NATIONAL EXAMINATIONS MAY 2012

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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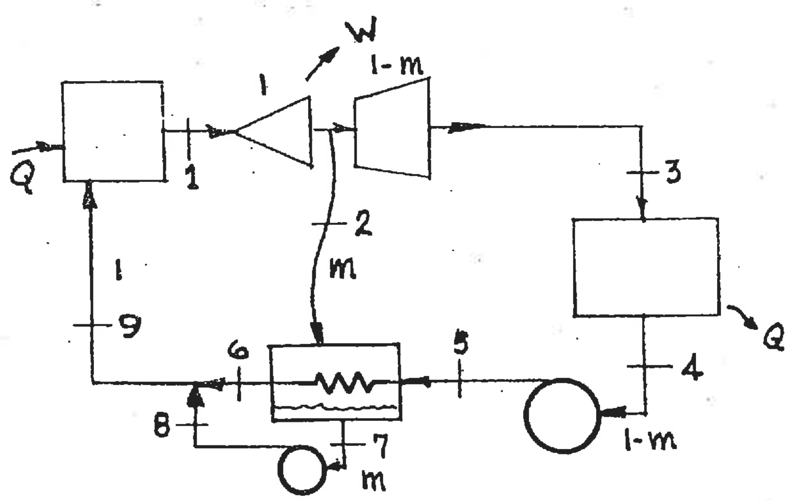
PART A – THERMODYNAMICS

1. A quantity of air initially 0.15 m^3 in volume at 379 kN/m^2 and 149°C is allowed to expand reversibly and adiabatically to 103 kN/m^2. Then by heating at constant pressure, the internal energy of the air is increased by 27.4 kJ. Sketch the processes on a pressure-volume diagram.

   (a) Determine the total work done by the air during these processes.

   (b) Determine the coefficient of expansion if the processes described above were replaced by a single reversible polytropic expansion.

2. A regenerative steam cycle is the comprised of one closed feedwater heater and two turbine stages. Steam enters the turbine at 5.5 MPa and 375°C, extraction occurs at 700 kPa and the remaining steam is discharged at 7.5 kPa. Each of the turbine stages is 85% efficient. The pumps that raise the pressure of the water from the condenser and the feedwater heater to the boiler pressure are 100% efficient. Determine the thermal efficiency of the cycle and the power required of the motors that drive the pumps if the total electrical output of the turbines is 18,000 kW and the efficiency of the electric generator is 90%.



3. An air standard Brayton cycle receives air at 100 kPa and 20°C. The upper pressure and temperature limits of the cycle are 415 kPa and 815°C respectively. The compressor efficiency is 85% and the turbine efficiency is 90%. Determine (a) the thermal efficiency of the cycle and (b) by how much the thermal efficiency of the cycle could be improved by installing an 83% efficient regenerator between the compressor and the turbine.

4. A centrifugal compressor compresses air having an inlet velocity of 110 m/s at the rate of 9.1 kg/s from 100 kPa and 15°C to the discharge conditions where the outlet velocity is 90 m/s. The compression ratio is 4:1 and the compressor has an isentropic efficiency of 80%. Sketch the process on a T-s diagram and determine (a) the outlet pressure (b) the outlet temperature and (c) the power required to drive the compressor.

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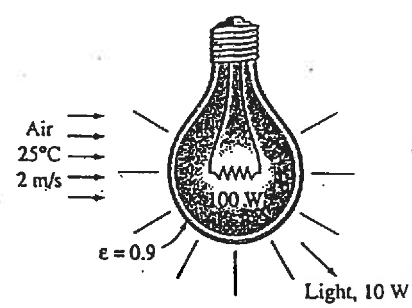
PART B - HEAT TRANSFER

5. Steam flowing in a 15 mm inside diameter by 21 mm outside diameter plain carbon steel tube maintains the inner surface of the tube at 300°C. The tube is to be covered with insulation of sufficient thickness that the temperature of the outer surface of the insulation will not exceed 60°C when exposed to air at 25°C. The heat transfer coefficient on the air side of the insulation is 8 W/m^2 °C. Find three different solutions to the problem using fibreglass, asbestos and gypsum plaster as the insulating materials. Which material would you recommend using ?

6. A smooth glass plate coated with a special electrically conductive film produces a constant heat flux on the surface of the plate when electric current flows through the film. A stream of air at 20°C flows over the upper surface of a 0.5 m by 0.5 m square section of the coated plate which is maintained at an average temperature of 65°C. Determine the velocity of the air stream required in order for 850 W to be dissipated.

7. An incandescent light bulb is a cheap but highly inefficient device for converting electrical energy into light. Only about 10 percent of the energy that it consumes is converted into light ; the other 90 percent is absorbed by the glass bulb which dissipates it to surroundings by convection and radiation. Consider a 100 W light bulb 10 cm in diameter cooled by a fan which blows 25°C air over it at a velocity of 2 m/s. The temperature of the surfaces of the room in which the light bulb is located are 25°C and the emissivity of the glass is 0.9 . Determine the equilibrium temperature of the bulb.



8. A heat exchanger is to be designed to remove heat from 425°C flue gases flowing inside a thin 2.5 cm diameter copper tube at 0.8 kg/s. A larger 5.0 cm diameter tube is to be placed around the smaller tube in order that 150°C water may flow through the annulus so created at 1.5 kg/s. The heat exchanger design is to be capable of exchanging 175 kW. Determine the length of the heat exchanger, assuming that the properties of flue gas may be considered to be the same as those of atmospheric air.

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