Physics 10154 - Exam #5A

Partial credit will be given provided you show all work and are solving parts of the problem correctly. Points will be deducted if you don't show your work (or if some parts are incorrect) even if you get the right answer. Clearly indicate your answer with a circle or box and remember to include correct units and significant figures.

1. (25 pts) The temperature inside a home is 72° F, and the outside temperature is 24° F. Energy costs 12 cents per kilowatt-hour to keep the home heated. The thickness of a single pane of glass is 0.50 cm. The thermal conductivity of glass is 0.84, and the thermal conductivity of air is 0.024.

a) If the home has a total of 8.5 square meters of single-pane glass windows, how much does it cost to keep the home warm for one day?

b) If the home instead has 8.5 square meters of double-pane windows (two single panes sandwiched around a 0.5 cm layer of air), how much does it cost to keep the home warm for one day?

a) $\Delta T = \frac{5}{9}(72-24) = 26.67^\circ C$

$$P = \frac{kA\Delta T}{\ell} = \frac{(0.84)(8.5)(26.67)}{.005} = 38{,}080\,W$$

$$E = P\Delta t = 38{,}080\,\frac{J}{s} \cdot \frac{86400\,s}{day} = 3.3\times10^9\,J$$

$$Cost = 3.3\times10^9\,J \cdot \frac{1\,kWhr}{3.60\times10^6\,J} \cdot \frac{12\,¢}{kWhr} = 1.1\times10^4$$

or $\boxed{\$110}$

b) $P = \frac{A\Delta T}{R\text{-value}}$ $\quad R\text{-value} = \frac{\ell_1}{k_1} + \frac{\ell_2}{k_2} + \frac{\ell_3}{k_3}$

$$= \frac{.005}{.84} + \frac{.005}{.024} + \frac{.005}{.84} = 0.2202$$

$$P = \frac{(8.5)(26.67)}{.2202} = 1030\,W$$

$$Cost = 1.1\times10^4 * \frac{1030\,W}{38{,}080\,W} = 297\,¢ \text{ or } \approx \boxed{\$3.00}$$

2. (25 pts) An ideal gas is in a sealed chamber so that the number of particles cannot change. The measured density of the gas is 0.255 kg/m³. The initial temperature of the gas is 85.0 °C. The pressure of the gas increases by a factor of 4.50, and the temperature increases to 215 °C. What is the new density of the gas?

$$\frac{V_2}{V_1} = \frac{\left(\frac{n_2}{n_1}\right)\left(\frac{R}{R}\right)\left(\frac{T_2}{T_1}\right)}{\left(P_2/P_1\right)} = \frac{(1)(1)\left(\frac{488}{358}\right)}{(4.50)} = 0.303$$

$$\frac{\rho_2}{\rho_1} = \frac{\left(\frac{M_2}{M_1}\right)}{\left(\frac{V_2}{V_1}\right)} = \frac{1}{.303}$$

$$\rho_2 = \frac{\rho_1}{.303} = \boxed{0.842\ kg/m^3}$$

3. (25 pts) A speaker emits sound uniformly in all directions with no reflections. The intensity of the sound at a location 22 meters away from the source is 76 dB. What is the intensity at a location 75 meters away, in dB?

$$76 = 10 \log\left(\frac{I}{I_0}\right) = 10 \log\left(\frac{I}{10^{-12}}\right)$$

$$7.6 = \log \frac{I}{10^{-12}}$$

$$10^{7.6} = \frac{I}{I^{-12}} \qquad I = 10^{-4.4} = 3.98 \times 10^{-5} \frac{W}{m^2}$$

$$P_s = I(4\pi r^2) = 0.242\ W$$

$$I_{new} = \frac{P_s}{4\pi r_{new}^2} = \frac{0.242}{4\pi (75)^2} = 3.43 \times 10^{-6} \frac{W}{m^2}$$

$$I(dB) = 10 \log\left(\frac{3.43 \times 10^{-6}}{10^{-12}}\right) = \boxed{65\ dB}$$

Shorter: $\Delta I = 10 \log\left(\frac{I_{old}}{I_{new}}\right) = 10 \log\left(\frac{1/22^2}{1/75^2}\right)$

$$= 10 \log(11.6)$$

$$= 10.7\ dB$$

So I_{new} is 11 dB less than I_1

4. (25 pts) The speed of sound in air is 343 m/s. Two speakers are broadcasting a sound wave with a frequency of 8500 Hz, in phase.

a) If the two speakers are lined up in a straight line with the listener, what is the minimum separation (in meters) of the speakers in order for the listener to experience destructive interference?

b) If a speaker has a circular aperture of 22 cm, what is the diffraction angle of the sound wave?

$\lambda = \frac{v}{f} = \frac{343}{8500} = 0.0404\,m$

a)

For minimum DI, phase shift = $\frac{1}{2}$ wave

so distance difference = $\boxed{.0202\,m}$

b) $\theta = \sin^{-1}\left(\frac{1.22\lambda}{D}\right) = \sin^{-1}\left(\frac{(1.22)(0.0404)}{.22}\right)$

$= \boxed{12.9^\circ}$