20+3=23

UNIVERSITY OF OTTAWA
Principles of Physics
PHY1321/31 Fall 2018
Dr. A. Czaikowski

STUDENT [redacted]

NAM[redacted]

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

Released: Sept 21, **Due: Sept 28** **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?

2 a) In state-of-the-art vacuum systems, pressures as low as 10^{-10} Pa are being attained. Calculate the number of molecules in a 1.00-m^3 vessel at this pressure if the temperature is 21.0°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 23.0×10^{-6} (°C)$^{-1}$. What fraction of the length of the compound wire is copper?

3 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?

PRROVIDE THE FULL SOLUTION ON THE OPPOSITE PAGE

ASSIGNMENT 2:CONT

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4 a) A water heater is operated by solar power. If the solar collector has an area of 8.00 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 17.0°C to 62.0°C?

4 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. Assume that the emissivity is 0.995.

5 At high noon, the Sun delivers 1 100 W to each square meter of a blacktop road. If the hot asphalt loses energy only by radiation, what is its equilibrium temperature?

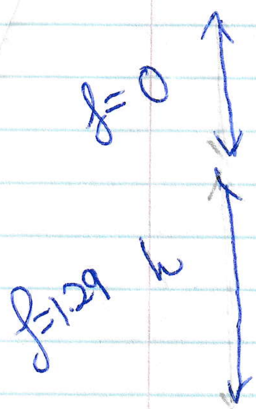
6 A 2kg of ice at -20° C is added to 3 kg of steam at 140°C. answer the following questions:
a) What is the phase of the system of ice + steam if no heat escaped from it.
b) What is the final temperature when the equilibrium is established
CHECK THE CLASS NOTES FOR THE DISCUSSION OF THIS TYPE OF PROBLEM

PROVIDE THE FINAL ANSWER HERE:
(use the opposite side of this page to provide the detailed solution)

[redacted]

PHY 1331 A Assignment #2

1.) $\rho_{air_{0°C}} = 1.29 kg/m^3$. As explained, value of h must be at 1.00atm (101,300Pa) and have density of 1.29kg/m³.



$$P = \rho g h$$

$$101{,}300 Pa = (1.29 kg/m^3)(9.81 m/s^2)(h)$$

$$h = 8{,}012.97 m$$

4

∴ the height of Everest measures 8,848m so it would break such an atmosphere.

2.) a.) $PV = nRT$

$$n = \frac{PV}{RT}$$

$$n = \frac{(10^{-10} Pa)(1.00m^3)}{(8.314 \frac{J}{mol \cdot K})(294K)}$$

$$n = 4.09 \times 10^{-14} mol$$

→ $\#molecules = 4.09 \times 10^{-14} mol \cdot \frac{6.022 \times 10^{23} molecules}{1 mol}$

$$\#molecules = 2.46 \times 10^{-10}$$

3

6.) $\alpha_{total} = 23.0 \times 10^{-6} (°C)^{-1}$

$\alpha_{copper} = 17.0 \times 10^{-6} (°C)^{-1}$

$\alpha_{lead} = 29.0 \times 10^{-6} (°C)^{-1}$

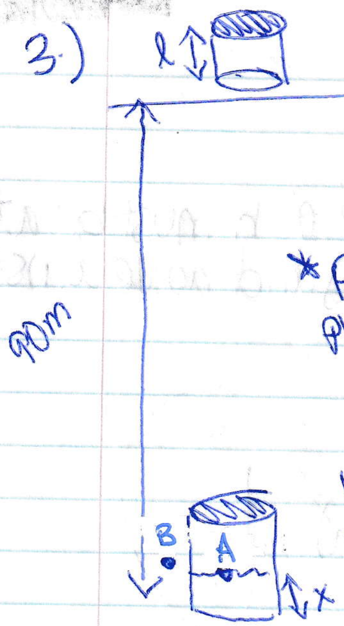
→ take average of α_{copper} and α_{lead}.

$$\alpha_{avg} = \frac{17.0 \times 10^{-6} \times 29.0 \times 10^{-6}}{2}$$

$$= 23.0 \times 10^{-6}$$

∴ 50% of wire is copper and 50% of wire is lead.

3.)



$T_1 = 298K$

$P_1 = atm = 101{,}300 Pa$

$V_1 = A(l)$

*pts A and B are equal in pressure.

