AUIS ENGR 352 (Thermodynamics), Section 1, Course Assignment 5

Deadline:[1] November 23, 2017

Tutorial Discussion: November 28, 2017

1) A **refrigerator**[2] operating with the working fluid **R134a** keeps the refrigerated space at a temperature of –35 °C. In the condenser of the refrigerator, heat is transferred from the working fluid to **cooling water**, which enters the condenser at 18 °C and leaves it at 26 °C. The mass flow rate of the water is 250 g s^{-1}. R134a enters the condenser at 1.2 MPa and 50°C and leaves it at the same pressure as a liquid, with a temperature 5 K below the boiling point at that pressure. If the refrigerator has a power consumption of 3.3 kW, determine

- **(a)** the mass flow rate of the working fluid;
- **(b)** the cooling capacity of the refrigerator;
- **(c)** the coefficient of performance;
- **(d)** the minimum theoretical power input for a refrigerator operating between the same temperatures with the same cooling capacity.

2) Saturated **R134a vapor** at a pressure of 140 kPa enters a **compressor**,[3] which operates under stationary conditions, with a mass flow rate of 106 g s^{-1}; it leaves the compressor at a pressure of 1.4 MPa. During the compression, which is <u>not adiabatic</u>, heat is transferred to the surroundings at a rate of 400 W. Determine the **power input of the compressor**.

3) Two equal masses of **argon and nitrogen**, $m(\mathrm{Ar}) = m(\mathrm{N_2}) = 10$ g, which are initially separated from each other at the same temperature T = 250 K and pressure p = 40 kPa, undergo an adiabatic and isochoric mixing process by which they combine to form an **ideal mixture of ideal gases**. Determine the **change of Helmholtz free energy** $A = U - TS$ during this process.

4) At steady state, a **power cycle** receives energy by heat transfer at a temperature of 463 °C and discharges energy by heat transfer to a river.[4] Upstream of the power plant, the river has a volume flow rate of 67.87 m^3 s^{-1} and a temperature of 20 °C. From environmental considerations, the river temperature (downstream of the plant) may not exceed 22 °C. Determine the **maximum theoretical technical power output** of the cycle under these conditions.

5) The **specific entropy of a pure ideal gas** is given by the differential form of the Sackur-Tetrode equation, i.e., $ds = Rv^{-1}\,dv + c_v T^{-1}\,dT$, wherein $v^{-1}\,dv$ can also be written as $d \ln v$ and $T^{-1}\,dT$ can also be written as $d \ln T$. Since it relates ds to dv and dT, this is a total differential for $s(v, T)$ as a function of v and T. However, s can be given as a function of any combination of two intensive quantities, e.g., pressure and enthalpy. Based on general relations between the properties of ideal gases, **give a total differential for $s(p, h)$**, relating ds to dp and dh.

---

1 *Each problem contributes 0.5% to the overall grade. Submissions, individually or in groups of two, can be handed in on November 23 (after, <u>not during</u> the lecture), or deposited in the B-F2-01 mailbox <u>by November 22</u>. Note that it may be necessary to* **look up thermodynamic properties** *(NIST website, books, or other sources).*

2 *This is "Problem I" from the Selected Literature Problems, i.e., Problem 6–97 from Çengel and Boles.*

3 *This is "Problem L" from the Selected Literature Problems, i.e., Problem 4.45 from Moran, Shapiro, et al.*

4 *This is "Problem J" from the Selected Literature Problems, i.e., Problem 5.29 from Moran, Shapiro, et al.*