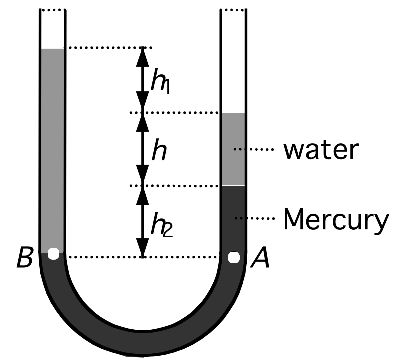
PROBLEM 1



Let h be the height of the water column added to the right side of the U–tube. Then when equilibrium is reached, the situation is as shown in the sketch at right. Now consider two points, A and B shown in the sketch, at the level of the water–mercury interface. By Pascal's Principle, the absolute pressure at B is the same as that at A. But,

$$P_A = P_0 + \rho_w gh + \rho_{Hg} gh_2 \text{ and}$$
$$P_B = P_0 + \rho_w g(h_1 + h + h_2).$$

Thus, from $P_A = P_B$, $\rho_w h_1 + \rho_w h + \rho_w h_2 = \rho_w h + \rho_{Hg} h_2$, or

$$h_1 = \left[\frac{\rho_{Hg}}{\rho_w} - 1\right] h_2 = (13.6 - 1)(1.00 \text{ cm}) = \boxed{12.6 \text{ cm}}.$$

PROBLEM 2

Problem set with

A 1.00-kg iron cube is taken from a forge at 900°C and dropped into 4.00 kg of water at 10.0°C. Assuming that no energy is lost by heat to the surroundings, determine
a) final temperature of the system. (7p)
b) the change of the volume of the iron cube as result of its temperature change . (3p)
c) the power radiated by the iron cube just before it was dropped into the water, and after the final temperature was established. (3p)

a)

$$c_{Fe} m_{fe}(T_f - T_1) + c_{H_2O} m_{H_2O}(T_f - T_2) = 0$$
$$448(1)(T - 900) + 4186(4)(T - 10) = 0$$
$$448T - (900)(448) + 4186(4)T - (4186)(4)(10) = 0$$
$$17192T - 2077600 = 0$$
$$T = \frac{570640}{17192} = 33.192 = 33.2^o C$$

b) $\varrho_{iron} = 7830 \text{kg/m}^3 \Rightarrow \rho = \frac{m}{V} \Rightarrow V = \frac{m}{\rho} = \frac{1kg}{7830 kg/m^3} = 0.0001277 m^3$

$\Delta V = \gamma \Delta T V_i = 3\alpha \Delta T V = 3(11\text{x}10^{-6})(900 - 33.2) = 2.8604 \cdot 10^{-2} \Delta V$ =3.6526x10^{-6}m^3

c) P = e σ A T^4 = (1)(5.67) x 10^{-8}W/(K^4m^2) (6)(0.0025359)$(1173)^4$= 1633.25W
(we get area from taking cubic root of volume (that is the length of the side) squaring it, and multiplying by 6)

PROBLEM 3

(a) See the diagram at the right.

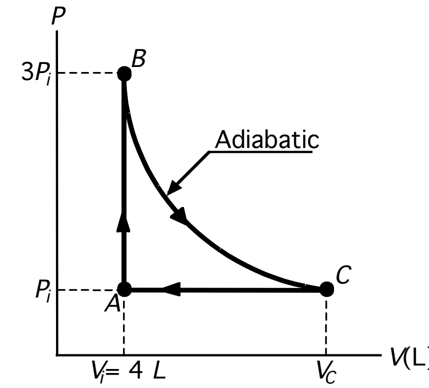


FIG. P21.29

(b) $P_B V_B^\gamma = P_C V_C^\gamma$

$3P_i V_i^\gamma = P_i V_C^\gamma$

$V_C = \left(3^{1/\gamma}\right) V_i = \left(3^{5/7}\right) V_i = 2.19 V_i$

$V_C = 2.19(4.00\text{ L}) = \boxed{8.77\text{ L}}$

(c) $P_B V_B = nRT_B = 3P_i V_i = 3nRT_i$

$T_B = 3T_i = 3(300\text{ K}) = \boxed{900\text{ K}}$

(d) After one whole cycle, $T_A = T_i = \boxed{300\text{ K}}$.

(e) In AB, $Q_{AB} = nC_V \Delta V = n\left(\frac{5}{2}R\right)(3T_i - T_i) = (5.00)nRT_i$

$Q_{BC} = 0$ as this process is adiabatic

$P_C V_C = nRT_C = P_i(2.19V_i) = (2.19)nRT_i$

so $T_C = 2.19T_i$

$Q_{CA} = nC_P \Delta T = n\left(\frac{7}{2}R\right)(T_i - 2.19T_i) = (-4.17)nRT_i$

For the whole cycle,

$Q_{ABCA} = Q_{AB} + Q_{BC} + Q_{CA} = (5.00 - 4.17)nRT_i = (0.829)nRT_i$

$(\Delta E_{\text{int}})_{ABCA} = 0 = Q_{ABCA} + W_{ABCA}$

$W_{ABCA} = -Q_{ABCA} = -(0.829)nRT_i = -(0.829)P_i V_i$

$W_{ABCA} = -(0.829)\left(1.013\times 10^5\text{ Pa}\right)\left(4.00\times 10^{-3}\text{ m}^3\right) = \boxed{-336\text{ J}}$

