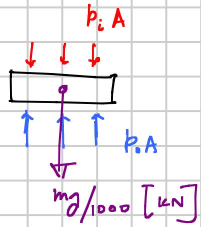
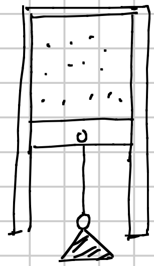
Quiz – 1 (online)

FBD of piston :



A vertical force balance (no accl) produces

$$p_i A + \frac{mg}{1000} = p_o A$$

$$\Rightarrow \quad m = (p_o - p_i) A * 1000 / g$$

$$= (100 - 50) * \frac{\pi (.05)^2}{4} * \frac{1000}{9.81}$$

$$= 10 \text{ kg}$$

Finding $\rho$ & $v$ are trivial since $m$ & $V$ were supplied

Quiz - 2

#1 . 180 Calorie in a food label means

$180 * 4.187$ kJ [ Calorie means bio Calorie = 1 kcal ]

$\Rightarrow$ 42 g releases $180 * 4.187$ kJ $\cong$ 4.2 kJ

1 kg " $\frac{180 * 4.187}{42} \times 1000 = 17.94 \times 10^3$ kJ

Heating value of granola bar = $\boxed{17.94 \text{ MJ.}}$ Ans

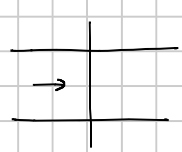
From table heating value of gasolene = 47.3 MJ

We will need to burn $\frac{47.3}{17.94} = 2.637$ kg

of granola bar or $\frac{2.637}{(42/1000)} \cong \boxed{63 \text{ bars}}$ Ans

to get the same amount of heat.

#2 .



$$\dot{m} = \rho A V$$

$$= \frac{AV}{v}$$

$$\Rightarrow \quad v = \frac{AV}{\dot{m}}$$

$$= \frac{\pi (.05)^2}{4} * \frac{50}{0.2} \quad \frac{m^3}{kg}$$

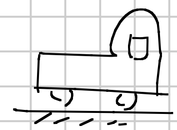
$$= 0.49 \quad \frac{m^3}{kg}$$ Ans

$$\overset{\circ}{V} = A\bar{V} \quad [= \dot{m} v] \quad = \frac{\pi (.05)^2}{4} * 50 \quad \frac{m^3}{s}$$

$$= 0.098 \quad \frac{m^3}{s}$$ Ans

#3

$$KE = \frac{mV^2}{2000} \quad kJ$$



$$= \frac{20{,}000 * (70 * 0.447)^2}{2000} \quad kJ$$ [Using TEST Unit Converter]

$$= 9790.6 \quad kJ$$

$$= 9.79 \quad MJ$$ A3

(b) 50% of KE will be stored

$\therefore$ stored energy $= 0.5 * 9.79 = 4.89$ MJ

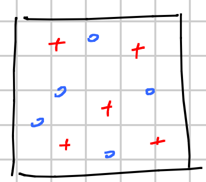
$= 4.89 * 0.277 = 1.356$ kWh b3

#3.

(a) $N_2$ : $m = 14$ kg

$\bar{M} = 28$ kg/kmol

$\therefore \quad n = \frac{m}{\bar{M}} = 0.5$ kmol A3



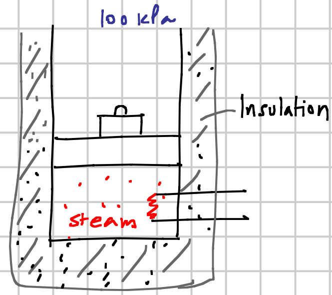
(b) $H_2 + N_2$ : $n = 0.5 + 1 = 1.5$ kmol A3

(c) $m = 14 + n_{H_2} \bar{M}_{H_2} = 14 + 2 = 16$ kg

$\Rightarrow \bar{M} = \frac{m}{n} = \frac{16}{1.5} = 10.67$ A3

Quiz . 3

#3



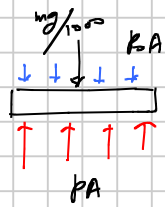

(a) $v_1 = \frac{V_1}{m_1} = 0.712 \ \frac{m^3}{kg}$

Final volume $= 2V_1$

Final mass $m_2 = m_1$

$\Rightarrow$ Final sp. vol $= \frac{2V_1}{m_1} = 2v_1 = 1.432 \ \frac{m^3}{kg}$ Ans

