NATIONAL EXAMINATIONS MAY 2018

16-Mec-A1 Applied Thermodynamics and Heat Transfer

3 Hours Duration

Notes :

1. If doubt exists concerning the interpretation of any question, the candidate is urged to make assumptions and clearly explain what has been assumed along with the answer to the question.

2. The examination is open book. As a consequence, candidates are permitted to make use of any textbooks, references or notes.

3. Any non-communicating calculator is permitted. However, candidates must indicate the type of calculator(s) that they have used by writing the name and model designation of the calculator(s) on the inside of the cover of the first examination book.

4. It is expected that each candidate will have copies of both a thermodynamics text and a heat transfer text in order to make use of the information presented in the tables and graphs contained.

5. The answers to five questions, either three questions from Part A and two questions from Part B or two questions from Part A and three questions from Part B, comprise a complete examination.

6. Candidates must indicate the answers that they wish to have graded on the cover of the first examination book. Otherwise the answers will be graded in the order in which they appear in the examination book(s) up to a maximum of three answers per section .

7. The answer to any question carries the same value in the grading .

Continued on Page 2

Continued on Page 2

PART A - THERMODYNAMICS

1. (a) The table below gives data for a system undergoing a thermodynamic cycle consisting of four processes in series. Potential energy and kinetic energy effects are to be neglected in the analysis. Determine the missing entries in the table and whether the cycle is a power cycle or a refrigeration cycle.

Process	ΔU	Q	W
1-2			-610 kJ
2-3	670 kJ		230 kJ
3-4		0	920 kJ
4-1	-360 kJ		0

(b) A closed rigid container V = 0.5 m^3 in volume initially containing a two phase mixture of saturated liquid water and saturated water vapour at a pressure of P_1 = 1 bar with a quality X = 0.5 is placed on a hot plate. After heating, the pressure P_2 = 1.5 bar. Indicate the initial and final states on a temperature / specific volume diagram and determine the temperature and mass of vapour present at each state. What would the pressure P_3 be in the container if the heating were continued until only water vapour were contained in the container ?

2. In an ideal regenerative steam cycle with a single closed feedwater heater, steam enters the turbine at 4.0 MPa, 325°C. The condenser pressure is 15.0 kPa. Steam is extracted at 0.7 MPa to heat the water passing through the feedwater heater, leaving the feedwater heater at the temperature of the condensing steam. Condensate from the feedwater heater drains through a trap to the condenser.

(a) Show the various states of the cycle on a temperature entropy diagram.

(b) Calculate the fraction of mass flowrate extracted, the net work done per unit mass of steam entering the turbine and the thermal efficiency of the cycle.

3. (a) A large diesel engine operates with a compression ratio of 14:1 and a cutoff ratio of 2.0. Assuming isentropic compression and expansion, determine the work output per unit mass and the efficiency of the cycle if the inlet temperature and pressure of the air are 20°C and 1 atmosphere respectively.

(b) The diesel engine produces 3.750 kW. Assuming an air/fuel ratio of 16:1 and a heating value of 4.65 kJ/kg for the fuel being used, determine the fuel consumption rate required to produce the power output stated above. Show the diesel cycle on a properly labelled temperature / entropy diagram.

4. A large centrifugal air compressor handles 9.1 kg/s and compresses it from 100 kPa and 15°C with an inlet velocity of 110 m/s to discharge pressure with an outlet velocity of 90 m/s. The compression ratio is 4:1 and the compressor has an isentropic efficiency of 80 %. Determine (a) the outlet pressure (b) the outlet temperature and (c) the power required to drive the compressor.

Continued on Page 3

PART B - HEAT TRANSFER

5. Heat is generated uniformly at the rate of $q''' = 50\ W/cm^3$ in a long wire $r_{wire} = 0.2$ cm having thermal conductivity $k_{wire} = 15\ W/m°C$. The wire is sheathed in a $\delta_{ceramic} = 0.5$ cm thick layer of ceramic material having thermal conductivity $k_{ceramic} = 1.2\ W/m°C$. The ceramic insulated wire is located in quiescent air at T = 20°C and the heat transfer coefficient at the ceramic surface h = 50 W/m °C. Determine the temperature $T_{interface}$ at the interface between the wire and the ceramic and at the temperature at the centerline of the wire $T_{centerline}$.

6. Water flowing at 0.01 kg/s passes through a 1 cm diameter thin walled tube which is immersed in a bath of crushed ice and water such that the wall temperature may be assumed to be $T_w = 0°C$. The inlet water temperature $T_i = 40°C$ and the outlet water temperature $T_o = 6°C$. The tube is long enough that the flow may be assumed to be fully developed both hydrodynamically and thermally over the length of the tube. Calculate the total rate at which heat is transferred between the stream of water and the cooling bath and determine the length of the tube required to effect the rate of heat transfer under these conditions.

7. Frost forms on a grapefruit when the temperature of its surface reaches 0°C. At night, the grapefruit is assumed to be completely surrounded by the night sky acting as a black body at -45°C. The emissivity of the grapefruit is approximately 0.93 while the heat transfer coefficient between the grapefruit and the air surrounding it is $17\ W/m^2°C$. The grapefruit may be assumed to be at steady state without internal heat generation and energy conduction up the stem may be neglected. Determine the lowest temperature to which the air can fall during the night without frost formation forming on the surface of the grapefruit.

8. A fluid having a specific heat of 800 J/kg°C flowing at 2.4 kg/s enters a counterflow heat exchanger at 300°C where it is heated to 700°C by a fluid having a specific heat of 960 J/kg°C flowing at 2.0 kg/s which enters the counterflow heat exchanger at 1000°C. If all of these values <u>and</u> the overall heat transfer coefficient remain the same, determine by how much the heat exchanger surface area would have to be increased for the cooler fluid to be heated to 800°C.

The End