Problem Set 14, PS14 due Monday June 21

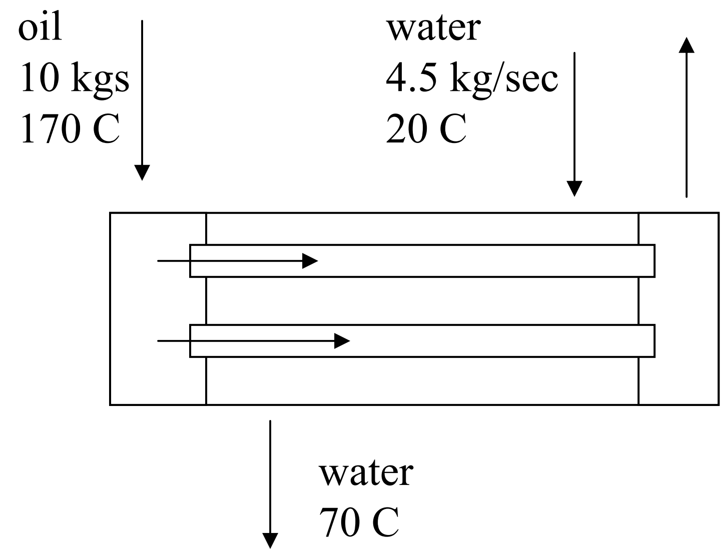
PS14-1 Oil enters a well insulated heat exchanger at 170 C at a flow rate of 10 kg/sec and is cooled by water. The water flows at a rare of 4.5 kg/sec and is heated from 20 C to 70 C. The specific heat of the oil is 2.3 kJ/kg C. Determine a) the exit temperature of the oil and b) the rate of entropy generation in the heat exchanger.

PS14-2 A two stage compressor operates with an inlet temperature of 27 C and compresses .02 kg/sec of air from 100 kPa to 900kPa. The pressure ratio of the two stages are equal and both stages are isentropic. Air is cooled to the inlet temperature between stages. Determine the power required to operate the compressor. Compare the result with the compression taking place in a single stage.

PS14-3 Air at 100 kPa and 27 C enters the evaporator of a window air conditioner at a flow rate of 6 m^3/min. Refrigerant R134a enters the evaporator at 120 kPa, a quality of .3 and a flow rate of 2 kg/min .The outside surfaces of the air conditioner are insulated. Heat is transferred to the evaporator from the surrounding air at 32 F at a rate of 30 kJ/min. The refrigerant leaves the evaporator as a saturated vapor. Determine the evaporator exit temperature and the entropy generated by the process.

PS14-4 Liquid water enters an open feel water heater at .8 MPa and 35 C and steam enters at .8 MPa and 350 C. The leaving stream is saturated liquid at pressure of .8 MPa. Determine the ratio off the mass flow rates of the water and steam. Determine the rate at which entropy is produced in the feed water heater.

PS14-1



open thermodynamic system

Steady Flow Energy Equation

a) $Q_{\text{lost by oil}} = Q_{\text{gained by water}}$

$$\left(m \times c_p \times \Delta T\right)_{oil} = \left(m \times c_p \times \Delta T\right)_{water}$$

$$10\ \text{kg/sec} \times 2.30 \frac{\text{kJ}}{\text{kg}^o\text{C}} \times \left(170 - T_o\right) =$$

$$4.5\ \text{kg/sec} \times 4.18 \frac{\text{kJ}}{\text{kg}^o\text{C}} \times \left(70 - 20\right)$$

$$T_o = 129.1^O\,C$$

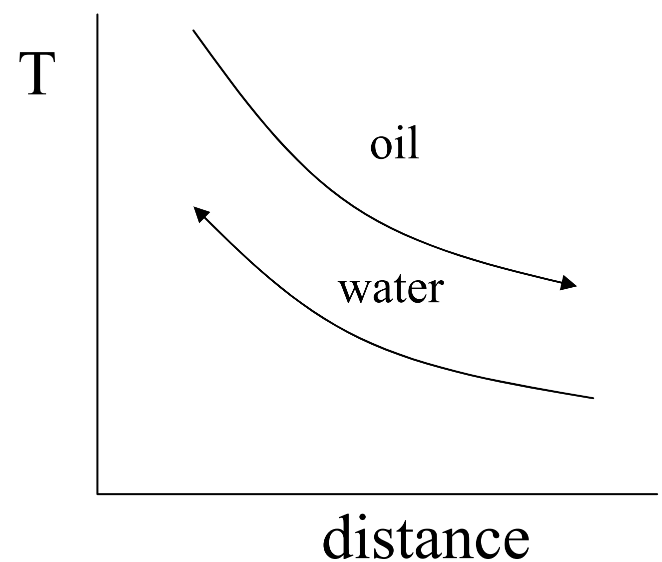
b) $\Delta S = m \times c_p \times \ln\left(\frac{T_2}{T_1}\right)$

