1.

(a)

$$\begin{cases} P_1 = 1\,\text{MPa} \\ T_1 = 300^\circ C \end{cases} \longrightarrow s_1 = 7.1246 \ \text{kJ/kg·K}$$

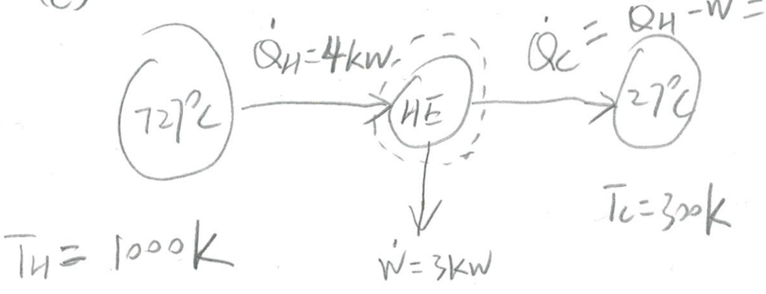
$$\begin{cases} P_2 = 2\,\text{MPa} \\ T_2 = 300^\circ C \end{cases} \longrightarrow s_2 = 6.7684 \ \text{kJ/kg·K}$$

$$\begin{cases} s_2 - s_1 = \frac{Q}{T} + \overset{0}{\cancel{s_{gen}}} \Rightarrow Q = T(s_2 - s_1) = -204.1 \ \text{kJ/kg} \\ T = 300^\circ C + 273 = 573\,K \end{cases}$$

(b)

$$s_2 - s_1 = \underset{\substack{0 \\ (T_2 = T_1)}}{c_v \ln \cancel{\frac{T_2}{T_1}}} + R \overset{(V_2 = 2V_1)}{\frac{V_2}{V_1}} = \underset{\substack{\uparrow \\ 0.2081 \ \text{kJ/kg·K}}}{R} \ln 2 = 0.144244 \ \text{kJ/kg·K}$$

(c)



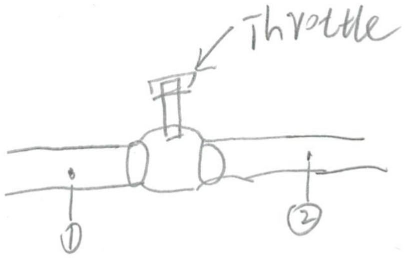
2L for HE:

$$\overset{}{\underset{0}{\cancel{\frac{dS}{dt}}}} = \frac{\dot{Q}_H}{T_H} - \frac{\dot{Q}_C}{T_C} + \dot{S}_{gen}$$

$$\Rightarrow \dot{S}_{gen} = \frac{\dot{Q}_C}{T_C} - \frac{\dot{Q}_H}{T_H} = \frac{1}{300} - \frac{4}{1000} = -0.000667 \ \frac{kW}{K} < 0$$

$\dot{S}_{gen} < 0$ → impossible!

(d)



For throttle: $\underline{h_1 = h_2}$ ✓

$\Rightarrow U_1 + P_1 V_1 = U_2 + P_2 V_2$, $\underline{v_1 = v_2 = v}$ ✓ subcooled liquid

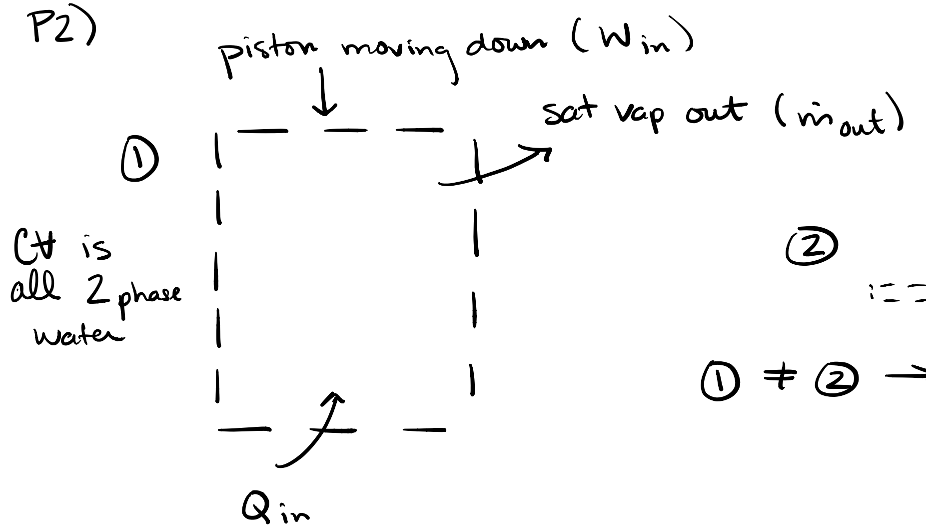
$\Rightarrow U_1 + P_1 v = U_2 + P_2 v$, $P_1 > P_2$

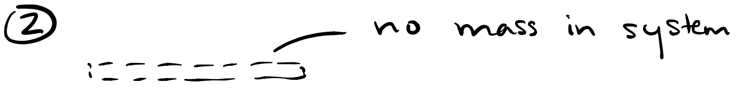
$\Rightarrow \underline{U_1 < U_2}$ ✓

$\Rightarrow CT_1 < CT_2 \Rightarrow \underline{T_1 < T_2}$ ✓

$s_2 - s_1 = C \ln \frac{T_2}{T_1} \xrightarrow{T_1 < T_2} \underline{s_1 < s_2}$ ✓

P2)





① ≠ ② → unsteady!

