

CARLETON UNIVERSITY

FINAL
EXAMINATION
December 9, 2003

DURATION: 3 HOURS

No. of Students: 100+78

Department Name & Course Number: **Mechanical & Aerospace Engineering MAAE 2400
Thermodynamics and Heat Transfer - Sections A and B**
Instructors: **Profs. T. Kaya and J. Gu**

AUTHORIZED MEMORANDA

Open book, Open Notes, Calculators are 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.

Important Notes:

- a) There are five (5) questions. Attempt all the questions.
- b) Questions have different values as indicated.

QUESTION 1 (25 POINTS) Water vapour at 300 kPa and 280°C and liquid water at 300 kPa and 20°C are mixed in a chamber. Liquid water enters the chamber with a mass flux rate of 2.5 kg/s, and vapour enters the chamber with a mass flux rate of 0.2 kg/s. The mixture leaves the chamber at 300kPa and 60°C. During this process, the chamber loses heat to the surrounding air at 20°C.

- (a) Calculate the energy transferred by heat from the chamber to the surroundings.
- (b) Calculate the rate of ~~energy~~ ^{energy} generation during the mixing process. Explain briefly the meaning of your result if the sign is positive or negative.

QUESTION 2 (25 POINTS) An air-conditioning system uses Refrigerant 134a as working fluid which enters the compressor as superheated vapour at 0.14 MPa and -10°C at a rate of 0.06 kg/s and leaves at 0.8 MPa and 50°C. The refrigerant is cooled in the condenser to 26°C and 0.72 MPa and is throttled to 0.15 MPa. Disregarding pressure drops in the connecting lines between the components, determine

- (a) the rate of heat removal from the air-conditioned space (cooling capacity) and the power input to the compressor,
- (b) the isentropic efficiency of the compressor,
- (c) the coefficient of performance (COP) of this air-conditioning system.
- (d) Show schematically the cycle on a T-s diagram.

QUESTION 3 (20 POINTS) Consider a power plant operating on an ideal Brayton cycle with a pressure ratio of 8. The gas temperature is 303 K at the compressor inlet and 1273 K at the turbine inlet. Utilizing the air-standard analysis, determine

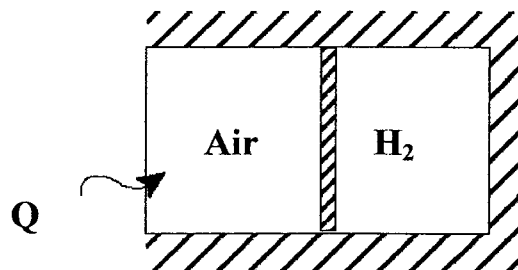
- (a) the gas temperature at the exits of the compressor and the turbine,
- (b) the back work ratio,
- (c) the thermal efficiency of the cycle.

QUESTION 4 (20 POINTS) A thermometer is placed in a 50 cm square duct to measure the temperature of an air stream. When the walls of the duct are at 35°C, the thermometer records a temperature of 50°C. The thermometer can be considered a 3-mm diameter sphere with an emissivity of 0.85. The convective heat transfer between the thermometer and the air stream is 30 W/m² K.

- a) Calculate the temperature of the air stream.
- b) Briefly explain why there is a difference between the temperature of the air stream and thermometer.

QUESTION 5 (10 POINTS) The two chambers shown in the figure initially have equal volumes of 28 liters and contain air and hydrogen, respectively. The chambers are separated by a frictionless, insulated piston. Both gases are initially at 140 kPa and 40°C. Heat is added to the air side until the pressure of both gases reaches 280 kPa. All outside walls are insulated except for the surface where heat is added to the air. For the pressure and temperature ranges in question, both gases approximate ideal gas behaviour. Determine,

- a) the final temperature of the air and the hydrogen,
- b) the amount of heat transferred to the air,
- c) the amount of work done on the hydrogen,
- d) the entropy change for the air and the hydrogen in kJ/K.



For hydrogen use:

$$k = 1.409$$

$$R = 4.1243 \text{ kJ/kgK}$$

$$C_v = 10.0849 \text{ kJ/kgK}$$

$$C_p = 14.209 \text{ kJ/kgK}$$

NOTE: Question 5 is from the problem assignment set 7. DO NOT attach a separate sheet with your solution. Show your answer on the Examination Booklet.