(f) Cp=9/2R Cv=7/2R

4a $v_{MP} = \sqrt{\frac{2kT}{m}} = \sqrt{\frac{2RT}{M}}$ $\frac{k}{m} = \frac{R}{M}$

$\boxed{N_v = P(v) N_A}$ $P(v) = \left[\frac{1}{2\pi} \frac{m}{kT}\right]^{3/2} v^2 e^{-\frac{mv^2}{2kT}} dv$

$\left[\frac{1}{2\pi} \frac{m}{kT}\right]^{3/2} = \left[\frac{1}{2\pi} \frac{M}{RT}\right]^{3/2} = 2.3899 \times 10^{-9}$; $\underline{M(N_2) = 0.028 kg}$

$v^2 = (421)^2 \, m^2/s^2$

$e^{-\frac{mv^2}{2kT}} = e^{-\frac{Mv^2}{2RT}} = e^{-0.99533} = 0.3696$

$dv = 2 m/s$

$P_v = 0.0003131$ $N = 1.8856 \times 10^{20}$

4.b) $$v_{MP} = \sqrt{\frac{2kT}{m}} = \sqrt{\frac{2RT}{M}}$$

v_{MP} – most probable velocity (spee[...]

is reached when $\frac{dP}{dv} = 0$

$$P = 4\pi \left[\frac{1}{2\pi}\frac{m}{kT}\right]^{3/2} v^2 e^{-\frac{mv^2}{2kT}}$$

$$\frac{dP}{dv} = 0$$

$$\frac{d}{dv}\left(v^2 e^{-\frac{mv^2}{2kT}}\right) = 0$$

$$2v e^{-\frac{mv^2}{2kT}} + v^2 e^{-\frac{mv^2}{2kT}}\left(-\frac{mv}{kT}\right) = 0$$

$$e^{-\frac{mv^2}{2kT}}\left(2v - \frac{m}{kT}v^3\right) = 0$$

↑

never 0 !

$$2v - \frac{m}{kT}v^3 = 0$$

$$v\left(2 - \frac{m}{kT}v^2\right) = 0$$

$$v = 0 \quad \text{or} \quad v^2 = \frac{2kT}{m}$$

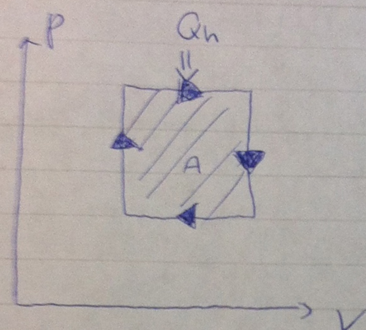
$$v = \sqrt{\frac{2kT}{m}}$$

$$v_{MP} = \sqrt{\frac{2kT}{m}} = \sqrt{\frac{2RT}{M}} \quad //$$

4c γ at $T = 300K$ will take value of

$$\frac{7}{5} \quad \left(\frac{C_p}{C_v} = \frac{\frac{7}{2}R}{\frac{5}{2}R} \right)$$

4d



$$e = \frac{W}{Q_h} = \frac{W}{n C_p \Delta T}$$

If the engine operates between the set values of pressure and volume (set vertices on p-V diagram) the area will be the same regardless of C_v, (C_p). => $W = const$

Since: $e = \frac{const}{C_p}$;

greater C_p (or C_v) leads to diminished efficiency!!

	N2	O2	O2	Ar
R	8.31	8.31	8.31	8.31
M	0.028	0.032	0.032	0.04
T	300	300	300	300
V	421	394	394.5	353
dv	2	1	1	2
	1.78754E-06	2.0429E-06	2.0429E-06	2.5536E-06
Const	2.38992E-09	2.9199E-09	2.9199E-09	4.0807E-09
exp argumen	0.995336542	0.99630004	0.99883032	0.99967108
P	0.000313119	0.00016737	0.00016737	0.00037425
Nv	1.8856E+20	1.0079E+20	1.0079E+20	2.2537E+20

PROBLEM 5

The efficiency is

$$e_c = 1 - \frac{T_c}{T_h} = 1 - \frac{|Q_c|}{|Q_h|}$$

Then $\frac{T_c}{T_h} = \frac{\frac{|Q_c|}{\Delta t}}{\frac{|Q_h|}{\Delta t}}$

$$\frac{|Q_h|}{\Delta t} = \frac{|Q_c|}{\Delta t}\frac{T_h}{T_c} = 15.4\text{ W}\frac{(273+100)\text{ K}}{(273+20)\text{ K}} = 19.6\text{ W}$$

(a) $|Q_h| = W_{\text{eng}} + |Q_c|$

The useful power output is $\frac{W_{\text{eng}}}{\Delta t} = \frac{|Q_h|}{\Delta t} - \frac{|Q_c|}{\Delta t} = 19.6\text{ W} - 15.4\text{ W} = \boxed{4.20\text{ W}}$

(b) $|Q_h| = \left(\frac{|Q_h|}{\Delta t}\right)\Delta t = mL_V$

$$m = \frac{|Q_h|}{\Delta t}\frac{\Delta t}{L_V} = (19.6\text{ J/s})\left(\frac{3\,600\text{ s}}{2.26\times 10^6\text{ J/kg}}\right) = \boxed{3.12\times 10^{-2}\text{ kg}}$$