PHY1321 PHY1331 Fall 2019 Assignment 2. Due Sept 27, 6:00PM

MARK: LAST NAME (TYPED): ________________ ASSIGNED NUMBER(BRIGHSPACE)________

/28 **Ideal Gas Equation. Heat Transfer. Hydrostatic Pressure.**

Each question is marked out of 4 points, In addition to this there are 4points for presentation/aesthetics for the whole assignment.

TA:

1 a) Interstellar space, far from any stars, is filled with a very low density of hydrogen atoms (H, not H_2). The number density is about 1atom / cm^3 and the temperature is about 3K. Estimate the pressure in interstellar space. Give your answer in Pa and in atm.

$pV = nRT \text{ so } pV = RT\frac{N}{N_A} \text{ and thus } p = RT\frac{N}{VN_A} = \frac{N}{V}\frac{RT}{N_A} = \frac{10^6}{m^3}\frac{(8.314)(3)Pa\, m^3}{6.02\cdot 10^{23}} = 4.14\cdot 10^{-17}Pa$

b) In the best performing vacuum systems, pressures as low as 10^{-10} Pa are being attained. Calculate the number of molecules in a 1.00-cm^3 vessel at this pressure if the temperature is 21.0°C. $pV = RTn = RT\frac{N}{N_A}$ and so $N = \frac{pVN_A}{RT} = \frac{(10^{-10}Pa)(10^{-6}m^3)(6.02\cdot 10^{23})}{(8.314)(294)\ Pa\, m^3} = 24629$

2 Given the data from the previous problem, estimate the number of collisions experienced by the spherical interstellar ship of diameter of 500m moving at the 10% of the speed of light in the interstellar space in 1 second of its motion.

ANSWER: The number of collisions will equal the number of atoms inside the cylinder of base of radius 500m and the height of 3 10^7m(0.1c)(1s). Given the interstellar number density of 1 atom per cm^3 we get 2.356 $\cdot 10^{19}$ of atoms and the same number of collisions.

3 a) A water heater is operated by solar power. If the solar collector has an area of 12.00 m^2, and if the intensity delivered by sunlight is 550 W/m^2, how long does it take to increase the temperature of 1.00 m^3 of water from 15.0°C to 60.0°C?

SOLUTION:

The heat necessary to heat up the water is $Q = mc\Delta T = (1000)(4186)(60-15) = 188370000J$

The Power delivered by the sunlight P=550 12 =6600W. this means 6600 J of energy every second,
It will take 7.92hours to heat up this amount of water. (7 hrs. 56min.)

b) The surface of certain star n has a surface temperature of about 5 800 K.
The radius of the star is 9×10^8 m. Calculate the total energy radiated by this star in each second.

B) $P = \sigma AeT^4 = (5.67\cdot 10^{-8})(4\pi\left(9\cdot 10^8\right)^2 5800^4 W = 6.53\cdot 10^{34}W$

4 A diving bell in the shape of a cylinder with a height of 2.70 m is closed at the upper end and open at the lower end. The bell is lowered from air into sea water (ρ = 1.033 g/cm^3).The air in the bell is initially at 25.0°C. The bell is lowered to a depth (measured to the bottom of the bell) of 90.0 m. At this depth the water temperature is 4.0°C, and the bell is in thermal equilibrium with the water.

(a) How high does sea water rise in the bell?

(b) To what minimum pressure must the air in the bell be raised to expel the water that entered?

USE THE OPPOSITE SIDE OF THIS PAGE TO PRESENT YOUR FULL SOLUTION TO THIS PROBLEM

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5 German soldiers, members of the *Afrika Korps*. were taking pictures cooking eggs on the plates of their tanks. At high noon, the Sun delivers 1 200 W to each square meter of a blacktop road. If the hot asphalt loses energy only by radiation, what is its equilibrium temperature?

ANSWER:

We treat the earth below is an insulator. The square meter must radiate in the infrared as much energy as it absorbs, $P = \sigma A e T^4$*.*
Assuming that $e = 1.00$ *for blackbody blacktop:*

$$P = \sigma A T^4 \text{ so that } 1200W = 5.67\ 10^{-8}\frac{W}{K^4 m^2}(1m^2)T^4$$

T=384K (Yes! You can cook an egg on it.)

