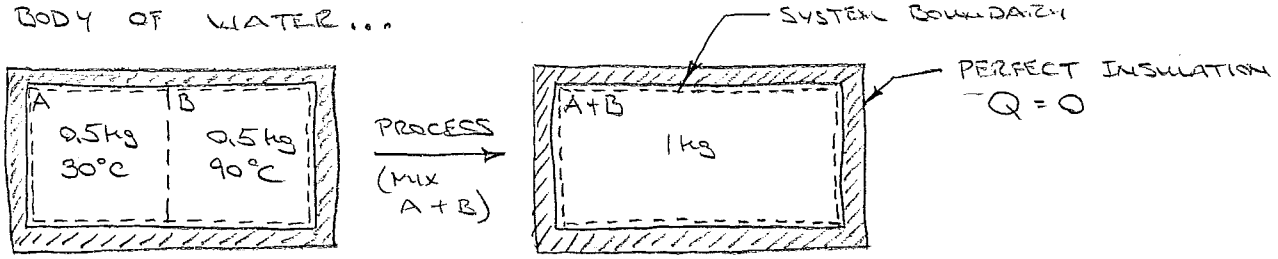
THERMODYNAMICS - ENTROPY

① A BODY OF WATER...



INITIAL

Ⓐ: $h_A = 125.79$ kJ/kg
$S_A = 0.4369$ kJ/kg-K.

Ⓑ: $h_B = 376.92$ kJ/kg
$S_B = 1.1925$ kJ/kg-K

FINAL.

$h_{A+B} = m_A h_A + m_B h_B = 251.355$ kJ

FROM STEAM TABLES: $T_{A+B} = 60.0538\,^\circ C$

$S_{A+B} = 0.8328$ kJ/kg-K

② IS THE PROCESS REVERSABLE?

$S_{INITIAL} = m_A S_A + m_B S_B = 0.8147 \frac{kJ}{K}$ $\quad S_{FINAL} = m_{A+B} S_{A+B} = 0.8328 \frac{kJ}{K}$

NOTE THAT $S_{INITIAL} < S_{FINAL}$ ... ENTROPY WAS PRODUCED.

IN GENERAL:

$$S_F - S_I = \int_I^F \left(\frac{dQ}{T}\right)_b + \rho$$

CHANGE IN ENTROPY, WITHIN THE SYSTEM.

$S_F - S_I \begin{cases} > 0 \\ = 0 \\ < 0 \end{cases}$

ENTROPY TRANSFER ACROSS THE SYSTEM BOUNDARY "b" ALONG WITH HEAT.
- DEPENDS ON THE PROCESS.

Q = HEAT TRANSFER INTO SYSTEM

T_b = ABSOLUTE TEMP. AT SYSTEM BOUNDARY WHERE "Q" OCCURS.

ENTROPY PRODUCTION WITHIN A SYSTEM DURING A PROCESS

$\rho \begin{cases} > 0 & \underline{\text{IRREVERSIBLE}} \text{ PROCESS} \\ = 0 & \underline{\text{REVERSIBLE}} \text{ PROCESS} \end{cases}$

NOTE: WHEN Q IS STEADY
- AND -
T_b = CONSTANT

$$\int_I^F \left(\frac{dQ}{T}\right)_b = \frac{Q}{T_b}$$

(IF $\rho < 0$ THEN THE PROCESS IS NOT POSSIBLE.)

SO... $S_F - S_I = \int_I^F \left(\frac{dQ}{T}\right)_b + \rho$

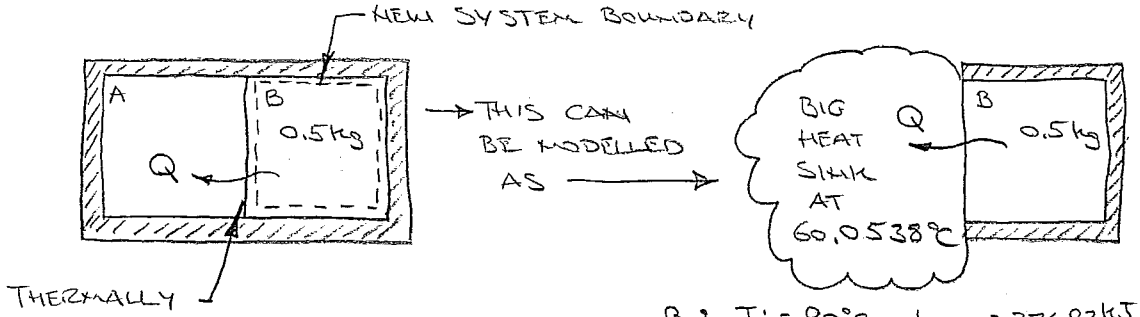
0 BECAUSE $Q = 0$ (PERFECT INSULATION)

SO... $S_F - S_I = \rho$

$0.8328 - 0.8147 = 0.0181 \frac{kJ}{K} = \rho$ AND $\frac{\rho}{m_{A+B}} = 0.0181 \frac{kJ}{kg\text{-}K}$

$\rho > 0$ ∴ PROCESS IS IRREVERSIBLE.

③ CHANGE THE SYSTEM BOUNDARY AND EXAMINE "B"



B: $T_i = 90°C$, $h_{i(B)} = 376.92 \frac{kJ}{kg}$, $s_{i(B)} = 1.1925 \frac{kJ}{kg\text{-}K}$

$T_f = 60.0538$, $h_{f(B)} = 251.355 \frac{kJ}{kg}$, $s_{f(B)} = 0.8328 \frac{kJ}{kg\text{-}K}$

BY THE FIRST LAW: $\Delta E = Q_{in} - W_{out}$ ($W_{out} \to 0$)

$$m_B(h_{f(B)} - h_{i(B)}) = Q_{in}$$

$$0.5(251.355 - 376.92) = -62.7825 \text{ kJ} = Q_{in}, \quad (\text{NOTICE, } -Q_{in} = Q_{OUT})$$

ALSO $T_b = 60.0538°C$ (BOUNDARY TEMPERATURE)

④ HOW ABOUT THE ENTROPY? (IS THE PROCESS REVERSABLE?)

RECALL: $S_F - S_I = \int_I^F \left(\frac{dQ}{T}\right)_b + P$

SO $P = m_B(s_{F(B)} - s_{I(B)}) - \left(\frac{Q}{T}\right)_b$

NOTICE: T_b = CONSTANT.

Q = TOTAL HEAT TRANSFER.

$$\int_I^F \left(\frac{dQ}{T}\right) = \frac{1}{T_b}\int_I^F dQ = \left(\frac{Q}{T}\right)_b$$

$$= 0.5(0.8328 - 1.1925) - \frac{(-62.7825)}{(60.0538 + 273.15)}$$

$$P = 0.0086 \text{ kJ/K} \quad \leftarrow P > 0 \therefore \text{IRREVERSIBLE PROCESS.}$$

or $\frac{P}{m_B} = \frac{0.0086}{0.5\text{kg}} = 0.0171 \text{ kJ/kg-K}$

⑤ COMPARE:

NOTICE THAT THE SPECIFIC ENTHALPY PRODUCT, $\frac{P}{m}$ FOUND IN ② AND ③ ARE ABOUT THE SAME.

THEY ARE ABOUT 5% DIFFERENT FROM ONE ANOTHER.

THIS SMALL ERROR IS MOST LIKELY DUE TO ROUNDING AND INTERPOLATION ERRORS.

⑥ ASIDE: IF "x" IS KNOWN (FOR USE "UNDER THE DOME" ONLY):

$$s = s_f + x(s_g - s_f)$$