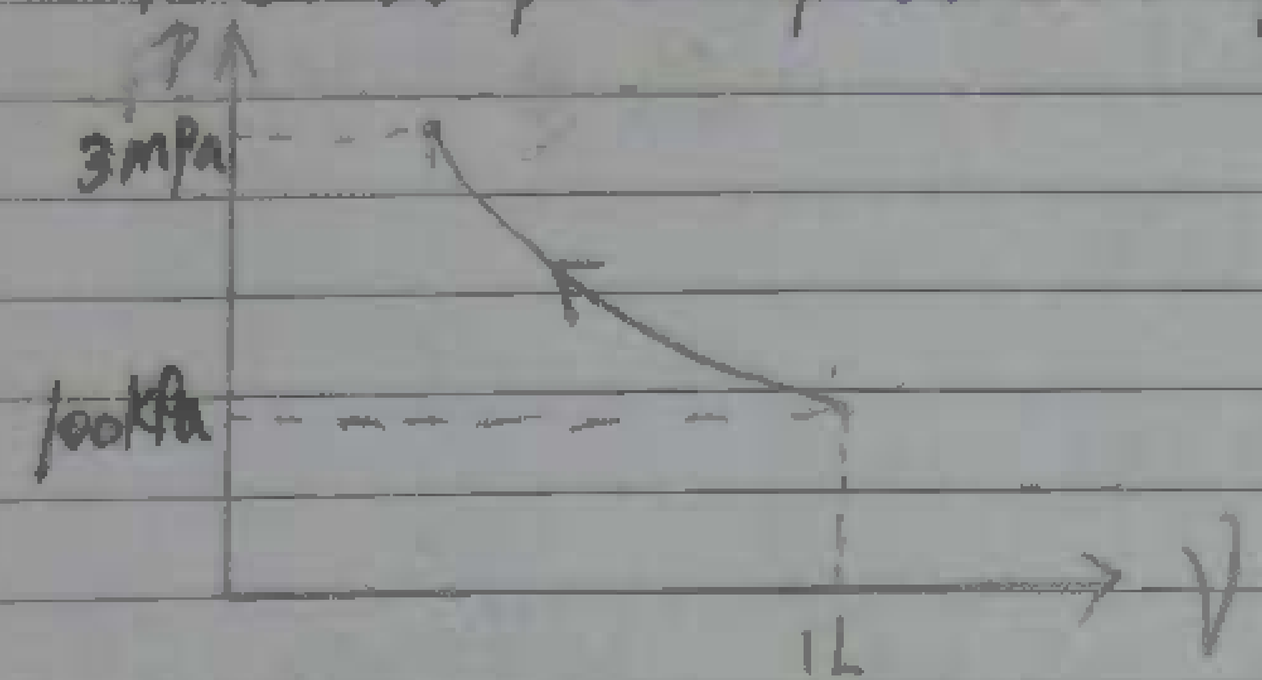
MP2010 (2008-2009Sem1)

1 (a) Sketch the process path in a p – V diagram



(b) Find the value of n

According to the ideal gas law $pV = mRT$

in this process $\frac{pV}{T}$ = constant, since m is unchanged, R is a constant

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{100k \times 1 \times (350+273)}{(30+273) \times 3M} = 0.06854L$$

Given $p_1 V_1^n = P_2 V_2^n = C$

$$\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^n \qquad \frac{1}{30} = \left(\frac{0.06854}{1}\right)^n$$

$$n = \frac{\log(\frac{1}{30})}{\log 0.06854} = 1.27$$

(c) Derive the equation for calculating the compression process work & hence calculate the compression work.

$$C = p_1 V_1^{1.27} = 100k \times [10^{-3}]^{1.27} = 15.49$$

$$Work = \int p\,dV = \int \frac{15.49}{V^{1.27}} dV = \frac{15.49}{-0.27} V^{-0.27} \Big|_{V_1}^{V_2} = -\frac{15.49}{0.27} V^{-0.27} \Big|_{V_1}^{V_2}$$

Hence $Work = \frac{15.49}{0.27} \times (1 - 0.06854^{-0.27}) \times (10^{-3})^{-0.27} = -344.77J$

(d) Compute the actual work required & heat transfer from the system

Work required to overcome friction $W_f = \frac{F(V_1 - V_2)}{A} = \frac{200 \times (1 - 0.06854) \times 10^{-3}}{10^{-2} m^2} = 18.63J$

Work done by air $W_a = p(V_1 - V_2) = 100k \times (1 - 0.06854) \times 10^{-3} = 93.146J$

Actual work required $W_T = W_P - W_{air} - Work$

$= 18.63 - 93.146 + 344.77$

$= 270.254\ J$

Use $\rho = 1.1614\ kg/m^3$ $C_p = 1.007\ KJ/kg \cdot k$

Hence $\Delta U = (\rho V) \cdot C_p \cdot \Delta T = 1.1614 \times 10^{-3} \times 1.007 \times (350-30)$

$= 0.374\ kJ$

$= 374\ J$

Heat transfer from the System

$Q = W_T - \Delta U = 270.254 - 374J = 104J$

2 (a) Calculate the mass flow rate of steam from the boiler.

