Physics 10154 - Exam #4B

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. (30 pts) A container with a large opening on top is filled with water to a depth of 36 cm. A small circular hole at the bottom of the container allows water to flow out of the hole so that it can fill up a 1.0 gallon container in 12 seconds. The container is surrounded by air on all sides. What is the diameter of the hole (you may assume it is at least 10 times smaller than the opening on top)? Answer with 2 SF.

$P_{top} = 101300\ Pa$ $\quad v_{top} \approx 0$ (large vs small opening)

$P_{bot} = 101300\ Pa$ $\quad y_{top} = 0.36\ m$ $\quad y_{bot} = 0$

$$\overset{same}{\cancel{P_{top}}} + \cancel{\rho} g y_{top} + \cancel{\tfrac{1}{2}\rho \overset{\nearrow 0}{v_{top}^2}} = \overset{same}{\cancel{P_{bot}}} + \cancel{\rho g \overset{\nearrow 0}{y_{bot}}} + \tfrac{1}{2}\cancel{\rho} v_{bot}^2$$

$$g y_{top} = \tfrac{1}{2} v_{bot}^2$$

$$v_{bot} = \sqrt{2 g y_{top}} = \sqrt{2gh} = 2.656\ m/s$$

$$A_{bot} v_{bot} = \frac{1.0\ gal}{12\ sec} \cdot \frac{3.786 \times 10^{-3}\ m^3}{1\ gal} = 3.155 \times 10^{-4}\ \frac{m^3}{sec}$$

$$\Rightarrow A_{bot} = \frac{3.155 \times 10^{-4}}{2.656} = 1.188 \times 10^{-4} = \pi r^2$$

$$r = 6.15 \times 10^{-3}\ m = 6.15\ mm$$

$$d = 2r = \boxed{12\ mm} \text{ or } 0.012\ m$$

2. (30 pts) 54 grams of water is at an initial temperature of 38°C. This water is poured into a hot 1.5 kg iron skillet at a temperature of 245°C. The specific heat of iron is 448 J/kg-C. Answer with 2 SF.

What is the final temperature of the system?

If the final temperature of the system is 100°C, determine how much of the water vaporizes.

ΔQ to cool iron to 100°C $= (1.5)(448)(-145) = -97440\ \text{J}$

ΔQ to heat water to 100°C $= (.054)(4186)(62) \approx 14\,015\ \text{J}$

ΔQ to boil water $= (.054)(2.26 \times 10^6) = 122\,040\ \text{J}$

so there is enough energy in iron to heat water to 100°C but not enough to boil all water,

$\boxed{T_F = 100^\circ C}$, now find m_s (mass of vaporized water)

$$\Delta Q_{Al} + \Delta Q_w = 0$$

$$-97440 + 14015 + m_s(2.26 \times 10^6) = 0$$

$$m_s = \frac{83425}{2.26 \times 10^6} \approx .037\ \text{kg}$$

or $\boxed{37\text{g vaporizes}}$

3. (20 points) The density of an ideal gas at a temperature of 65°C and pressure of 1.0 atm is 0.28 kg/m³. If the temperature falls to 25°C and the pressure increases to 2.4 atm, keeping the number of molecules constant (answer with 2 SF)…

a) What is the new density of the gas?

b) If the gas is Argon (mass number 40), what is the rms velocity of the gas particles? at 25°C?

must be in Kelvin!

$$a)\quad \frac{V_2}{V_1} = \frac{\left(\frac{N_2}{N_1}\right)\left(\frac{k_B}{k_B}\right)\left(\frac{T_2}{T_1}\right)}{\left(P_2/P_1\right)} = \frac{(1)(1)\left(\frac{298}{338}\right)}{\left(\frac{2.4}{1.0}\right)} = .367$$

$$\frac{\rho_2}{\rho_1} = \frac{\left(\frac{M_2}{M_1}\right)}{\left(\frac{V_2}{V_1}\right)} = \frac{1}{.367} = 2.722$$

$$\rho_2 = 2.722\,\rho_1 = \boxed{0.76\ \mathrm{kg/m^3}}$$

$$b)\quad \frac{1}{2} m_{Ar} v_{rms}^2 = \frac{3}{2} k_B T$$

$$m = 40u * \left(\frac{1.67\times10^{-27}\,\mathrm{kg}}{u}\right) = 6.68\times10^{-26}\,\mathrm{kg}$$

$$v_{rms} = \sqrt{\frac{3k_B T}{m}}$$

$$= \sqrt{\frac{3(1.38\times10^{-23})(298)}{6.68\times10^{-26}}}$$

$$= \boxed{430\ \mathrm{m/s}}$$

4. (20 pts) A speaker emits sound uniformly in all directions with no reflections. 25 meters away from the speaker, the intensity is measured to be 82 dB. What is the intensity at a location 63 meters away, in dB?

$$\Delta \beta = 10 \log \left(\frac{P_1 / P_2}{4\pi r_1^2 / 4\pi r_2^2} \right) =$$

$$= 10 \log \left(\frac{1}{25^2 / 63^2} \right)$$

$$= 10 \log (6.35) = 8.0 \text{ dB}$$

$$\text{New loudness} = 82 - 8 = \boxed{74 \text{ dB}}$$

must be smaller since we are further from source,