$V_2 = A(l-x)$

$P_2 = P_{atm} + \rho g(h-x)$

$T_2 = 277K$

① $P_1V_1 = nRT_1$ ② $P_2V_2 = nRT_2$

$\frac{P_1V_1}{T_1} = nR$ $\frac{P_2V_2}{T_2} = nR$

∴ ① = ②

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{P_1V_1T_2}{T_1} = (P_{atm} + \rho g(h-x))(A(l-x))$$

$$\frac{(101{,}300)(A(2.7)(298)}{(277)} = (101{,}300 + (1.033)(9.81)(90-x)(A(2.7-x))$$

$$0 = 223.960743 - 92.7x + x^2$$

∴ $x_1 = 90.2175m$ ⇒ (inadmissable as $0 < x < 2.7m$)

$x_2 = 2.48\ m$ ✓

b.) $P = P_0 + \rho gh$

$P = (101{,}300 Pa) + (1{,}033\ kg/m^3)(9.81 m/s^2)(90 - 2.7m)$

$P = 985{,}974\ Pa$

4.) a.) $A = 8.00 m^2$

$P = 550 W/m^2 \times 6m^2 = 3300 J/s$

$\Delta T = (335K - 290K = 45K)$

$V = 1.00 m^3 = 1{,}000{,}000 g$

$C = 4.18 J/g \cdot K$

(1) $Q = mc\Delta T$

$= (1{,}000{,}000 g)(4.18 \frac{J}{g \cdot K})(45K)$

$= 188{,}100{,}000 J$

(2) $P = \frac{Q}{\Delta T}$

$3300 J/s = \frac{188{,}100{,}000 J}{\Delta t}$

$\Delta t = 57{,}000 secs$

$\Delta t = 950 hours$

2

b.) $T = 5{,}800K$

$A = \pi r^2 = \pi(9 \times 10^8)^2 = 2{,}827{,}433{,}388 m^2$

$e = 0.995$

(1) $P = \sigma A e T^4$

$P = (5.6696 \times 10^{-8} \frac{W}{m^2 \cdot K^4})(2{,}827{,}433{,}388 m^2)(0.995)(5{,}800K)^4$

$P = 1.81 \times 10^{17} W$

5.) (1) $P_{incoming} = 1{,}100 \cdot A$

(2) $P_{outgoing} = \sigma A e T^4$

∴ (1) = (2)

$1{,}100 \cdot A = \sigma A e T^4$

$1{,}100 = (5.6696 \times 10^{-8})(1)(T)^4$

$T = 373.22 K$

4

Ice

6) ① Heat ice to 0°C

$Q = mc\Delta T$

$Q = (2kg)(2{,}030\ J/kg°C)(20°C)$

$Q = 81{,}200\ J$ needed.

② Turn ice/water mixture to full water

$Q = mL_f$

$Q = (2kg)(334{,}000\ J/kg)$

$Q = 668{,}000\ J$ needed

③ Heat water to 100°C

$Q = m_w C_w \Delta T$

$Q = (2kg)(4186\ J/kg°C)(100°C - 0°C)$

$Q = 837{,}200\ J$

④ Turn boiling water to steam @100°C

$Q = m_w L_e$

$Q = (2kg)(2264760\ J/kg)$

$Q = 4{,}529{,}520\ J$

TOTAL: 6,115,920 J needed to turn ice to steam @100°C

Steam

① Cool steam to 100°C

$Q = m_s C_s \Delta T$

$= (3kg)(1950\ J/kg°C)(-40°C)$

$= +234{,}000\ J$ released

(-234,000 J is actual value, meaning that this process is exothermic hence "release").

② Steam to boiling water @100°C

$Q = L_e m_s$

$Q = (-2264760\ J/kg)(3kg)$

$Q = -6{,}794{,}280\ J$

∴ 6,794,280 J released.

③ TOTAL: 7,028,280 J released when turning steam to boiling water.

DIFFERENCE: 7,028,280 J − 6,115,920 J = 912,360 J

∴ 912,360 J still available to ~~turn~~ evaporate some of the boiling water back to steam @100°C

$Q = m_w L_e$

$912{,}360\ J = m_w (2264760\ J/kg)$

$m = 0.403\ kg$

(4) ✓

∴ All 2kg of ice was turned to steam @100°C as well as 0.403kg of the 3kg of boiling water.

∴ 2.403kg of steam @100°C exists as well as 2.597kg of boiling water @100°C exists.