

MECH-341 Thermo 2

FINAL EXAM

Friday, December 12, 2008, 2:00 pm – 5:00 pm

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Note:

- This is a **CLOSED BOOK** examination.
- Tables from Cengel & Boles, *Thermodynamics*, 6th ed. provided.
- 6 problems total. The value of each problem is given in left margin.
- This examination paper may be kept (does not need to be handed in).
- You are permitted translation dictionary.
- Faculty standard calculator permitted only.
- This examination is printed on both sides.

20 pts. 1. The ideal Diesel cycle consists of the following steps:

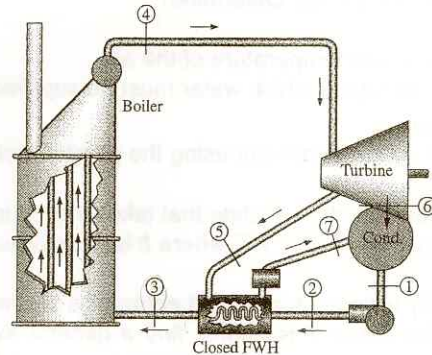
- 1 → 2 Isentropic compression
- 2 → 3 Constant pressure heat addition
- 3 → 4 Isentropic expansion
- 4 → 1 Constant volume heat rejection

For this particular problem, the compression ratio (V_1/V_2) is 18 and the cut-off ratio (V_3/V_2) is 1.5. The initial state of the air before compression is 100 kPa and 300 K. Find the thermal efficiency of this cycle η assuming...

- Constant specific heats at their room temperature values $c_p = 1.005$ kJ/kg-K, $c_v = 0.718$ kJ/kg-K, $k = c_p/c_v = 1.4$ (i.e., cold air standard analysis)
- Variable specific heats in the form of tabulated data (air standard analysis)
- Draw and label all states and processes on P - v and T - s diagrams.

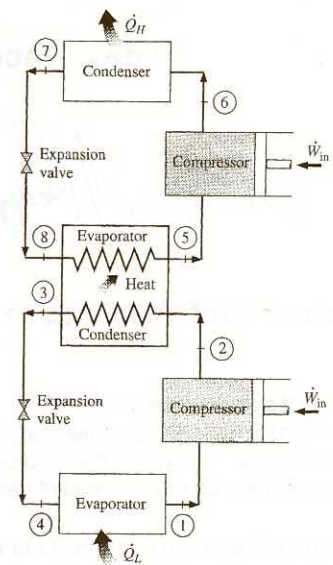
20 pts. 2. Consider a powerplant that operates on the Rankine cycle with regeneration using a closed feedwater heater. The plant maintains the turbine inlet at 3000 kPa and 350 °C. The condenser operates at 20 kPa. Steam is extracted at 1000 kPa for use in the closed feedwater heater, which discharges into the condenser after being throttled to the condenser pressure.

- Find the thermodynamic state for stations 1 – 7 and complete a table giving the values of pressure, temperature, enthalpy, etc. required to complete parts (c) and (d) below.



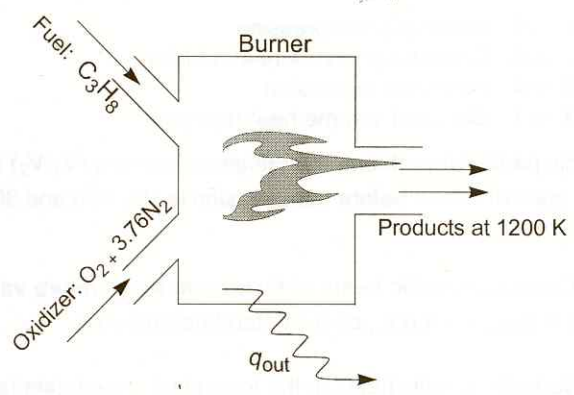
- Draw and label all states (1 – 7) on a T - s diagram.
- Compute the turbine work output and pump work input per kg of steam exiting the boiler.
- Find the thermal efficiency η of the cycle.

15 pts. 3. Consider a two-stage cascade refrigeration system operating between the pressures of 1.2 MPa and 200 kPa with R-134a as the working fluid. The heat rejection from the lower cycle to the upper cycle takes place in an adiabatic counterflow heat exchanger where the pressures in the upper and lower cycles are 0.4 MPa and 0.5 MPa, respectively. In both cycles the refrigerant is a saturated liquid at the condenser exit and a saturated vapor at the compressor inlet. The compressors are assumed isentropic (100% efficient). If the mass flow rate in the lower cycle is 0.15 kg/s, determine:



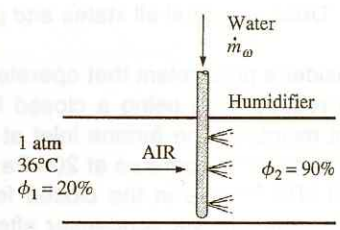
- The mass flow rate of the upper cycle
- The overall coefficient of performance (COP) of the entire (combined) cycle
- Draw the cycle on a T - s diagram and label all states.

15 pts. 4. ^{Gas} Liquid propane (C_3H_8) enters a combustion chamber at 298 K at a rate of 1.2 kg/min, where it is mixed and burned with a stoichiometric mixture of air that enters the chamber also at 298 K. If the combustion is complete (no dissociation) and the temperature of the products is 1200 K, determine:



- The mass flow rate of the air [kg/min].
- The rate of heat transfer out of the combustion chamber [kW].

15 pts. 5. Air enters an evaporative cooler at 1 atm, 36°C and 20% relative humidity and leaves with a relative humidity of 90%. The water is supplied at 20 °C. Determine:



- The exit temperature of the air
- The rate at which water must be supplied, as kg- H_2O per kg-dry-air.
- Verify your answer using the psychrometric chart.

15 pts. 6. A simple equation of state that takes the volume of molecules into account is the **Abel-Nobel equation of state**: $P(v - b) = RT$, where b is the covolume term.

- By taking enthalpy and entropy as a function of pressure and temperature $h(T,p)$, $s(T,p)$ and using the Maxwell relations, find a general expression for the change of enthalpy and entropy for an **isothermal process** between pressure P_1 and P_2 . How do these expressions compare to Δh and Δs for an ideal gas?
- When in the liquid state, the atoms or molecules of a substance are in direct contact, with no empty space in between. Knowing that the density of liquid Helium (molecular weight = 2) is 0.125 kg/L, estimate the value of b [units: m^3/kg] for use in the Abel-Nobel equation for gaseous helium.