(b) A FBD of the piston produces:

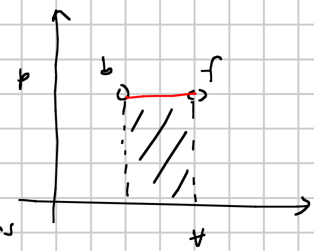



$$pA = p_0 A + \frac{mg}{1000} \quad [kN]$$

$$\Rightarrow m = \frac{(p - p_0) A \times 1000}{g} = \frac{(300-100)\pi (0.2)^2 \times 1000}{4 \times 9.81}$$

$$= 640.5 \text{ kg}$$ Ans

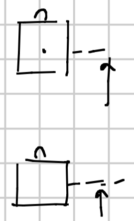
(c) $W_B = \int_b^f p\, dV$




= area of the rectangle as the pressure remains constant.

$$= 300 \times (2-1) = 300 \text{ kJ}$$ Ans

(d) The weight is pushed upward by a distance of



$$\frac{\Delta V}{A} = \frac{1}{\pi \cdot 2^2/4} = 31.8 \text{ m}$$

The work done $W = \int F\, dx$

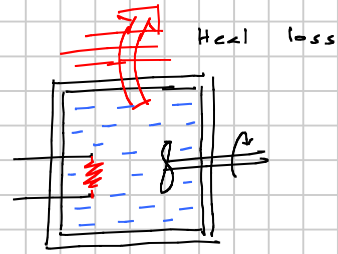
$$= \frac{mg}{1000} \times dx$$

$$= \frac{640.5 \times 9.81}{1000} \times 31.8 = 200 \text{ kJ}$$ Ans

(e) Since steam temperature increases, it must be receiving more energy from heater than it is delivering through boundary work (300 kJ). So my pick is 1300 kJ. Ans

Please work through this problem carefully. You will learn a lot of thermo just from this single problem. Ask yourself, if steam does 300 kJ of work, & the weight needs only 200 kJ, then what happens to the difference? After all, energy cannot be created or destroyed.

#2.




(a) $|\dot{W}_{sh}| = 2\pi n T$

$= 2\pi \frac{\cancel{1000}}{60} \frac{100}{\cancel{1000}}$ kN.m

$= \frac{2\pi * 10}{6}$ kJ

$= 10.47$

With sign $\dot{W}_{sh} = -10.47$ kJ

(b) $|\dot{W}_{el}| = \frac{VI}{1000} = \frac{110 * 10}{1000} = 1.1$ kW

$\dot{W}_{el} = -1.1$ kW

$\therefore \quad W_{el} = \dot{W}_{el} \Delta t = -11$ kJ

(c) energy coming in by work

$= 10.47 + 1.1 = 11.57$ kW

$\therefore \quad \dot{Q} = -11.57$ kW

Ans

#1 (a) closed, (b) adiabatic

(c) isolated

# Quiz - 4

#1. $\dot{W}_{sh} = \eta \, \dot{KE}$

$= \eta \, \dot{m} \, (ke)$

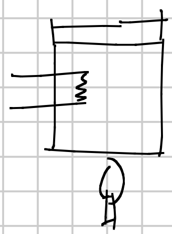
$= \eta \, \dot{m} \left( \frac{\cancel{m} V^2}{2000 \times \cancel{m}} \right) = \eta \, \frac{\dot{m} V^2}{2000}$

$= \eta \, \frac{\rho A V \cdot V^2}{2000}$

$= 0.53 \times \frac{(1.1)(\pi)(50)^2 (20 \times 0.447)^3}{4 \times 2000}$

$= 409$ kW Ans

#2. $Q = 20$ kJ A3



$W_{ext} = W_{el} + W_B$

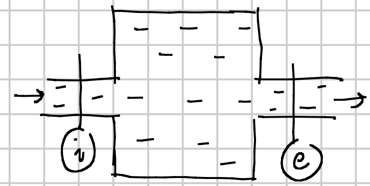
$= -10 + 5$

$= -5$ kJ A3

Net transfer of energy $= 20 + 10 - 5 = 25$ kJ

A3

#3.