At state 1, Saturated liquid $P_1 = 0.7MPa$, $T_1 = 164.95°C$ $hf_1 = 697\ kJ/kg$

At state 4, $P_4 = 0.7MPa$ $T = 200°C$, $hf_4 = \frac{2850.6 + 2839.8}{2} = 2845.2\ kJ/kg$

power absorbed by coolant water : $W_c = \frac{4500}{3600} kg/s \times 4.2 kJ/kg \cdot k \times (80-10k)$

$= 367.5\ kW$

power transfed from condenser : $W_h = W_c = 367.5\ kW$

Since $W_h = \dot{m}(h_{f4} - hf_1)$

$\dot{m} = \frac{W_h}{hf_4 - hf_1} = \frac{367.5\ kW}{2845.2 - 697\ kJ/kg} = 0.171\ kg/s$

(b) Calculate the power generated by the steam turbine

At state 3, $P_3 = 5MPa$ $T_3 = 400°C$, $h_3 = 3196.7\ kJ/kg$

electrical power $= \dot{m}(h_3 - h_4) = 0.171 \times (3196.7 - 2845.2) = 58.57\ kW$

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(c) The cycle is adjusted to have saturated vapour at 10 kPa at the turbine outlet

State 4 changed. $P_4' = 10kPa$ $T_4' = 45.81°C$ $h_4' = 2583.9kJ$

Hence Electrical Power' $= \dot{m}(h_3 - h_4') = 0.171 \times (3196.7 - 2583.9) = 104.79kW$

(d) Calculate the mass flow rate of the hot water. Explain why the hot water flow rate has changed

State 1 changed $P_1' = 10kPa$ $T_1' = 45.81°C$ $h_1' = 191.81\ kJ/kg$

Total power transfered to hot water $W = EP' - EP + \dot{m}_s(h_4' - h_1')$

$= 104.79 - 58.57 + 0.171 \times (2583.9 - 191.81)$

$= 501.44\ kW$

$\dot{m}' = \frac{W}{C_p \Delta T}$ ⇒

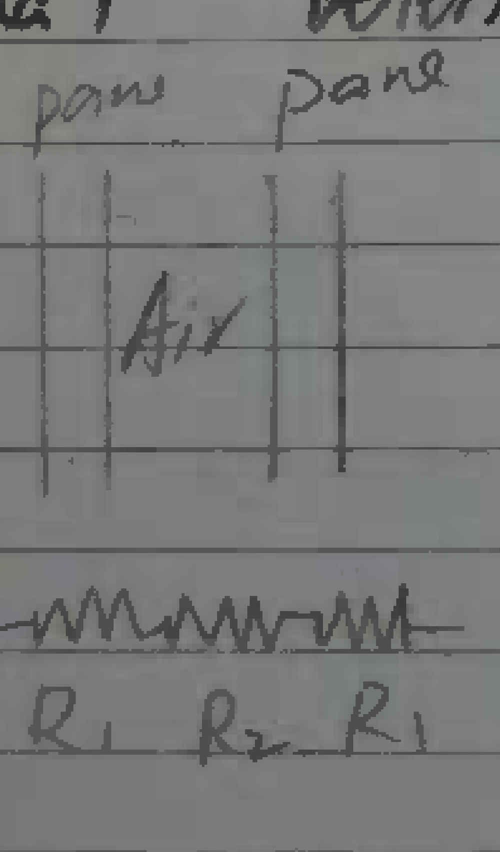
$= \frac{501.44k}{4.2 \times 70}$

$= 1.71\ kg/s$

The reason is due to change of state!

More heat can be used for Power Generation and heating. Since power generation ~~increased~~ of 58.57kW deducted, the remaining part has all be used to heat the coolant water. Hence can heat up more coolant water.