$$\Delta S_{water} = 4.5\ \text{kg/sec} \times 4.18 \frac{\text{kJ}}{\text{kg}^o\text{C}} \ln\left(\frac{70 + 273.}{20 + 273.}\right) = 2.9637\ \text{kJ/sec}$$

$$\Delta S_{oil} = 10\ \text{kg/sec} \times 2.3 \frac{\text{kJ}}{\text{kg}^o\text{C}} \ln\left(\frac{129.1 + 273.}{170 + 271}\right) = -2.228\ \text{kJ/sec}$$

$$\Delta S_{generated} = \Delta S_{oil} + \Delta S_{water} = 2.9637 - 2.228$$

$$\Delta S_{generated} = .7357\ \text{kJ/sec}$$



PS14-2

$$p_2 = (p_1 \times p_{r1})$$

$$p_4 = p_3 \times p_{r2}$$

$$p_3 = p_2$$

$$p_4 = (p_1 \times p_{r1}) \times p_{r2}$$

$$\frac{p_4}{p_1} = p_r^2$$

$$p_r = \left(\frac{p_4}{p_1}\right)^{/5} = \left(\frac{900}{100}\right)^{.5} = 3$$

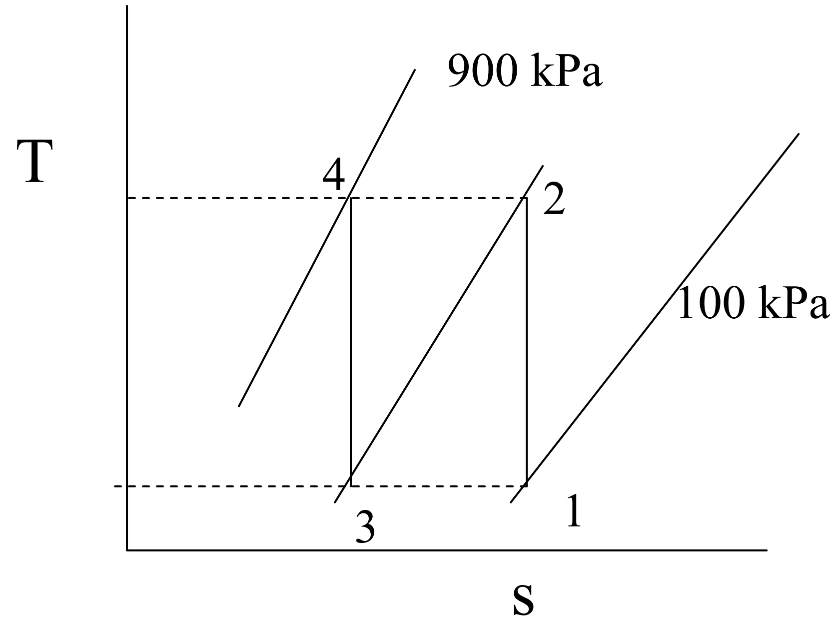
$$W_1 = m \times \Delta h = m \times c_p\left(T_2 - T_1\right)$$

$$W_1 = m \times c_p \times T_1\left(\left(\frac{p_2}{p_1}\right)^{\frac{k-1}{k}} - 1\right)$$

$$W_1 = .02\text{kg/sec} \times 1.005 \times 300^{O}\text{K}\left(3^{.2857} - 1\right)$$

$$W_1 = 2.22 \ \text{kJ/sec}, \ (\text{KW})$$

$$W_{total} = 2 \times 2.22 = 4.44 \ \text{kJ/sec}, \ (\text{KW})$$



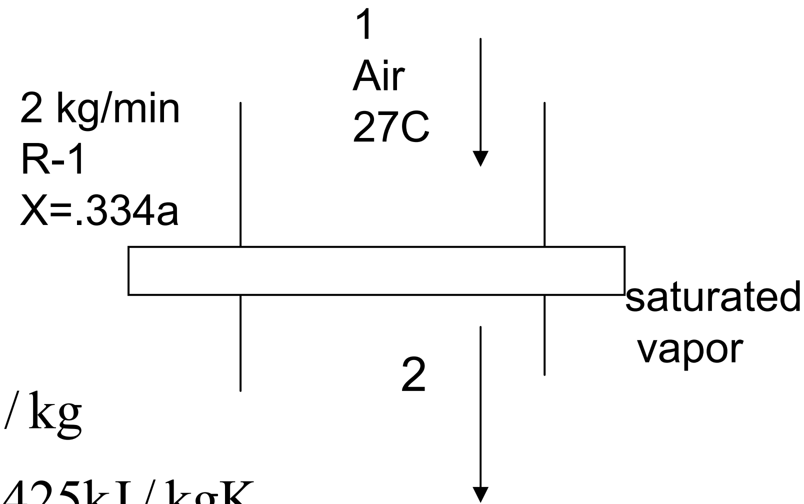
Single Stage

$$W_1 = m \times c_p \times T_1\left(\left(\frac{p_2}{p_1}\right)^{\frac{k-1}{k}} - 1\right)$$

