental and the other one is the 1st Overtone, then the pipe in this instrument is:
   A = Closed at both ends B = Open at both ends
   C = Closed at one end and open at the other end D = None of these
   Diagrams for Problem 1(j):
   Fundamental
   1st Overtone

Your Friendly Neighborhood Water Company…
Physics 107 / Exam 3 [Form-A] Fall 2004 Page 3

**One Million Gallons of Pure Clean Sweet Fresh Water (50,000 points)**

2.) A city water tank contains 1,000,000 gallons of water (3.80 \times 10^6 L volume, 3.80 \times 10^6 kg mass) at a temperature of 9.00°C (48.2°F). (a) When a valve is opened at the bottom of the tank, water comes out at a speed of 20.0 m/s. What is the height \( h \) to the top of the water in the tank? The properties of water include: 

\[ c_{\text{water}} = 4186 \text{ J/kg} \cdot \text{°C}, \]

\[ L_f = 334,000 \text{ J/kg}, \]

\[ L_v = 2,260,000 \text{ J/kg}, \]

\[ g_{\text{water}} = 1000 \text{ kg/m}^3 \]

and \[ \beta_{\text{water}} = 210 \times 10^{-6} \text{ °C}^{-1}. \]

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

\[
\rho g h_1 = \frac{1}{2} \rho v_1^2
\]

\[
h_1 = \frac{v_1^2}{2g} = \frac{(20.0 \text{ m/s})^2}{2(9.81 \text{ m/s}^2)} = 20.39 \text{ m}
\]

(b) During the day, the temperature of the water rises from 9.00°C to 15.00°C (59.0°F). Find the new volume of the tank of water. For the purposes of this question only, give your answer to 5 significant figures.

\[
\Delta V = \beta V_0 \Delta T
\]

\[
= (210 \times 10^{-6} \text{ °C}^{-1})(3.80 \times 10^6 \text{ L})(15.00 \text{ °C} - 9.0 \text{ °C})
\]

\[
= +4788 \text{ L}
\]

\[
V = V_0 + \Delta V
\]

\[
= 3.80 \times 10^6 \text{ L} + 4788 \text{ L}
\]

\[
= 3.804,788 \text{ L} = 3.804,800 \text{ L}
\]

Note that you can leave the volume in liters (L), because the only requirement is that \( V_0 \) and \( \Delta V \) have the same units.

(c) How much heat energy \( Q \) did the water have to absorb during this expansion?

\[
Q = mc \Delta T = (3.80 \times 10^6 \text{ kg})(4186 \text{ J/kg°C})(+6.00 \text{ °C})
\]

\[
= 95,440,000,000 \text{ J or } 9.544 \times 10^{10} \text{ J}
\]

---

Physics 107 / Exam 3 [Form-A] Fall 2004 Page 4

(d) During the night a pump is used to refill the tank, replacing the water used during the day. The 13.1 hp engine driving the pump does a useful work of 9780 J each second, while wasting 5470 J of heat energy each second. The Second Law Efficiency of this engine is 97.0% (0.970). Find the Actual Efficiency of this engine.

\[
Q_W = W + Q_c
\]

\[
= 9780 \text{ J} + 5470 \text{ J} = 15,250 \text{ J}
\]

\[
\epsilon_{\text{Actual}} = \frac{W}{Q_W} = \frac{9780 \text{ J}}{15,250 \text{ J}} = 0.6413 \text{ or } 64.13\%
\]

In case you were wondering, 13.1 hp = 9770W = 9770J/s. (Dr. Phil worked the problem backwards.)

(e) Find the Carnot Efficiency of this engine. If you didn’t get an answer to (d), use \( \epsilon_{\text{Actual}} = 40.0\% \).

\[
\epsilon_{\text{2nd Law}} = \frac{\epsilon_{\text{Actual}}}{\epsilon_{\text{Carnot}}}
\]

\[
\epsilon_{\text{Carnot}} = \frac{\epsilon_{\text{Actual}}}{0.970} = 0.6611 \text{ or } 66.11\%
\]

For those of you looking only for temperatures, you forgot we had two equations with \( \epsilon_{\text{Carnot}} \) in them.