$$\dot{W}_{F,i} = (pAV)_i$$

$$= (\rho A V)_i \cdot \frac{p}{\rho_i}$$

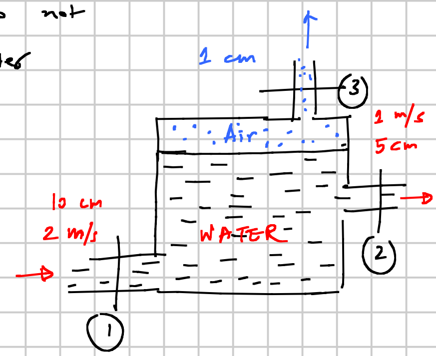
$$= \frac{\dot{m} p_i}{\rho_i}$$

$$= \frac{200 * 100}{1000} = 20 \text{ kW}$$ Ans

$$\dot{KE} = \dot{m}\,(ke) = \dot{m}\,\frac{V^2}{2000}$$

$$= (200)\left(\frac{10^2}{2000}\right) = 10 \text{ kW}$$ Ans

#4. Because air & water do not mix, we can write for water




$$\frac{dm}{dt} = \dot{m}_1 - \dot{m}_2$$

$$\dot{m}_1 = \rho_1 A_1 V_1 = (1000)\left(\pi\frac{0.1^2}{4}\right)(2)$$

$$= 15.71 \text{ kg/s}$$ Ans

$$\dot{m}_2 = \rho_2 A_2 V_2 = (1000)\left(\pi\frac{0.05^2}{4}\right)(1) = 1.96 \text{ kg/s}$$ Ans

$$\frac{dm}{dt} = \dot{m}_1 - \dot{m}_2 = 15.71 - 1.96 = 13.75 \text{ kg/s}$$ Ans

$$\frac{dm}{dt} = \frac{d}{dt}(\rho V) = \rho\frac{dV}{dt}$$

$$\Rightarrow \frac{dV}{dt} = \frac{13.75}{1000} \quad \left[\frac{kg}{s}\,\frac{m^3}{kg} = \frac{m^3}{s}\right]$$

This must also be the rate at which air is being expelled.

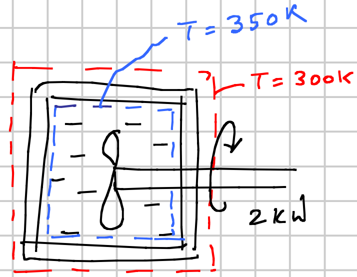
Therefore, $\dot{V}_3 = 0.0137 \frac{m^3}{s}$.

Given $\rho_{air} = 1 \text{ kg}/L$ $\quad \dot{m}_3 = 0.0137 \frac{kg}{s}$ Ans

$$\dot{m}_3 = \rho_3 A_3 V_3 \Rightarrow 0.0137 = (1)\left(\frac{\pi\ 0.01^2}{4}\right) V_3$$

$$\Rightarrow V_3 = 174 \text{ m/s}$$ Ans

Quiz - 5




#1.

$$\cancel{\frac{dE}{dt}}^{0} = \cancel{\sum \dot{m}_i h_i}^{0} - \cancel{\sum \dot{m}_e h_e}^{0} + \dot{Q} - \dot{W}_{ext}$$

$$0 = [\dot{Q}] - [\dot{W}_{ext}]$$

(a) $\dot{W}_{ext} = -2\ kW$ Ans

$$= \dot{Q} - [-2]$$

(b) $\Rightarrow \dot{Q} = -2\ kW$ Ans

$$\cancel{\frac{dS}{dt}}^{0} = \cancel{\sum \dot{m}_i s_i}^{0} - \cancel{\sum \dot{m}_e s_e}^{0} + \frac{\dot{Q}}{T_B} + \dot{S}_{gen,univ}$$

$$\Rightarrow 0 = \frac{-2}{300} + \dot{S}_{gen,univ}$$

(c) $\dot{S}_{gen,univ} = \frac{2}{300} \frac{kW}{K}$ Ans

To calculate entropy generated inside, consider a system boundary that excludes the wall & the surroundings, passing through the water. [blue boundary]

$$\cancel{\frac{dS}{dt}}^{0} = \cancel{\sum \dot{m}_i s_i}^{0} - \cancel{\sum \dot{m}_e s_e}^{0} + \frac{\dot{Q}}{T_B} + \dot{S}_{gen,int}.$$

$$\Rightarrow 0 = \frac{(-2)}{350} + \dot{S}_{gen,int}$$

$\Rightarrow$ (d) $\dot{S}_{gen,int} = \frac{2}{350} \frac{kW}{K}$ Ans

(e) $\dot{W}_{sh} = 2\pi N T$

$$\Rightarrow N = \frac{\dot{W}_{sh}}{2\pi T} = \frac{2}{2\pi [0.00637]}$$

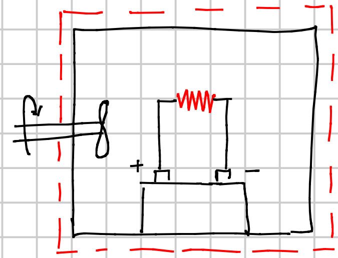
$$= 50 \frac{rev}{s}$$

$\therefore$ Shaft RPM = $50 * 60$ = 3000 RPM Ans

#2.

