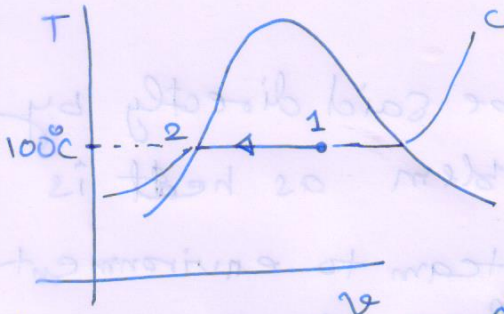
6.3



constant pressure line

process path 1 → 2

at 1, $x = 0.6$

2, $x = 1.0$

$m = 20$ kg

at constant pressure

$Q = m(\Delta u + P\Delta v) = m\Delta(u + Pv) = m\Delta h$

hence $Q = m(h_2 - h_1)$

using steam table, $h_1 = h_g x + h_f(1-x)$ $(x = 0.6)$ $\Rightarrow h_1 = 1773.2$ kJ/kg

at 100°c

$h_2 = h_f = 419.06$ kJ/kg
(100°c)

hence $Q_{\text{to steam}} = m(h_2 - h_1) = -27083$ kJ

1→2 process is quasi-static, hence

$Q_{\text{to steam}}$ can also be calculated using entropy change

$Q = mT(s_2 - s_1)$

$x = 0.6$

$s_1 = s_g x + s_f(1-x)$

at 100°c

$= 4.936$ kJ/kg K

$s_2 = s_f$ at 100°c

$= 1.3069$ kJ/kg K

hence $Q = 20 \times (373.15)(s_2 - s_1) = -27084$ kJ/kg K

≒ answer obtained in (a)

(b) $\Delta S_{\text{total}} = \Delta S_{\text{steam}} + \Delta S_{HR}$

$= m(s_2 - s_1) + \underbrace{Q_{HR}}_{T_{HR}} \rightarrow (-Q_{\text{to steam}})$

$= m(s_2 - s_1) - \frac{Q_{\text{to steam}}}{T_{HR}} = m(s_2 - s_1) + \frac{T(s_2 - s_1)}{T_0}\, m$

(373.15 K, 100°C)

$= m\left[(s_2 - s_1) - \frac{T}{T_0}(s_2 - s_1)\right]$

$= 18.528$ kJ/K.

$\Delta S_{\text{total}} > 0$
hence heat transfer from steam to environment is irreversible.

further it can also be said directly by just reading the problem as heat is transferring from steam to environment by finite temp. difference, hence heat transfer is irreversible.

More specifically if we consider steam as system, then phase chang process in steam is reversible (as we discussed, Phase change is always reversible except Flash process (you will read in future.), Hence this process is internally reversible.

However heat transfer from steam to environment is due to finite temp difference (steam temp at any instant is finitely greather than environment temp). Hence heat transfer is irreversible, hence this process is externally irreversible.

Hence process is overall irreversible.