NATIONAL EXAMINATIONS DECEMBER 2008

07-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 .

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PART A - THERMODYNAMICS

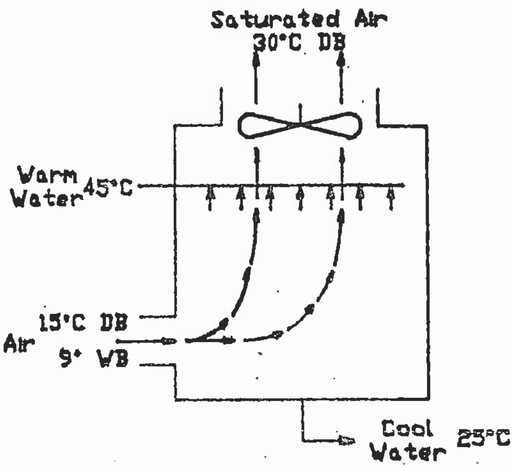
1. An engine operates on an ideal cycle comprised of isentropic compression of the working substance, isometric heat addition to the working substance, isentropic expansion of the working substance and isometric heat rejection from the working substance. The working substance is assumed to be ideal air with $\gamma = 1.4$ and $R = 0.287$ kJ/kgK. At the beginning of the compression process, the pressure is 138 kPa and the temperature is 37.8 °C. The compression ratio is 8:1 and the maximum temperature in the cycle is 1172 K. Compute all of the other temperatures and pressures in the cycle and show all of the values on properly drawn p-v and T-s diagrams. What is the thermal efficiency of the cycle ? Determine the power output corresponding to a heat addition of 0.37 kW.

2. A cooling tower utilizes the evaporative cooling phenomenon to remove heat from water. The diagram at the right is a schematic representation of the cooling tower. Determine

(i) the mass flowrate of atmospheric air required to cool 100,000 kg of water per hour

(ii) the rate at which the water is evaporated

Use the psychrometric chart which can be found appended to the end of the examination paper.



3. Steam which is admitted to a high pressure steam turbine at 2.75 MPa and 300°C expands adiabatically without friction to 500 kPa. Then the steam is reheated at constant pressure to 250°C after which it is throttled to 300 kPa before being admitted to a low pressure steam turbine where it expands to 7.5 kPa with an efficiency of 78%. The steam flowrate is 0.30 kg/s. Represent the process on a properly drawn and labelled T-s diagram and determine the following

(a) the heat supplied to the reheater per unit mass of steam

(b) the Rankine cycle efficiency of the low pressure turbine

(c) the dryness of the steam exiting the low pressure turbine

(d) the power developed by the low and high pressure turbines

4. A gas turbine power plant operates between temperature limits of 300 K and 900 K and pressure limits of 100 kPa and 400 kPa respectively. The efficiency of the compressor is 80% and the efficiency of the turbine is 85%. Determine the thermal efficiency of the power plant, the power produced by the turbine for driving an external load and the air mass flowrate corresponding to a fuel consumption of 0.45 kg/s. In the analysis, use $\gamma = 1.4$ and $C_p = 1.0035$ kJ/kgK for the specific heat of both the air and the products of combustion at constant pressure and HHV = 41,900 kJ/kg for the higher heating value of the fuel. Show the processes in the cycle on a properly drawn and labelled T-s diagram.

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PART B - HEAT TRANSFER

5. (a) A double glazed window is comprised of two sheets of glass separated by an air gap sufficiently thin that convection between the sheets of glass is prevented. The area of the window is A, the thickness of each sheet of glass is Δ and the thickness of the gap is δ. The thermal conductivities of the glass and the air are k_g and k_a, the surface heat transfer coefficients inside and outside the window are h_i and h_o and the corresponding air temperatures are T_i and T_o. Neglecting radiation heat transfer, derive a relationship for the rate of heat transfer q through the window in terms of the parameters defined above.

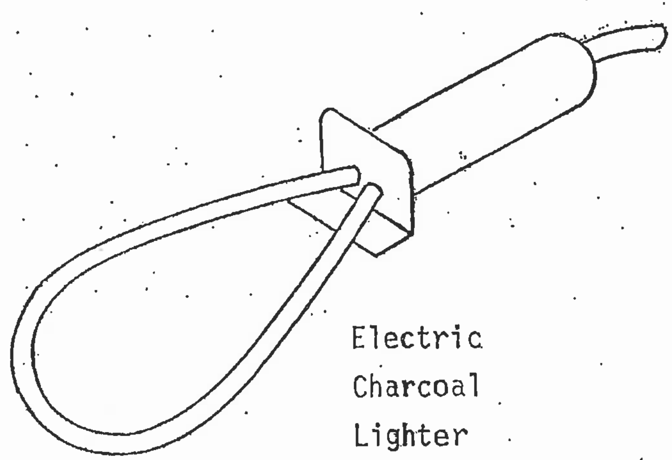
(b) Find the percentage reduction in heat loss when a single glazed window is replaced by a double glazed window. Assume that the values of the parameters defined above are the same for both windows where appropriate. Use the following numerical values for the parameters in performing the analysis.

Δ = 0.318 cm	δ = 0.635 cm
k_g = 0.868 W/m°C	k_a = 0.026 W/m°C
h_i = 8.52 W/m °C	h_o = 14.2 W/m °C

6. (a) A bare cylindrical copper conductor 2.54 cm diameter is situated in still air at 15°C. An electric current passing along the conductor causes heat to be generated within it at the rate of 20 W/m length. Determine the equilibrium surface temperature of the conductor, assuming radiation heat transfer to be negligible so that natural convection is the only means of dissipating the heat.

(b) Assuming that "lumped system analysis" is appropriate, determine the time required for the copper conductor to cool to 18°C after the electric current has stopped. Use ρ = 8970 kg/m³ for density of copper, C = 376 J/kg°C for specific heat of copper and k = 386 W/m°C for thermal conductivity of copper.

7. The element of the electric charcoal lighter 1 cm in diameter by 70 cm in length depicted in the diagram at the right is rated at 425 W. The emissivity is approximately 0.30. When the lighter is located outside in a horizontal orientation where the air temperature is 28°C and the wind velocity is negligible, determine the steady state temperature of the element when the lighter has been left plugged in.



Electric
Charcoal
Lighter

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8. (a) Cold fluid enters a simple tube in shell heat exchanger at $T_{ci} = 30°C$ and leaves at $T_{co} = 200°C$ while hot fluid enters at $T_{hi} = 360°C$ and leaves at $T_{ho} = 300°C$. The hot fluid has a flow rate capacity $\dot{m}_h C_h = 2500$ W/°C and the heat exchanger area A = 1 m . Determine the overall heat transfer coefficient for counterflow operation U corresponding to the conditions outlined above.

(b) After the heat exchanger had been in operation for one year, it was discovered that the cold fluid outlet temperature $T_{co} = 120°C$ and the hot fluid outlet temperature $T_{ho} > 300°C$ when the flow rate capacities were the same as before. What caused the deterioration in the performance of the heat exchanger ? Justify your explanation mathematically.

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