2. A rigid tank of volume $V = 1$ m$^3$ contains $m = 5$ kg of water at an initial temperature of $T_i = 20^\circ C$. The tank is cooled to the environment temperature of $25^\circ C$.

(a) Calculate the thermal transfer during the process.
(b) Calculate the irreversibility of the process and the reversible work. Irreversibility is the difference between reversible and actual work. The tank is rigid, so what is the actual work?

$$T_c = 25^\circ C, \ U_c = U_i = 0 \Rightarrow \text{get } u_c, s_c$$

Irreversibility: $I = W_{rev} - W_{act}$

Claud system: $S_g = \frac{M(S_c-S_i)}{T_i} - \frac{Q_c}{T}$

$S_g$ is the entropy generated during process.

$T_c$: Environment $T$ in $K$

$W_{rev} - W_{act} = T_c S_{gen} \geq 0$

$\Rightarrow$ lost work potential

Also: $I = T_c S_{gen}$

$\text{Irreversible: } I = W_{rel} - W_{act}$

work done by actual work during process

reversible $\text{HX}$

before ($\text{HP}$ of $\text{HE} + \text{HP}$): and $Q_c = Q_{HP}$

and as before: $\dot{Q}_c = \dot{m}_c (h_2-h_1)_c$

$\dot{Q}_H = \dot{m}_H (h_0-h_1)_H$

$\Rightarrow$ assume:

- $\text{inlet and exit states of } H + C \text{ fluids are sure}$
- $\text{mass flow of } C \text{ fluid is sure}$
- $\text{find: minmum required mass flow of hot fluid needed to heat the cold fluid}$

$S_{gen} = \frac{M_{HP\text{HP}} (S_c - S_i)_H + M_c (S_c - S_i)_C - \frac{Q_o}{T_o}}{T_o} \geq 0$

$\text{Minimum mass to ideal heat sink}$

$\text{reversible process}$

$\text{zero entropy generation}$

before ($\text{HP}$ of $\text{HE} + \text{HP}$): $\dot{Q}_c + \dot{Q}_H = 0$

and as before: $\dot{Q}_c = \dot{m}_c (h_2-h_1)_c$

$\dot{Q}_H = \dot{m}_H (h_0-h_1)_H$

$\Rightarrow$ assume:

- $\text{inlet and exit states of } H + C \text{ fluids are sure}$
- $\text{mass flow of } C \text{ fluid is sure}$
- $\text{find: minmum required mass flow of hot fluid needed to heat the cold fluid}$

$T_H$

$\text{revolvable: } S_{gen} = 0$

$$S_{gen} = \frac{M(S_c-S_i)}{T_i} - \frac{Q_H}{T_H} - \frac{Q_o}{T_o} = 0$$

$2 \text{ unknowns: } M_H, Q_o$

$\text{need to generate } S_{gen}$ to include heat from to source other than environment

$S_{gen} = \frac{M(S_c-S_i)}{T_H} - \frac{Q_H}{T_H} - \frac{Q_o}{T_o} > 0$

$S_{gen} = \frac{M(S_c-S_i)}{T_H} - \frac{Q_H}{T_H} - \frac{Q_o}{T_o} > 0$

$2 \text{ unknowns}$

$M_H, Q_o$

A heat exchanger uses hot air to heat water. Water flows into the HR at 21$^\circ$C and 2 MPa and leaves at 300$^\circ$C at the same pressure, and takes a flow rate of 10 kg/s. Hot air streams into the HR at 800 K and leaves at 400 K.

(a) Calculate the required flow rate of the air. Use either the tables or a constant specific heat assumption.

(b) Calculate the rate of irreversibility of the process.

(c) Calculate the theoretical minimum air mass flow rate required to heat the water, assuming a completely reversible process. Take the environment temperature to be 296 K.

(d) Draw a diagram to describe how the irreversible heat exchanger would operate. It will involve a coupled heat engine/heat pump system.

$\dot{Q}_o + \dot{Q}_c = 0$

$\dot{Q}_o + \dot{Q}_c + \dot{Q}_o = 0$

$\dot{m}_H (h_0-h_1)_H + \dot{m}_c (h_2-h_1)_c + \dot{Q}_o = 0$

$\text{2 unknowns, } \dot{m}_H, \dot{Q}_o$