UNIVERSITY OF OTTAWA
Principles of Physics
PHY1321/31 Fall 2016
Dr. A. Czaikowski

STUDENT #: _______________	
NAME: ______________________	
GROUP:_____________________	

ASSIGNMENT 2: Pressure, Ideal Gas Equation, First Law of Thermodynamics, Heat Transport. Calorimetry

Released: Sept 23, Due: Sept 30 6PM

1 Evangelista Torricelli was the first person to realize that we live at the bottom of an ocean of air. He correctly surmised that the pressure of our atmosphere is attributable to the weight of the air. The density of air at 0°C at the Earth's surface is 1.29 kg/m^3. The density decreases with increasing altitude (as the atmosphere thins). On the other hand, if we assume that the density is constant at 1.29 kg/m^3 up to some altitude *h,* and zero above that altitude, then *h* would represent the depth of the ocean of air. Use this model to determine the value of *h* that gives a pressure of 1.00 atm at the surface of the Earth. Would the peak of Mount Everest rise above the surface of such an atmosphere?

$P = \rho g h$ $\qquad 1.013\times 10^5 = 1.29(9.80)h$

$h = \boxed{8.01\text{ km}}$ $\qquad$ For Mt. Everest, $29\,300\text{ ft} = 8.88\text{ km}$ $\quad \boxed{\text{Yes}}$

2 a) In state-of-the-art vacuum systems, pressures as low as 10^{-9} Pa are being attained. Calculate the number of molecules in a 1.00-m^3 vessel at this pressure if the temperature is 27.0°C.

b) A copper wire and a lead wire are joined together, end to end. The compound wire has an effective coefficient of linear expansion of 20.0 × 10^{-6} (°C)$^{-1}$. What fraction of the length of the compound wire is copper?

a) $N = \frac{PVN_A}{RT} = \frac{(10^{-9}\text{ Pa})(1.00\text{ m}^3)(6.02\times 10^{23}\text{ molecules/mol})}{(8.314\text{ J/K}\cdot\text{mol})(300\text{ K})} = \boxed{2.41\times 10^{11}\text{ molecules}}$

b) The effective coefficient is defined by $\Delta L_{total} = \alpha_{effective} L_{total}\Delta T$ where $\Delta L_{total} = \Delta L_{Cu} + \Delta L_{Pb}$ and $L_{total} = L_{Cu} + L_{Pb} = xL_{total} + (1-x)L_{total}$.

Then by substitution

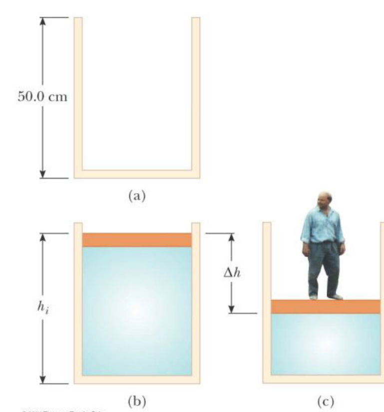
$$\alpha_{Cu}L_{Cu}\Delta T + \alpha_{Pb}L_{Pb}\Delta T = \alpha_{eff}(L_{Cu}+L_{Pb})\Delta T$$

$$\alpha_{Cu}x + \alpha_{Pb}(1-x) = \alpha_{eff}$$

$$(\alpha_{Cu} - \alpha_{Pb})x = \alpha_{eff} - \alpha_{Pb}$$

$$x = \frac{20\times 10^{-6}\ 1/C^\circ - 29\times 10^{-6}\ 1/C^\circ}{17\times 10^{-6}\ 1/C^\circ - 29\times 10^{-6}\ 1/C^\circ} = \frac{9}{12} = \boxed{0.750}$$

3 cylinder that has a 40.0-cm radius and is 50.0 cm deep is filled with air at 20.0°C and 1.00 atm. A 20.0-kg piston is now lowered into the cylinder, compressing the air trapped inside (Fig. P19.68b). Finally, a 75.0-kg man stands on the piston, further compressing the air, which remains at 20°C (Fig. P19.68c). (a) How far down (Δh) does the piston move when the man steps onto it? (b) To what temperature should the gas be heated to raise the piston and man back to h_i?



PROVIDE THE FULL SOLUTION ON OPPOSITE PAGE

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ASSIGNMENT 2:CONT

4 a) A water heater is operated by solar power. If the solar collector has an area of 6.00 m^2, and 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 20.0°C to 60.0°C?

b) The surface of certain star n has a temperature of about 15 800 K. The radius of the star is 9×10^8 m. Calculate the total energy radiated by this star each second. Assume that the emissivity is 0.995.

