C A R L E T O N U N I V E R S I T Y

FINAL
EXAMINATION
April 28, 2004

DURATION: 3 HOURS No. of Students: 122

Department Name & Course Number: **Mechanical & Aerospace Engineering MAAE 2400 Thermodynamics and Heat Transfer**
Instructors: **T. Kaya**

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 **3** 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 the same values as indicated.

QUESTION 1 (20 POINTS) Consider an ideal Rankine cycle using water as the working fluid. The pressure and temperature at the turbine inlet are 1200 lbf/in^2 and 1000^{O}F, respectively. The condenser pressure is 1 lbf/in.^{2}. The water exits the condenser as saturated liquid. The mass flow rate of the cycle is given as 0.5x10^6 lb/h.

a) Determine the net power developed by the cycle in Btu/h,
b) Determine the thermal efficiency of the cycle,
c) Which state is the most desirable for the cycle at the exit of the condenser: compressed liquid, saturated liquid or saturated mixture? Explain briefly why.

ANS. 2.92x10^8 Btu/h, 0.41

QUESTION 2 (20 POINTS) A refrigerator uses R-134a as the working fluid and operates on an ideal vapour-compression refrigeration cycle between 0.12 and 0.8 MPa. The throttling valve in this cycle is replaced by an isentropic turbine to produce some useful work. The working fluid enters compressor as saturated vapor and it enters turbine as saturated liquid. The mass flow rate of the refrigerant is 0.05 kg/s. The pressure drops in the connecting lines are negligible, determine

a) the rate of heat removal from the refrigerated space,
b) the power input to the compressor and power generated by the turbine,
c) the rate of heat rejection to the environment,
d) the coefficient of performance (COP) of this refrigerator.

ANS. 7.392 kW, 1.959 kW, 0.37 kW, 3.77

QUESTION 3 (20 POINTS) Consider an air-standard Otto cycle with a volumetric compression ratio of 9. The lowest temperature of this cycle is 22^{O}C and the highest temperature of this cycle is 767^{O}C. At the beginning of compression process, the pressure inside the cylinder is 100 kPa. The mass of air inside the cylinder is $5x10^{-3}$ kg, determine

a) the heat added to the cylinder and show the area on a T-s diagram,
b) the heat rejected from the cylinder and show the area on a T-s diagram,
c) the net work and show the area on a T-s diagram,
d) the thermal efficiency of this cycle.

NOTE: The specific heats are not constant.

ANS. 1.445 kJ, 0.6342 kJ, 0.8105 kJ, 0.56

QUESTION 4 (20 POINTS) An insulated tank contains 0.4 m^3 of saturated water vapor at 500 kPa. This tank is connected to an initially evacuated (initially empty) and insulated piston-cylinder device as shown in Fig. 1. The pressure required to raise the piston is 150 kPa. The valve opens and part of the steam flows into the cylinder, raising the piston. This process continues until the pressure inside the tank drops to 150 kPa. If the steam inside the tank undergoes a reversible and adiabatic process, determine

a) the final temperature inside the tank,
b) the final mass inside the tank and inside the piston-cylinder device,
c) the final temperature inside the piston-cylinder device by using the first law of thermodynamics.

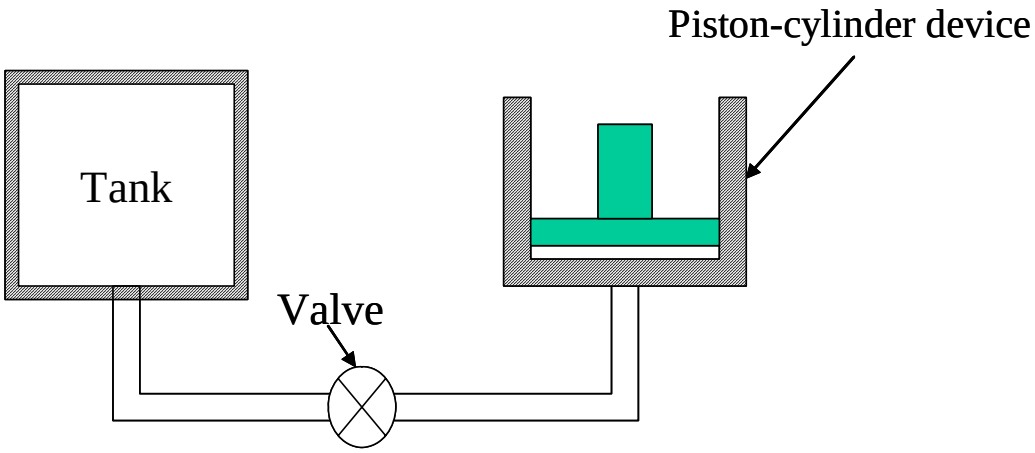

Figure 1

NOTE: The pressure drops in the connecting line and valve are negligible. The lines are perfectly insulated and their volume is negligible.

ANS. 111.37 C, 0.371 kg(tank), 0.696 kg(piston-cylinder), 111.37 C

QUESTION 5 (20 POINTS) The emissivity of a horizontal roof of a building is 0.8. The thermal conductivity of the roof material is 10 W/mK and the thickness of the roof is 10 cm. The convective heat transfer coefficient between the roof and outside air is 12 W/m^2K, and between the roof and air inside the building is 8 W/m^2K.

a) The measurements indicated that when the air temperature inside the building is 20^OC , the temperature of the inner surface of the roof is 10.74^OC. If the effective temperature of the night sky as a black body is 0^OC, determine the temperature of the outside air in (^OC).
b) What is the rate of heat loss per area by convection from the roof top to the outside air?
c) Show schematically the temperature distribution from the inside of the building to the outside air and indicate the corresponding temperature values on your drawing.

ANS. 7.076 C, 35.085 W/m^2