CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY - MARINE ENGINEER OFFICER

EXAMINATIONS ADMINISTERED BY THE
SCOTTISH QUALIFICATIONS AUTHORITY
ON BEHALF OF THE
MARITIME AND COASTGUARD AGENCY

STCW 78 as amended MANAGEMENT ENGINEER REG. III/2 (UNLIMITED)

040-32 - APPLIED HEAT

MONDAY, 27 MARCH 2017

1315 - 1615 hrs

Examination paper inserts:

Notes for the guidance of candidates:

1. Non-programmable calculators may be used.
2. All formulae used must be stated and the method of working and ALL intermediate steps must be made clear in the answer.

Materials to be supplied by examination centres:

Candidates examination workbook
Graph paper
'Thermodynamic and Transport Properties of Fluids' by Mayhew & Rogers (5th edition)

APPLIED HEAT

Attempt SIX questions only.

All questions carry equal marks.

Marks for each part question are shown in brackets.

1. A mass of 0.2 kg of helium is compressed reversibly in a cylinder according to the law pV^n = constant.

   The initial pressure and temperature are 1.01 bar and 25°C respectively.

   The final pressure and temperature are 9.5 bar and 213°C respectively.

   (a) Sketch the process on Pressure-Volume and Temperature-specific entropy diagrams. (4)

   (b) Calculate EACH of the following:

   (i) the index of compression; (2)

   (ii) the work transfer; (2)

   (iii) the heat transfer; (2)

   (iv) the change in entropy. (6)

   Note: for helium c_v = 3.116 kJ/kgK, R = 2.077 kJ/kgK

2. In an air standard diesel cycle, the volume at the end of heat supply is 1.8 times the volume at the beginning of the heat supply.

The temperature at the beginning of compression is 300 K and at the end of expansion it is 678.6 K.
The thermal efficiency is 66.9%.

(a) Sketch the cycle on Pressure-Volume and Temperature-specific entropy diagrams. (4)

(b) Calculate EACH of the following for 1 kg of air:

(i) the heat supply; (6)

(ii) the network output; (2)

(iii) the maximum cycle temperature; (2)

(iv) the volume compression ratio. (2)

Note: for air $\gamma = 1.4$ *and* $c_p = 1.005$ *kJ/kgK*

3. A gaseous fuel has the following volumetric analysis: 44% H_2, 28% CH_4, 12% CO, 14% N_2, 2% O_2.

The dry volumetric analysis of the combustion products is 9.39% CO_2, 86.76% N_2, 3.85% O_2.

(a) Determine the full combustion equation in kmols per kmol of fuel. (10)

(b) Calculate EACH of the following:

(i) the percentage excess air supplied; (2)

(ii) the mass analysis of the wet exhaust gas. (4)

Note: Relative atomic masses C = 12, H = 1, O= 16, N = 14
Air contains 21% oxygen by volume.

4. An ideal steam reheat cycle operates between pressure of 40 bar and 40 millibar, with a superheat temperature of 400°C. The first expansion is carried out to the point where the steam is dry saturated. The steam is then reheated at constant pressure to the original superheat temperature.
There is 6 K sub-cooling in the condenser and the feed pump work cannot be ignored.

(a) Sketch the cycle on a Temperature- specific entropy diagram. (4)

(b) Determine EACH of the following:

(i) the quality of the steam entering the condenser; (4)

(ii) the cycle efficiency; (5)

(iii) the specific steam consumption. (3)

5. The steam condition at a stage in a 50% reaction turbine is 0.16 bar and 0.95 dry. The speed of rotation is 3600 rev/min with a mass flow rate of 36 tonne/hour. At these conditions the stage develops a power of 1000 kW. The moving blade exit angle is 18° and the axial velocity of the steam is 80% of the blade velocity at the mean radius.

(a) Sketch the velocity vector diagram for the stage and identify the whirl velocities at inlet and exit. (3)

(b) Calculate EACH of the following:

(i) the mean diameter of the blade ring; (6)

(ii) the blade height; (3)

(iii) the diagram efficiency. (4)

6. A reverse heat engine operates on the reverse Carnot cycle.

The working fluid is R134a and the cycle operates between temperature limits of -5°C and +40°C.

(a) Sketch the cycle on a Temperature-specific entropy diagram indicating the network. (4)

(b) Calculate EACH of the following:

(i) the dryness fraction at the beginning of compression; (3)

(ii) the heat removed per kg of fluid from the low temperature reservoir; (3)

(iii) the heat rejected per kg of fluid to the high temperature reservoir; (2)

(iv) the cycle network input; (2)

(v) the cycle co-efficient of performance. (2)

7. The flow rate of lubricating oil to an engine is measured using a vertical venturi meter.

The venturi meter has an inlet diameter of 150 mm and the throat, which is 200 mm above the inlet, has a diameter of 100 mm.

A differential pressure gauge connected to the inlet and throat gives a reading of 5 kN/m^2.

The venturi has a coefficient of discharge of 0.95 and the relative density of the oil is 0.82.

Calculate EACH of the following:

(a) the net increase in kinetic energy for 1 kg of oil; (8)

(b) the velocity of the oil at the venturi meter inlet; (5)

(c) the mass flow rate of oil in tonne per hour. (3)

8. The overall pressure ratio in a two stage, single acting reciprocating air compressor designed for minimum work is 12.25:1.

At the beginning of the compression stroke the LP cylinder contains 0.0234 kg of air at a pressure and temperature of 1.013 bar and 25°C respectively.

The polytropic index for all the expansion and compression processes is 1.28.

The clearance volume in both stages is 4% of their respective swept volumes.

The stroke of each stage is 300 mm and the speed is 320 rev/min.

(a) Sketch the processes on a pressure-Volume diagram indicating ALL the volumes. (3)

(b) Calculate EACH of the following:

(i) the volumetric efficiency of each stage; (3)

(ii) the cylinder bore of each stage; (6)

(iii) the total indicated power. (4)

Note: for air R = 0.287 kJ/kgK

9. Superheated steam at a pressure and temperature of 10 bar 350°C respectively enters a convergent divergent nozzle with negligible velocity.

The steam expands isentropically to a throat pressure of 3 bar and exits the nozzle at a pressure of 0.2 bar.

The enthalpy drop from the throat to the exit is 209.367 kJ.

The mass flow of steam is 1.713 tonne/hour.

Calculate EACH of the following:

(a) the diameter of the nozzle at the throat; (5)

(b) the diameter of the nozzle at exit; (6)

(c) the isentropic efficiency of the divergent section. (5)