ME 417.3 – THERMODYNAMICS II

Department of Mechanical Engineering
University of Saskatchewan

Midterm Exam

Wednesday, October 18, 2006, 11:30 a.m. – 1:30 p.m.

Instructor: Prof. David Sumner

PLEASE READ CAREFULLY:

This exam has 3 pages. The exam is closed book. You may use a scientific calculator. Some equations and other information are found below. A booklet of Thermodynamic Property Tables will be provided for your use during the exam; the booklet and the exam question sheets must be returned at the end of the exam. No other aids are permitted.

There are 3 problems on the exam worth a total of 120 marks. Attempt all 3 problems.

Please ensure that your answers are clear and legible.

The gas constant for air is $R = 287$ J/kgK.

$$\Delta \text{KE} + \Delta \text{PE} + \Delta U = Q - W$$

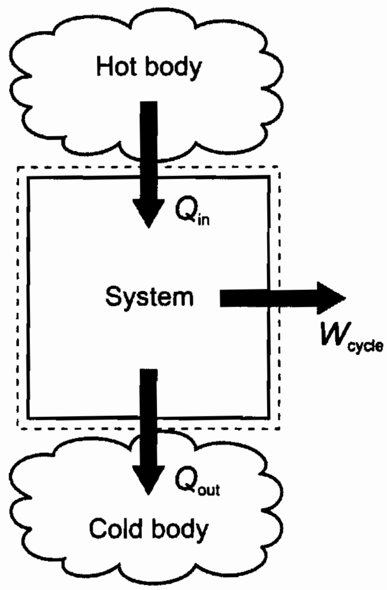
$$\frac{dE_{cv}}{dt} = \dot{Q}_{cv} - \dot{W}_{cv} + \sum_i \dot{m}_i \left(h_i + \frac{V_i^2}{2} + gz_i \right) - \sum_e \dot{m}_e \left(h_e + \frac{V_e^2}{2} + gz_e \right)$$

$$Tds = du + Pdv$$

$$Tds = dh - vdP$$

Problem 1 (30 marks)

5 a. For a power cycle operating between two thermal reservoirs (hot and cold bodies, as depicted in the figure below), the heat transfers are Q_{in} = 50 kJ and Q_{out} = 35 kJ. Determine the net work produced by the cycle and the thermal efficiency.



5 b. Define the following terms related to reciprocating engines: stroke, bore, top dead centre, displacement volume, and compression ratio.

5 c. What simplifications are introduced in "air-standard analysis" compared to the events occurring within the cylinders of actual internal combustion engines?

5 d Why are high compression ratios not used in spark-ignition engines?

5 e In a gas-turbine engine, where is the maximum temperature encountered? What limits the maximum temperature that can be attained in these engines?

5 f. A gas-turbine engine is modeled as an air-standard Brayton cycle. With the aid of a clearly labeled *T-s* diagram, explain the purpose of using a two-stage turbine with a reheat combustor. Why might it be advisable to add a regenerator to this configuration also?

Problem 2 (40 marks)

Consider an air-standard Otto cycle with a compression ratio of $r = 8$. At the beginning of the compression process, $P_1 = 100$ kPa and $T_1 = 290$ K. During the constant-volume heat-addition process, 800 kJ/kg of heat is transferred to the air.

5 a. Sketch the *P-v* diagram for the air-standard Otto cycle and label the four processes that make up the cycle.

20 b. Using Table A-22 (in the booklet of Thermodynamics Property Tables provided) and the information given above, determine the properties P (in kPa), T (in K), v (in m^3/kg), and u (in kJ/kg) at each of the four states.

5 c. Calculate the net work per unit mass of air (in kJ/kg).

5 d. Calculate the thermal efficiency.

5 e. Calculate the mean effective pressure (in kPa).

Problem 3 (50 marks)

A gas-turbine engine operates as an ideal air-standard Brayton cycle with a compressor pressure ratio of 8. At the compressor inlet, the air temperature is 300 K and the pressure is 100 kPa. At the turbine entrance, the air temperature is 1300 K. The mass flow rate is 0.5 kg/s.

5 a. Sketch the *T-s* diagram for the ideal air-standard Brayton cycle and label the four processes that make up the cycle.

20 b. Using Table A-22 (in the booklet of Thermodynamics Property Tables provided) and the information given above, determine the properties P (in kPa), T (in K), and h (in kJ/kg) at each of the four states.

5 c. Calculate the net power developed (in kW).

5 d. Calculate the thermal efficiency.

5 e. Calculate the back work ratio.

10 f. Now consider the same air-standard Brayton cycle, but with a compressor isentropic efficiency of 80%, and a turbine isentropic efficiency of 85%. Calculate the thermal efficiency and back work ratio, and compare the results to those obtained in parts (d.) and (e.) above, respectively.