A) The rate of collection of energy is $P = 550\ \text{W/m}^2(6.00\ \text{m}^2) = 3\ 300\ \text{W}$. The amount of energy required to raise the temperature of 1 000 kg of water by 40.0°C is:

$$Q = mc\Delta T = 1\ 000\ \text{kg}(4\ 186\ \text{J/kg}\cdot{}^\circ\text{C})(40.0^\circ\text{C}) = 1.67 \times 10^8\ \text{J}$$

Thus, $P\Delta t = 1.67 \times 10^8\ \text{J}$ or $\Delta t = \dfrac{1.67 \times 10^8\ \text{J}}{3\ 300\ \text{W}} = \boxed{50.7\ \text{ks}} = 14.1\ \text{h}$. ANS B

B) $P = \sigma A e T^4 = (5.669\ 6 \times 10^{-8}\ \text{W/m}^2\cdot\text{K}^4)\left[4\pi(6.96 \times 10^8\ \text{m})^2\right](0.965)(5\ 800\ \text{K})^4\ P = \boxed{3.77 \times 10^{26}\ \text{W}}$

5 At high noon, the Sun delivers 1 000 W to each square meter of a blacktop road. If the hot asphalt loses energy only by radiation, what is its equilibrium temperature?

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:
$1\ 000\ \text{W} = (5.67 \times 10^{-8}\ \text{W/m}^2\cdot\text{K}^4)(1.00\ \text{m}^2)(1.00)T^4\ T = (1.76 \times 10^{10}\ \text{K}^4)^{1/4} = \boxed{364\ \text{K}}$
(You can cook an egg on it.)

6 A 2kg of ice at -20° C is added to 5 kg of steam at 400°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 the solution)
CHECK THE CLASS NOTES FOR THE METHOD OF SOLUTION TO THIS PROBLEM

USING THESE VALUES FOR SPECIFIC HEATS:

Specific heat of water	4186	J/(kgC)
Specific heat of Ice	2030	J/(kgC)
Specific Heat of Steam	1950	J/(kgC)
Latent heat of fusion	334000	J/(kg)
Latent heat of evaporation	2264760	J/(kg)

SUMMARY :
It takes total of 6115920J of energy to convert the 2kg of ice to 2kg of steam at 100C.
The energy freed from 5kg steam while it cools to 100C and converts to water at 100C is 14248800J Giving excess (unused energy of 81328800J). That means that the final phase is water + steam at 100C with 5.59 kg (2kg + 3.59kg) of steam and 1.41kg of water. Using different values of c (steam) will lead to different results.

Problem 3

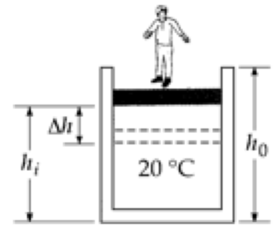

FIG. P19.68

With piston alone: T = constant, so $PV = P_0V_0$

or $P(Ah_i) = P_0(Ah_0)$

With A = constant, $P = P_0\left(\frac{h_0}{h_i}\right)$

But, $P = P_0 + \frac{m_p g}{A}$

where m_p is the mass of the piston.

Thus, $P_0 + \frac{m_p g}{A} = P_0\left(\frac{h_0}{h_i}\right)$

which reduces to

$$h_i = \frac{h_0}{1+\frac{m_p g}{P_0 A}} = \frac{50.0\text{ cm}}{1+\frac{20.0\text{ kg}(9.80\text{ m/s}^2)}{1.013\times10^5\text{ Pa}\left[\pi(0.400\text{ m})^2\right]}} = 49.81\text{ cm}$$

With the man of mass M on the piston, a very similar calculation (replacing m_p by $m_p + M$) gives:

$$h' = \frac{h_0}{1+\frac{(m_p+M)g}{P_0 A}} = \frac{50.0\text{ cm}}{1+\frac{95.0\text{ kg}(9.80\text{ m/s}^2)}{1.013\times10^5\text{ Pa}\left[\pi(0.400\text{ m})^2\right]}} = 49.10\text{ cm}$$

Thus, when the man steps on the piston, it moves downward by

$$\Delta h = h_i - h' = 49.81\text{ cm} - 49.10\text{ cm} = 0.706\text{ cm} = \boxed{7.06\text{ mm}}.$$

(b) P = const, so $\frac{V}{T} = \frac{V'}{T_i}$ or $\frac{Ah_i}{T} = \frac{Ah'}{T_i}$

giving $T = T_i\left(\frac{h_i}{h'}\right) = 293\text{ K}\left(\frac{49.81}{49.10}\right) = \boxed{297\text{ K}}$ (or 24°C)