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CARLETON UNIVERSITY

FINAL
EXAMINATION
April 8, 2009

DURATION: 3 HOURS No. of Students: 90+80

Department: **Mechanical & Aerospace Engineering**
Course: **MAAE 2400 Thermodynamics and Heat Transfer Sections B and C**
Instructors: T. Kaya and M. G. Mwaba

AUTHORIZED MEMORANDA
Open book, Open Notes, Hand 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.

BookLETS.

Important Notes:

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

QUESTION 1 (10 POINTS) An air-standard Otto cycle has a compression ratio of 10. At the beginning of the compression, the pressure, temperature and volume are 14.7 lbf/in^2, 90^{o}F, 0.0196 ft^3, respectively. The maximum pressure in the cycle is 1000 lbf/in^2. Using a cold-air standard analysis with k=1.4, calculate the power developed by the engine in Btu for one cycle.

QUESTION 2 (25 POINTS) A steam power plant operating on a reheat Rankine cycle has a net power output of 150 MW. Steam enters the high-pressure turbine at 10 MPa and 500^{o}C (**State 1**) and expands to 1 MPa (**State 2**). It is then reheated and enters the low-pressure turbine at 500^{o}C (**State 3**) where it is expanded to a pressure of 10 kPa (**State 4**). Steam leaves the condenser as a saturated liquid (**State 5**). The isentropic efficiency of both turbines is 80%, and that of the pump is 95%.

a) Show the cycle on a T-*s* diagram with respect to saturation lines.
b) Determine:
  i) pump work input.
  ii) enthalpy of the steam at exit of the low-pressure turbine and state the condition of the steam.
  iii) thermal efficiency of the cycle.
  iv) mass flow rate of the steam.

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QUESTION 3 (20 POINTS) Refrigerant-134a enters the compressor of a refrigerator as superheated vapour at pressure of 180 kPa, temperature -10°C and mass flow rate of 0.04 kg/s. It leaves the compressor at pressure and temperature of 700 kPa and 50°C, respectively. The refrigerant is cooled in the condenser to 24°C. Thereafter, the refrigerant is expanded to the compressor pressure.

a) show the cycle on a T-*s* diagram, clearly labelling the state points and pressures.
b) calculate the quality of the refrigerant at the end of the throttling process.
c) determine the rate of heat removal from the refrigerated space, and the power input to the compressor.
d) what is the isentropic efficiency of the compressor?
e) what is the COP of the refrigerator?

QUESTION 4 (25 POINTS) A 1 m^3 rigid and uninsulated tank contains air inside at 270 K and 100 kPa. A 300-W electric heater placed in the tank is turned on and kept on for 60 min. After this, the air pressure is measured to be 200 kPa. Assuming that the surrounding temperature is 300 K, determine

a) the final temperature of air in K,
b) the *net* amount of heat transferred from the tank to surroundings in J.
c) the entropy generation during this process in J/K.
d) What is the reason for entropy production?

Note: Air behaves as an ideal gas with constant specific heats and the kinetic and potential energy changes are negligible.
(Air constants: R= 287 J/kgK; c_v= 718 J/kgK; c_p= 1005 J/kgK).

QUESTION 5 (20 POINTS) Consider a room heater in the form a very thin vertical panel 1 m long and 0.5 m high. The air is allowed to circulate freely on both sides of the heater. The heater is generating a power of 1000 W. When the room temperature is maintained at 24°C, the heater surface temperature reaches at a temperature of 75°C. The emissivity of the heater surface is 0.9.

a) Write down the governing equation for this problem based on the heat exchange between the heater and surroundings.
b) Calculate the convection heat transfer coefficient from the heater surface to ambient air in W/m^2 K.
c) What do you say about the type of convection process?
d) List two important assumptions used in solving this problem.