3 (a) Determine the rate of heat conducted on a day



$R_1 = \frac{Thick}{k_1 \cdot Area} = \frac{3 \times 10^{-3}}{0.78 \times 1.2 \times 2} = 1.6 \times 10^{-3}\ k/W$

when $T = \frac{20+40}{2} = 30°C$. $k = 26.3 \times 10^{-3}\ W/mK$

$R_2 = \frac{12 \times 10^{-3}}{26.3 \times 1.2 \times 2 \times 10^{-3}} = 0.19\ k/W$

power $= \frac{\Delta T}{R_1 + R_2 + R_1} = \frac{20}{1.6 \times 10^{-3} \times 2 + 0.19} = 0.09\ kW$

rate of heat / day $= 0.09\ kW \times 3600s/day = 324\ kJ/day$

3 (b) Determine the rate of heat gained by the wall (convection)

Average tempeature $T = \frac{35+25}{2} = 30°C$

$\rho = 1.1614$ kg/m³ $\mu = 184.6\times10^{-7}$ N·s/m² $k = 26.3\times10^{-3}$ W/mK $Pr = 0.707$

$Re = \frac{\rho V L}{\mu} = \frac{1.1614\times55\times2.6\times10}{184.6\times10^{-7}} = 9.6\times10^6$ Mixed flow

$Nu = (0.037 Re^{4/5} - 871) Pr^{1/3} = 11,959$

Since $\overline{Nu} = \frac{hL}{K_f}$,

$h = \frac{\overline{Nu} K_f}{L} = \frac{11959\times26.3\times10^{-3}}{10} = 31.45\ W/m^2k$

$\dot{Q} = hA\cdot\Delta T = 31.45\times(10\times4)\times(35-25)$

$= 12.58\ kW$

4(a) Determine the net rate of radiation heat transfer.

Known $R_i = R_j = 0.6$ $L = 0.4$

$L/R_i = 0.4/0.6 = 0.67$ $R_j/L = 0.6/0.4 = 1.5$

From Figure 1 View Factor $= 0.5$

View Factor from disk to surrounding will be $1-0.5=0.5$

Since both disks are black and are maintained at 700K,

there is no radiation between the two disk.

The radiation from one disk to surrounding:

$R = \frac{1}{A\cdot F} = \frac{1}{\pi\times(\frac{0.6}{2})^2\times0.5} = 7.07$

$E_d = \sigma T_d^4 = 5.67\times10^{-8}\times700^4 = 13,614$

$E_s = \sigma T_s^4 = 5.67\times10^{-8}\times300^4 = 459.3$

$q = \frac{E_d - E_s}{R} = \frac{13,614 - 459.3}{7.07} = 1.86\ kW$

Since two disks transfer heat to surrounding

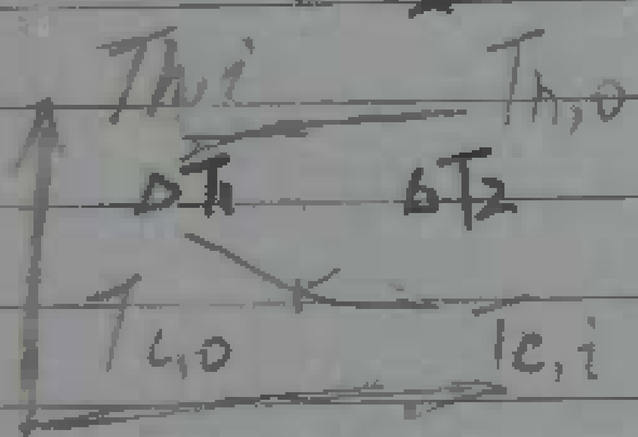
$$q' = q \times 2 = 3.72\,kW$$

Hence Net Rate of radiation heat transfer is 3.72kW

(b) Determine the length of pipe required.

$T_{h,i} = T_{h,o} = 120°C \quad T_{c,i} = 17°C \quad T_{c,o} = 80°C$

$$\Delta T_2 = 120 - 17 = 103\,°C \qquad \Delta T_1 = 120 - 80 = 40\,°C$$



$$LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1/\Delta T_2)} = \frac{40 - 103}{\ln(40/103)} = 66.61\,°C$$

$$q = \dot{m} c_p \cdot \Delta T = 3 \times 4.18 \times (80 - 17) = 790\,kW$$

Since $q = UA(LMTD)$

$$A_o = \frac{q}{U \cdot LMTD} = \frac{790000}{1500 \times (66.61)} = 7.91\,m^2$$

Total length of the tube

$$L = \frac{A_o}{\pi \times 0.025} = \frac{7.91}{\pi \times 0.025} = 100.7\,m$$

Thus the length of the pipe required is 100.7m