$\dot{Q} = -0.1 \text{ kW}$

$\dot{W}_{ext} = -0.1 \text{ kW}$



$$\frac{dE}{dt} = 0 - 0 + \dot{Q} - \dot{W}_{ext}$$

$$= [-0.1] - [-0.1]$$

$$= 0$$

In this system $\frac{dm}{dt} = 0$, $\frac{dE}{dt} = 0$; even then, the system is unsteady (Figure why).

#3.

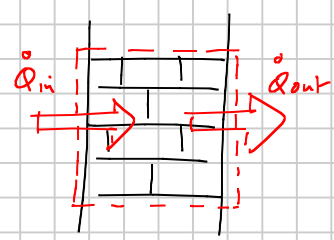
$$\eta_{th,\,Carnot} = 1 - \frac{T_C}{T_H} = 1 - \frac{300}{1500} = 80\%$$

$$\eta_{th} = \frac{\dot{W}_{net}}{\dot{Q}_{in}} \Rightarrow \dot{Q}_{in} = \frac{100 \text{ MW}}{\eta_{th}} = 200 \text{ MW}$$

$$\dot{Q}_{in} = \dot{m}_{fuel} \left(40 \frac{\text{MJ}}{\text{kg}}\right) \qquad \left[ \text{MW} = \frac{\cancel{\text{kg}}}{\text{s}} \cdot \frac{\text{MJ}}{\cancel{\text{kg}}} \right]$$

$$\Rightarrow \dot{m}_{fuel} = \frac{\dot{Q}_{in}}{40} = \frac{200}{40} = 5 \text{ kg/s.}$$

#4. If the wall is at steady state,




$$\cancel{\frac{dE}{dt}}^{\,0} = 0 - 0 + \dot{Q} - \cancel{\dot{W}_{ext}}^{\,0}$$

$$\Rightarrow 0 = [\dot{Q}_{in} - \dot{Q}_{out}]$$

$$\Rightarrow \dot{Q}_{in} = \dot{Q}_{out}$$

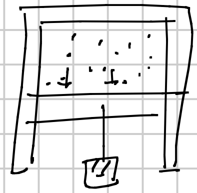
$\Rightarrow \dot{Q} = 0$ Of course $\dot{W}_{ext} = 0$

$$\frac{dS}{dt} = 0 \qquad [\text{steady state}]$$

$$\cancel{\frac{dS}{dt}}^{\,0} = 0 - 0 + \frac{\dot{Q}}{T_B} + \dot{S}_{gen,\,univ}$$

$$\Rightarrow \dot{S}_{gen,\,univ} = -\left[\frac{500}{1000} - \frac{500}{300}\right] = 1.1667 \ \frac{\text{kW}}{\text{K}}$$

TEST – 1

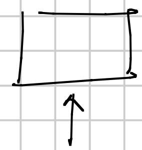


#1. $pA + \dfrac{mg}{1000} = p_0 A \quad [kN]$

$$\Rightarrow \quad m = (p_0 - p)A * \frac{1000}{g}$$

$$= [100 - 60]\ \frac{\pi (0.05)^2}{4} * \frac{1000}{9.81}$$

$$= \underline{8 \text{ kg}} \quad \text{Ans}$$



#2. $W_B = W_M = \int F\,dz$

$$= F \cdot \Delta z$$

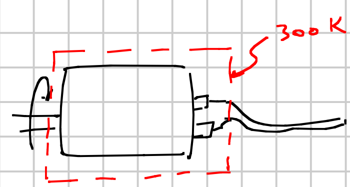
$$= 9.81 * 1 = \underline{9.81 \text{ kJ}} \quad \text{Ans}$$

The net force on the body is

$$9.81 - \frac{mg}{1000} = 9.81 - \frac{1000 * 9.81}{1000}$$

$$= 0$$

Therefore, all the work done goes into increasing the potential energy.




