

CHE 260 – Thermodynamics and Heat Transfer

Mid-Term Exam – 2010

You have 110 minutes to do the following five problems. You may use any type of non-communicating calculator. All questions are worth equal marks.

- 1) Air at a pressure of 150 kPa and with a volume of 1 L is contained in a piston-cylinder system where the piston is spring-loaded so that the pressure (P) varies linearly with volume (V) as $P = A + BV$, where A and B are constants. The gas is heated by adding 1 kJ of heat so that its volume increases to 1.5 L and the pressure increases to 800 kPa. Find the change in internal energy of the air during this process.
- 2) Nitrogen gas entering a nozzle at 500 kPa, 200°C and with a velocity of 10 m/s is to be accelerated to a velocity of 300 m/s. Determine the required exit pressure and cross-sectional area of the nozzle if the mass flow rate is 0.15 kg/s. Assume nitrogen is an ideal gas with $R=0.2968$ kJ/kgK, $c_p=1.042$ kJ/kgK, $\gamma=1.4$.
- 3) A rigid container is divided by a wall into two equal-sized compartments, each 1 m³ in volume. One is filled with a saturated water – steam mixture at 200 kPa with a quality of 0.8. The other contains steam at 2 MPa and a temperature of 400°C. The partition wall is removed and the water and steam are allowed to mix and lose heat to the surroundings until the system reaches a uniform state where its pressure is 1 MPa. Find the final temperature and the heat lost to the surroundings.
- 4) A 2 kg mass of ethane gas at 500 kPa and 100°C in a piston-cylinder system loses heat to the surrounding atmosphere at 20°C while undergoing a reversible expansion during which $Pv^{1.3}=\text{constant}$. The final gas temperature is 20°C. Calculate the total entropy generated during this process. Assume ethane is an ideal gas with $c_p=1.766$ kJ/kgK, $c_v=1.490$ kJ/kgK, $R=0.276$ kJ/kgK.
- 5) An adiabatic steam turbine operates with inlet steam conditions of 400°C, 2 MPa and a measured outlet condition of 10 kPa, $x=0.95$.
 - a. How much work per unit mass of steam will this turbine produce?
 - b. If the turbine were reversible how much work could it produce for an outlet pressure of 10 kPa?