$$W_{single\ stage} = .02 \ \text{kg/sec} \times 1.005 \times 300^{O}\text{K}\left(9^{.2857} - 1\right)$$

$$W_{single\ stage} = 5.267 \ \text{KW}$$

PS14-3



$$m_{air} = \frac{pV}{RT} = \frac{100 \times 6}{.287 \times 300} = 6.969 kg/min$$

$$h_1 = h_f + x \times h_{fg} = 21.32 + .3 \times 212.54 = 85.08 kJ/kg$$

$$s_1 = s_f + x \times s_{fg} = .0897 + .3 \times (.9322 - .0897) = .3425 kJ/kgK$$

a) $Q_{lostbyair} = Q_{gainedbyrefrigerant}$

$$m_a \times c_p \times (T_1 - T_2) = m_{ref} \times \Delta h_{ref}$$

$$T_2 = T_1 - \frac{m_{ref} \times \Delta h_{ref}}{m_a \times c_p} = 300 - \frac{2kg/min \times (233.86 - 85.02)}{6.969 \times 1.005} = 257.52K$$

a) $$\Delta S_{air} = m \times c_p \times \ln\left(\frac{T_2}{T_1}\right) = 6.969 \times 1.005 \times \ln\left(\frac{257.2}{300}\right) = -1.0739 kJ/K$$

$$\Delta S_{ref} = m_{ref} \times (s \quad - s \quad) = 2kg/min \times (.9354 - .3425) = 1.1858 kJ/K$$

$$S_{generated} = \Delta S_{air} + \Delta S_{ref} = -1.0739 kJ/K + 1.1858 kJ/K = .1119 kJ/K$$

PS14-4

@ state point 1

$$m_1 + m_2 = m_3 \quad \text{Mass Balance}$$

$$\frac{m_1}{m_3} + \frac{m_2}{m_3} = 1$$

$$m_1 h_1 + m_2 h_2 = m_3 h_3 \quad \text{Energy Balance}$$

$$\frac{m_1}{m_3} h_1 + \frac{m_2}{m_3} h_2 = h_3$$

$$\left(1 - \frac{m_2}{m_3}\right) h_1 + \frac{m_2}{m_3} h_2 = h_3$$

$$\frac{m_2}{m_3} = \frac{h_3 - h_1}{h_2 - h_1} = \frac{720.87 - 3162.2}{146.64 - 3162.2}$$

$$\frac{m_2}{m_3} = .8096, \quad \frac{m_1}{m_3} = 1 - \frac{m_2}{m_3} = .1904, \quad \frac{m_1}{m_2} = .235$$

$$m_3 = 1\,\text{kg}$$

$$\Delta S = m_1 (s_3 - s_1) + m_2 (s_3 - s_2)$$

$$\Delta S = .1904(2.0457 - 7.4107) + .8096(2.0457 - .5051)$$

$$\Delta S = -1.0215 + 1.2473$$

$$\Delta S = .2258 \ \text{kJ/kg K}$$

2

.8 MPa

35 C

$h_2 = h_f$ @ 35 C

$h_2 = 146.64$ kJ/kg

$s_2 = s_f$ @ 35 C

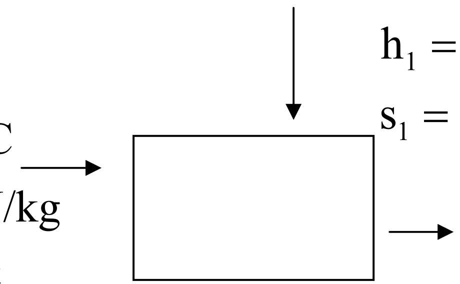
$s_2 = .5051$ kJ/kg K

1

.8 MPa, 350 C

$h_1 = 3162.2$

$s_1 = 7.4107$



3

$p = .8$ MPa

$h_3 = h_f$ @ .8 MPa

$h_3 = 720.87$ kJ/kg

$s_3 = s_f$ @ .8 MPa

$s_3 = 2.0457$ kJ/kgK