

School of Mechanical & Aerospace Engineering
MA3010 – Thermodynamics & Heat Transfer
AY21S1 – Continual Assessment 1

Instructions:

- Please read the questions carefully before answering them.
- There is no need to print this question sheet. Please write your workings and answers neatly on blank or foolscap paper.
- All workings and answers are to be scanned and uploaded before 11:14:59 am.

1. A refrigeration system is solely used to chill drinking water from T_1 to T_2 at a rate of $\dot{m}$ per second. If its COP is COP , calculate the power consumption. Utilize the properties of water at 25°C.

$$\dot{Q}_L = \dot{m}c(T_2 - T_1)$$

$$\dot{W} = \frac{\dot{Q}_L}{COP}$$

2. m of R134a liquid-vapour mixture with x vapour fraction at P_1 is heated to T_2 and P_2 . Calculate the entropy change of R134a.

s_1 = properties at saturation, P_1

s_2 = properties at T_2, P_2

$$s_1 = s_f + x s_{fg}$$

$$\Delta S = m(s_2 - s_1)$$

3. Air at T_1 undergoes an internally reversible three stage polytropic compression process with exponent $n = n$ and its pressure is doubled across each stage. If the total power consumption of the compression process is at a steady rate of $\dot{W}$, determine the mass flow rate of air. An average temperature of 400 K can be assumed.

$$\dot{W} = 3\dot{m} \frac{nRT_1}{n-1} [(2)^{(n-1)/n} - 1]$$

4. A tank is filled with saturated moist air at T and the total pressure in the tank is P . If the mass of water vapour in the tank is m_v , calculate the mass of dry air.

$P_g = P_{sat} @ T$

$$\omega = \frac{0.622\phi P_g}{P - \phi P_g}$$

$$m_a = \frac{m_v}{\omega}$$

5. A Carnot heat engine has a thermal efficiency of η while operating between two thermal energy reservoirs. The heat engine is now reversed and used as a refrigerator while keeping the same operating conditions. Determine the COP of the refrigerator.

$$\eta_{TH} = 1 - \frac{T_L}{T_H}$$

$$\frac{T_L}{T_H} = 1 - \eta_{TH}$$

$$COP_R = \frac{1}{T_H/T_L - 1}$$

6. A V ml cup of cold water initially at T_1 is left in large room at T_2 . Determine the total entropy generation after it has reached thermal equilibrium. Utilize the properties of liquid water at 0°C .

$$m = \rho V$$

$$Q = mc(T_2 - T_1)$$

$$S_{gen} = mc \ln \frac{T_2}{T_1} + \frac{(-Q)}{T_{sur}}$$

7. Nitrogen is compressed steadily at a rate of $\dot{m}$ by an adiabatic compressor from P_1 and T_1 to P_2 . If the compressor consumes $\dot{W}$ of power during operation, calculate its isentropic efficiency. Assume an average temperature of 350 K.

$$T_{2s} = T_1 \left(\frac{P_2}{P_1} \right)^{\frac{(k-1)}{k}}$$

$$\eta_c = \frac{\dot{m}c_p(T_{2s} - T_1)}{\dot{W}}$$

8. A gas mixture of oxygen, nitrogen, and hydrogen at 100 kPa is cooled at constant volume from T_1 to T_2 . The gravimetric analysis of the mixture is mf_o oxygen, mf_N nitrogen and mf_H hydrogen. Calculate the entropy change per unit mass of the mixture.

Gravimetric analysis = mass fraction

$$\Delta S = mf_o c_{v,o} \ln \frac{T_2}{T_1} + mf_N c_{v,N} \ln \frac{T_2}{T_1} + mf_H c_{v,H} \ln \frac{T_2}{T_1}$$