COM: $\frac{d}{dt}(M_{cv}) = \sum_i \underset{0}{\cancel{\dot{m}_i}} - \sum_e \dot{m}_e$

$\frac{d}{dt}(m_{cv}) = -\dot{m}_e$ integrate w.r.t. time b/c unsteady

$\underset{0}{\cancel{m_2}} - m_1 = -m_e$

$\underline{\underline{m_e = m_1}}$

Can solve this problem using either an energy (1st Law) or entropy (2nd Law) perspective:

Energy Perspective (probaly more intuitive | familiar):

1L, open: $\frac{d}{dt}(E_{cv}) = \dot{Q} - \dot{W} + \sum_i \underset{0}{\cancel{\dot{m}_i}}\theta_i - \sum_e \dot{m}_e\theta_e$ neglect ΔPE & ΔKE

$\frac{d}{dt}(E_{cv}) = \dot{Q} - \dot{W} - \dot{m}_e h_e$ integrate w.r.t. time

$\underset{0}{\cancel{m_2}}u_2 - m_1u_1 = Q - W - m_e h_e$

Note: we can evaluate $\int \dot{m}_e h_e$ b/c chose a CV where all mass leaving is sat. vapor @ constant P, so $h_e(t) = h_g(P) = \text{const}$ and thus $\int \dot{m}_e(t)h_e(t)\,dt = h_g(P)\int \dot{m}_e(t)\,dt = h_g(P)m_e$

$Q = m_e h_e - m_1u_1 + W$

$Q = m_1(h_e - u_1) + W$

need to find m_1, h_e, u_1, & W

$m_1: \; v_1 = \frac{\forall_1}{m_1} \rightarrow m_1 = \frac{\forall_1}{v_1}$ 1.5 mPa

$$v_1 = v_f(\overset{\downarrow}{P}) + \underset{\underset{0.7}{\uparrow}}{x} v_{fg}(\overset{\downarrow}{P}) \; ; \; v_f(P) = 0.001154 \text{ m}^3/\text{kg}$$

$$v_{fg}(P) = 0.130556 \text{ m}^3/\text{kg}$$

$$v_1 = 0.0925 \text{ m}^3\text{kg}$$

$$m_1 = \frac{2\cancel{m^3}}{0.0925 \cancel{m^3}/\text{kg}} \rightarrow \underline{\underline{m_1 = 21.6 \text{ kg}}}$$

$h_e: \; h_e = h_g(P) = 2791.0$ kJ/kg

$u_1: \; u_1 = u_f(P) + x u_{fg}(P) \; ; \; u_f(P) = 842.82$ kJ/kg

$$u_{fg}(P) = 1750.6 \text{ kJ/kg}$$

$$\underline{u_1 = 2068.2 \text{ kJ/kg}}$$

$$W: \; W = \int P d\forall = \underset{\underset{\text{Const}}{\uparrow}}{P} \int d\forall = P\Delta\forall = P(\underset{0}{\cancel{\forall_2}} - \forall_1) = -P\forall_1$$

$$W = -1.5 \text{ mPa}(2\text{m}^3) = \underline{-3000 \text{ kJ}} = W$$

Finally, $Q = 21.6 \cancel{\text{kg}} (2791.0 - 2658.2) \text{ kJ}/\cancel{\text{kg}} - 3000 \text{ kJ}$

$$Q = 12620 \text{ kJ} \rightarrow \boxed{Q = 12.6 \text{ mJ}}$$

Entropy Perspective (faster):

2L, open: $\frac{d}{dt}(S_{cv}) = \sum_j \frac{\dot{Q}_j}{T_j} + \sum_i \underset{0}{\cancel{\dot{m}_i}} s_i - \sum_e \dot{m}_e s_e + \underset{\text{"slowly" (reversible)}}{\cancel{\dot{S}_{gen}}}$

integrate w.r.t. time

$$\underset{0}{\cancel{m_2}} s_2 - m_1 s_1 = \frac{Q}{T_{bdy}} - m_e s_e$$

$$Q = (m_e s_e - m_1 s_1) T_{bdy}$$

$$Q = m_e T_{bdy} (s_e - s_1)$$

need m_e, T_{bdy}, s_e, s_1

m_e: see above

$T_{bdy}: \; T_{bdy} = T_{sat}(\overset{\overset{1.5 \text{ mPa}}{\downarrow}}{P}) = 198.29$ °C (Note this is Celsius!)