6 A 5kg block of ice at -10°C is put in the water (initial temperature 20°C) in an insulated container. How much water was there initially, if the final temperature after all of the ice melted is 16°C?

SOLUTION:
Unknown amount of water was cooled down from 16°C to 0 °C. It took Q_h of heat.

$$Q_h = m_{water}c_{water}(T_f - T_{i1}) = (m_{water})\left(4186\frac{J}{kg\ ^oC}\right)(16-20\ ^oC) = -16744m_{water}$$

The kg of ice had to go through three processes to reach the 16°C (as melted water)
It had to be warmed up as ice from -10°C to 0°C, had to be melted and the melted water had to be heated to 16°C. All of this required the total heat Q_c given by:

$$Q_c = +m_{ice}c_{ice}(0-(-10)) + m_{ice}L + m_{ice}c_{water}(16-0)$$

$$Q_c = (5)(2050)(10)\text{J} + (334000)(5)\text{J} + (5)(4186)(16)J = 2107380J$$

Since $Q_c + Q_h = 0$ $\quad 2107380J - 16744m_{water} = 0 \ and\ m_{water} = 125.9kg$

ANS: Initially there was 126kg of water at 20°C and 5 kg of ice at -10°C

7 A 1kg of ice at -10° C is added to 3 kg of steam at 130°C. Answer the following questions:
a) What is the phase of the system of ice + steam, if no heat escaped from it?
b) What is the final temperature when the equilibrium is established ?
(Use the opposite side of this page to provide details of the solution. Present the summary in the space below.)
CHECK THE CLASS NOTES FOR THE DISCUSSION OF THIS TYPE OF PROBLEM
L_1=334000 J/kg (laten heat of fusin) L_2=2260000J/kg (latent heat of evaporation)
c_{ice}=2108 J/(kg K); c_{steam}=1996 J/(kg K); c_{water}=4186 J/(kg K)

a) It takes 793200J to i) warm up the ice to 0°C, ii) melt it, iii) warm up the water to 100°C.
$Q_{ice} = Q_{ice1} + Q_{ice2} + Q_{ice3} = m_1 c_{ice}(10) + m_1 L + m_1 c_{water}(100)$
Q_{ice} = (2108)(10)+334000+(4186)(100) = 773680(J)
II) When the steam cools off to 100°C and converts to the liquid water it can give off 6959640J of heat.
$Q_{steam} = Q_{steam1} + Q_{steam2} = m_2 c_{steam}(30) + m_2 L_2 = 179640$ +6780000 = 6959640(J)
Since 6.9MJ>0.77MJ the 1 kg water from the ice will be brought to 100C before the whole steam will be converted to water. The final temperature (aquilibrium) will be 100°C

b) Thus only part of the steam will convert to liquid water: $Q_{steam} - Q_{ice} = m_{steam\ left}\ L_2$

In the equilibrium state there will be 2.74kg of steam and 1.26kg of water at 100°C

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Diving Bell SOLUTION

Lets h_i be initial height of the air column in the bell, h_f the final height of the air column in the bell when it is submerged. $V_i = Ah_i; \quad V_f = Ah_f$

(NOTE :
A has not been given (cross-section area of the bell)_ but it might be not needed to solve this problem

Using the ideal gas equation $pV = nRT$ we can write the following:

$p_i Ah_i = nRT_i; \quad p_f Ah_f = nRT_f$; since n stays constant as the bell is sealed by water, we have :

$\frac{p_i Ah_i}{RT_i} = n = \frac{p_f Ah_f}{RT_f}$ Þ $\frac{p_i h_i}{T_i} = \frac{p_f h_f}{T_f}$; where $p_f = 101300 + h_x \rho g$ and $h_x = 90m - (2.7 - h_f)$

Þ ;

$$h_f = \frac{T_f}{T_i}\frac{p_i}{p_f}h_i = \frac{298}{277}\frac{101300}{101300 + (90 - 2.70 + h_f)(9.8)(1033)}2.70m$$

Solving resulting quadratic equation gives the answer to be h_f =0.29m

The height of the air column at the top of the bell is 0.29m, so the water level in the bell will reach 2.41m.

(b) the additional pressure needed to push the water from the bell
(pressure exerted by 2.41m column) is 24,397Pa, so the total pressure needed is 1012406Pa.
(atmospheric pressure plus pressure of 90 m water column)