Physics 10154 - Exam #5D

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) 3.0 moles of a monatomic ideal gas (Neon, with atomic mass = 20.2 u) are placed in a container whose volume is 8200 cm^3. The absolute pressure of the gas is 6.4 atm. For ideal gases, the formula for kinetic energy of a particle can be found with KE = $1/2\ m_{particle}v_{rms}^2 = 3/2\ k_BT$.

a) What is the rms velocity of an atom of the gas?

b) If the number of particles is doubled while the pressure decreases to 4.5 atm, keeping the volume constant, what is the new rms velocity of an atom of the gas?

a) $T = \frac{PV}{nR}$ $\quad P = 6.4\text{ atm} = 648{,}320\text{ Pa}$

$V = 8200\text{ cm}^3 = 8.2\times10^{-3}\text{ m}^3$

$n = 3.0\text{ moles}$

$$T = \frac{(648{,}320)(8.2\times10^{-3})}{(3.0)(8.31)} = 213\text{ K}$$

$$\frac{1}{2} m v_{rms}^2 = \frac{3}{2} k_B T \qquad m = 20.2u = 3.35\times10^{-26}\text{ kg}$$

$$v_{rms}^2 = \frac{3k_BT}{m} = \frac{3(1.38\times10^{-23})(213)}{3.35\times10^{-26}}$$

$$= 263{,}000$$

$$\boxed{v_{rms} = 510\text{ m/s}}$$

b) $$\frac{T_2}{T_1} = \frac{\left(\frac{P_2}{P_1}\right)\left(\frac{V_2}{V_1}\right)}{\left(\frac{n_2}{n_1}\right)\left(\frac{R}{R}\right)} = \frac{\left(\frac{4.5}{6.4}\right)(1)}{(2)(1)} = 0.35$$

$T_2 = 0.35T_1$

$v_{rms} \propto \sqrt{T}$

so $v_{rms} = \sqrt{.35}\ v_{orig}$

$\boxed{300\text{ m/s}}$

2. (25 pts) For a monatomic ideal gas, the internal energy, U, can be given by 3/2 PV or 3/2 nRT. A gas gains 1300 J of heat while the internal energy of the system increases by 4200 J. The volume of the gas during this process decreases from 35 L to 25 L while keeping the pressure constant. What is the pressure of the gas, in Pascals?

$$\Delta U = Q - P\Delta V$$

$$4200 = 1300 - P(-10 \times 10^{-3})$$

$$2900 = P(10 \times 10^{-3})$$

$$\boxed{P = 290{,}000 \text{ Pa}}$$

3. (25 pts) At a racetrack pit area, protective earplugs reduce the sound intensity by a factor of 440. When a car is revving its engine, the sound intensity experience by a pit crew member is 86 dB.

a) What sound intensity level (in dB) would the crew member experience if the earplugs were removed?

b) How many Joules of energy pass through the earplugs in an hour if the cross-sectional area of the ear opening is 1.1 cm²?

a) $\Delta I(dB) = 10 \log(440) = 26\,dB$

$I_{new} = 86 + 26 = \boxed{112\,dB}$

b) $112 = 10 \log\left(\frac{I}{10^{-12}}\right)$

$10^{11.2} = \frac{I}{10^{-12}} \Rightarrow I = 10^{-.8} = 0.158 \frac{W}{m^2}$

$P = IA = (.158)(1.1 \times 10^{-4}) = 1.74 \times 10^{-5}\,W$

$E = P\Delta t = (1.74 \times 10^{-5})(3600) = \boxed{.063\,J}$

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

a) $\lambda = \frac{v}{f} = \frac{343}{8500} = .0404\ m$

For DI, min separation is $\frac{1}{2}$ wave, so distance difference $= \frac{1}{2}\lambda = \boxed{.0202\ m}$

b) $\theta = \sin^{-1}\left(\frac{1.22\lambda}{D}\right) = \sin^{-1}\left(\frac{1.22(.0404)}{.22}\right)$

$= \boxed{12.9°}$