$s_e : \quad s_e = s_g(P) = 6.4430 \ \text{kJ}|\text{kg-K}$

$s_1 : \quad s_1 = s_f(P) + x\, s_{fg}(P) \ ; \quad s_f(P) = 2.3143 \ \text{kJ}|\text{kg-K}$

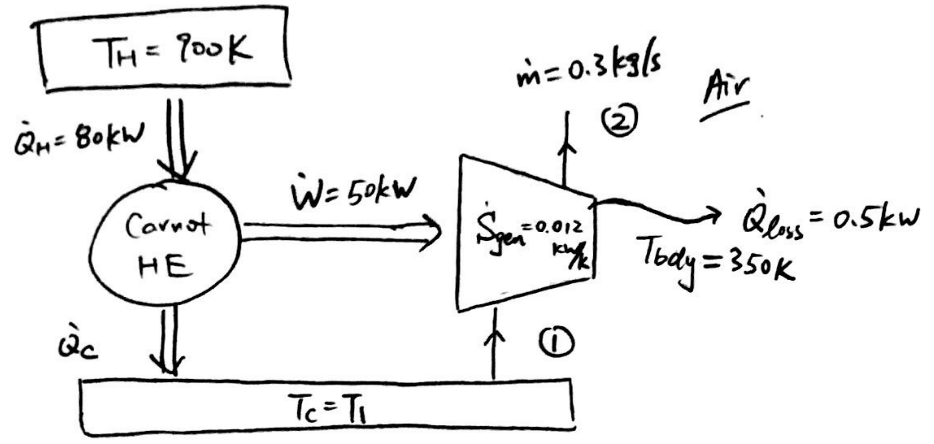
$s_{fg}(P) = 4.1287 \ \text{kJ}|\text{kg-K}$

$s_1 = 5.2044 \ \text{kJ}|\text{kg-K}$

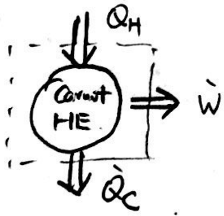
$$Q = (21.6 \ \cancel{\text{kg}})(198.29 + 273)\cancel{\text{K}}\,(6.4430 - 5.2044) \ \text{kJ}|\cancel{\text{kg}}\text{-}\cancel{\text{K}}$$

$$Q = 12616 \ \text{kJ} \ \rightarrow \ \boxed{Q = 12.6 \ \text{MJ}}$$

Q3).



a). CV: Carnot HE



2nd Law: $$0 = \frac{\dot{Q}_H}{T_H} - \frac{\dot{Q}_C}{T_C} + \cancelto{=0 \text{ (Carnot)}}{\dot{S}_{gen,HE}}$$

$$\Rightarrow \frac{\dot{Q}_H}{\dot{Q}_C} = \frac{T_H}{T_C}$$

1st Law: $$\dot{Q}_C = \dot{Q}_H - \dot{W}$$

$$\Rightarrow \frac{\dot{Q}_H}{\dot{Q}_H - \dot{W}} = \frac{T_H}{T_C} \Rightarrow \frac{80kW}{(80-50)kW} = \frac{900K}{T_C}$$

$$\boxed{T_C = 337.5K}$$

b). CV: Compressor

1st Law: $$\cancelto{S.S.}{\frac{d}{dt}}(E_{cv}) = \dot{Q} - \dot{W} + \dot{m}\overbrace{(h_1 - h_2)}^{=c_p(T_1-T_2)} \qquad [\dot{m}_1 = \dot{m}_2 = \dot{m}]$$

negative sign for heat lost

negative sign for work done on system.

$$0 = (-0.5kW) - (-50kW) + (0.3kg/s)(1.005\frac{kJ}{kg \cdot K})(337.5K - T_2)$$

Solve for T_2: $\boxed{T_2 = 502K}$

c) 2nd Law (Compressor).

$$\cancelto{S.S.}{\frac{d}{dt}}(S_{cv}) = \frac{\dot{Q}}{T_{bdy}} + \dot{m}(s_1 - s_2) + \dot{S}_{gen}$$

$$\dot{m}(s_2 - s_1) = \frac{\dot{Q}}{T_{bdy}} + \dot{S}_{gen}$$

$$(0.3kg/s)(s_2 - s_1) = \frac{-0.5kW}{350K} + 0.012\frac{kW}{K}$$

$$\boxed{(s_2 - s_1) = 0.035\frac{kJ}{kg \cdot K}}$$

Note for (c):

Recall for ideal gas with constant c_p,

$$s_2 - s_1 = c_p \ln\frac{T_2}{T_1} - R\ln\frac{P_2}{P_1},$$

However, P_1 and P_2 are not given in this problem, $(s_2 - s_1)$ cannot be found by evaluating this relation.