#3. $\dot{Q} = \underline{-20 \text{ kW}}$ Ans

Entropy leaves with heat & enters surroundings at 300 K at

$$\frac{20}{300}\ \frac{kW}{K} = \underline{0.0667\ \frac{kW}{K}}. \quad \text{Ans}$$

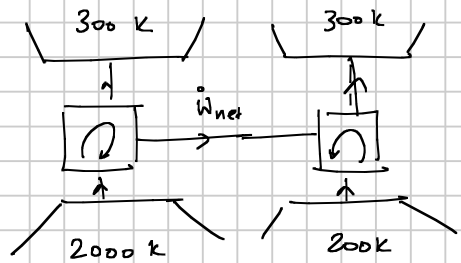
$$\cancel{\frac{dS}{dt}}^{\,0} = \frac{\dot{Q}}{T_B} + \dot{S}_{gen,univ}$$

$$\dot{S}_{gen\ univ} = -\frac{\dot{Q}}{T_B} = -\frac{[-20]}{300}$$

$$= \underline{0.0667 \text{ kW/K}} \quad \text{Ans}$$

$$\eta_I = \frac{\text{Desired Energy}}{\text{Reqd Input}} = \frac{100}{120} = 83.33\%$$

#4.




$$\dot{W}_{net} = \dot{Q}_{in}\,\eta_{th}$$

$$= 50\text{ kW} * 0.4$$

$$= 20\text{ kW}$$

$$(COP)_R = \frac{\dot{Q}_c}{\dot{W}_{in}} \Rightarrow \dot{Q}_c = 2 * 20 = 40\text{kW}$$

#5.

$$u = c_1 T + c_2 T^{\frac{1}{4}}$$

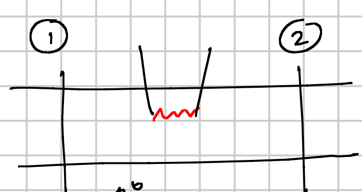
$$\therefore\ c_v = \left(\frac{\partial u}{\partial T}\right)_v = c_1 + c_2 \frac{1}{4} T^{\left(\frac{1}{4}-1\right)}$$

$$= 1 + 100 * \frac{1}{4} \frac{1}{(300)^{3/4}}$$

$$= 1.34 \frac{\text{kJ}}{\text{kg.K}}$$

A2

#6.




$$\cancel{\frac{dE}{dt}}^{\,0} = \dot{m} j_1 - \dot{m} j_2 - \dot{W}_{ext} + \cancel{\dot{Q}}^{\,0}$$

$$\dot{W}_{ext} = -\dot{m}(j_2 - j_1) = -\dot{m}(h_2 - h_1)$$

$$= -\dot{m}\, c_v (T_2 - T_1)$$

$$= -20 * 4.187 * (70 - 30)\ \text{kW}$$

$$= -3349\ \text{kW}$$

A2

$$\cancel{\frac{dS}{dt}}^{\,0} = \dot{m} s_1 - \dot{m} s_2 + \cancel{\frac{\dot{Q}}{T_b}}^{\,0} + \dot{S}_{gen,univ}$$

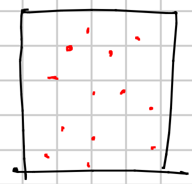
$$\Rightarrow \quad \dot{S}_{gen,univ} = \dot{m}\,(s_2 - s_1)$$

$$= \dot{m} c_p \ln \frac{T_2}{T_1} = 10 * 4.187 * \ln \frac{70+273}{30+273}$$

$$= 5.19 \ \frac{kW}{K}$$

Ans

#7. $m = 15$ kg $\quad V = 2 m^3$



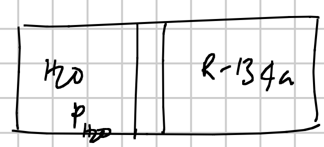
$\Rightarrow \quad v = \frac{2}{15} \ m^3/kg$

$x = 1$ [sat. vapor]

From sat. table $\Rightarrow$ $P_{sat} = 1487$ kPa Ans

$T_{sat} = 198\ ^\circ C$ Ans ; $\quad S = ms = 96.7 \ \frac{kJ}{K}$ Ans

#8.




$P_{H_2O} = P_{sat} @ 85.9\ ^\circ C$

$= 70$ kPa

Because the piston is in eql.

$P_{R-134a} = 70$ kPa

$\therefore \quad T_{R-134a} = T_{sat} @ 70 \text{ kPa} = -34\ ^\circ C$