CARLETON UNIVERSITY

Final
EXAMINATION
December 12, 2000

DURATION: 3 HOURS

No. of Students: **65+95**

Department Name & Course Number: **Mechanical & Aerospace Engineering 86.240A & 86.240B**
Instructor(s) **Dr L. Fernandes, Professor J.E.D. Gauthier**

AUTHORIZED MEMORANDA
Open Book, any calculator permitted

Students **MUST** count the number of pages in this examination question paper **before** beginning to write, and report any discrepancy immediately to a proctor. This question paper has **2** pages.
This examination question paper **MAY** be taken from the examination room.

Attempt all questions.
All questions are of equal value.

1. In a vapour-compression refrigeration unit using refrigerant R134a, the condenser temperature is 25°C and the evaporator temperature is -10°C. Saturated liquid enters the expansion valve, and dry saturated vapour enters the compressor, which has an efficiency of 80%. For a refrigeration effect of 3.5 kW, find

   a) the flow rate of refrigerant in kg/s; and

   b) the power input.

2. Refrigerant R134a is the working fluid in a solar power plant operating in a Rankine cycle. Saturated vapour at 60°C enters the turbine. The fluid leaves the condenser at a pressure of 6 bars, as a saturated liquid.

   a) Draw a sketch of the T-s diagram indicating the Rankine cycle;

   b) Find the specific work (kJ/kg) extracted by the turbine;

   c) Find the specific work (kJ/kg) supplied to the pump;

   d) Find the overall thermal efficiency of the cycle; and

   e) If the solar collector is absorbing 0.4 kW per m^2 of collector surface, find the minimum possible collector area in m^2 per kW of power developed by the plant.

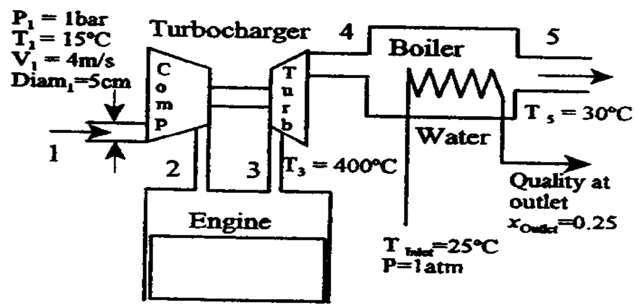
3. a) An Otto cycle operates with a compression ratio of 9 and a maximum temperature of 2500°C. The cycle begins at 15°C and 1 atm. Find the efficiency of the cycle.

b) In a spark ignition engine, working fluid can escape into the crankcase across the gaps between the piston, piston rings, and cylinder walls. This phenomena is called blowby. To assess the impact of blowby on engine performance, consider the following scenario. For the Otto cycle in a), assume that 10% of the mass in the cylinder escapes to the crankcase. For sake of simplicity, assume that the blowby occurs adiabatically and reversibly at the end of the compression stroke. Hence, this modified Otto cycle consists of 5 reversible processes:

1⇒2 Adiabatic compression while the piston travels from BDC to TDC
2⇒2' Blowby or adiabatic mass loss while the piston is at TDC
2'⇒3 Heat addition while the piston is at TDC
3⇒4 Adiabatic expansion while the piston travels from TDC to BDC
4⇒1 Heat removal while the piston is at BDC

Find the efficiency of the cycle.

4. A turbo-charged engine sketch is shown on the figure. The turbine shaft power is used exclusively to drive the compressor. The pressure ratio across the compressor is 2.5:1 and across the turbine 2.1:1. The isentropic efficiency of the compressor is 100%. Assume that C_p=1.005 kJ/kg·K and k=1.4. Find:



a) the mass flow of air in kg/h;

b) the shaft power available from the turbine in kW. (Neglect mechanical losses);

c) the isentropic efficiency of the turbine; and

d) the mass flow of water heated in the boiler in kg/s.

5. Consider a flat metal wall of thickness equal to 2 cm separating a hot (combusting) ambient at temperature equal to 1000°C from a coolant at temperature equal to 300°C. In addition to convection, include the effect of radiation on both sides. Assume that the wall behaves as a blackbody and that the heat transfer coefficient is 100 W/m²·K on both sides of the wall, that the thermal conductivity of the wall is 40 W/m·K and that temperature on the hot side of the wall is 800°C.

a) Find the rate of heat transfer across the wall in kW/m².

b) The temperature on the cold side of the wall.

Bonus problem for up to 10% extra marks

6. Hand in Assignment 9.7. No photocopy accepted.