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CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY MARINE ENGINEER OFFICER

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

040-32 - APPLIED HEAT

MONDAY, 11 DECEMBER 2023

1315 - 1615 hrs

Materials to be supplied by examination centres

Candidate's examination workbook Graph paper Thermodynamic and Transport Properties of Fluids (5th Edition) Arranged by Y.R. Mayhew and C.F.C. Rogers

Examination Paper Inserts

Notes for the guidance of candidates:

1. Examinations administered by the SQA on behalf of the Maritime & Coastguard Agency.
2. Candidates should note that 96 marks are allocated to this paper. To pass, candidates must achieve 48 marks.
3. Non-programmable calculators may be used.
4. All formulae used must be stated and the method of working and all intermediate steps must be made clear in the answer.

Maritime & Coastguard Agency

SQA

APPLIED HEAT

Attempt SIX questions only

All questions carry equal marks

Marks for each part question are shown in brackets

1. A mass of 1.55 kg of air at a pressure and temperature of 6.78 bar and 600°C respectively, expands in an isothermal process to 3.5 bar.

   At the end of expansion, the air is cooled at constant volume to a final pressure of 1.95 bar. The change of specific entropy during the isothermal process is 0.166 kJ/kgK.

   Calculate EACH of the following:

   (a) the net work transfer; (4)

   (b) the net heat transfer; (9)

   (c) the overall change in entropy. (3)

   Note: for air R = 287 J/kgK, Cp= 1005 J/kgK

2. The ratio of compression for an engine working on the otto cycle is 7:1.

   At the beginning of compression, the temperature is 2°C with a pressure of 0.89 bar. The maximum cycle pressure is 18 bar.

   (a) Sketch a pV and Ts graph of the cycle. (3)

   (b) Calculate EACH of the following:

      (i) the temperature at all points; (9)

      (ii) the air standard efficiency of the cycle; (2)

      (iii) the thermal efficiency for the ideal Carnot cycle. (2)

   Note: For air Cv= 0.718 kJ/kgK and Cp= 1.005 kJ/kgK

3. A single-acting, two stage reciprocating air compressor is designed for minimum work with perfect intercooling, and the LP cylinder has a volumetric efficiency of 94%. The compressor delivers 8 kg/min of air from an initial condition of 1.0135 bar and 20°C.

In each stage the clearance volume is 4% of the respective swept volume, and the index for all compressions and expansions is n = 1.3.

The speed of rotation is 360 r/min.

(a) Sketch the cycle on a pressure-volume diagram. (2)

(b) Determine EACH of the following:

(i) the final delivery pressure; (6)

(ii) the power; (4)

(iii) the induced volume per cycle. (4)

Note: For air Cv= 0.718 kJ/kgK and Cp= 1.005 kJ/kgK R = 287 j/KgK

4. In a steam plant, using superheat, the turbine receives the steam at a pressure and temperature of 8 bar and 250°C respectively. The steam isentropically expands to condenser pressure of 1 bar.

The feed pump work cannot be neglected, there is no undercooling in the condenser.

(a) Sketch the T-s diagram for the cycle; (3)

(b) Calculate the thermal efficiency of the cycle. (13)

5. A vapour compression cycle using R12 has compressor suction and discharge of 3.626 bar and 12.19 bar respectively. The vapour enters the compressor in a dry saturated state and leaves at a temperature of 67°C. The liquid refrigerant has 10 K of subcooling at the entry to the expansion valve.

(a) Sketch ph and Ts diagrams. (2)

(b) Calculate EACH of the following:

(i) the dryness factor entering the evaporator; (3)

(ii) the specific work done; (5)

(iii) the coefficient of performance; (2)

(iv) the isentropic efficiency of the compressor. (4)

6. Sea water is to be used to cool engine cooling water in a single pass shell and tube heat exchanger.

The cooling water enters the tubes at a temperature of 65°C and to be cooled to 14°C. The flow rate of cooling water will be 2 kg/s. The sea water will enter at a temperature of 2°C and its flow rate will be 9.5 kg/s. The specific heat capacities of both cooling water and sea water may be taken as 4.2 kJ/kgK.

The overall heat transfer coefficient is expected to be 8500 W/ m^2K, based on the outside surface area of the tubes.

The tube outside diameter is to be 50 mm.

Calculate EACH of the following:

(a) the outlet temperature of the seawater; (2)

(b) for counter flow the log mean temperature difference and area required; (6)

(c) for parallel flow the log mean temperature difference and length of tube required. (8)

7. Pentene (C_5H_{10}) is burned with 15% excess air. Analyse the percentage by mass of dry products. (16)

Note: by mass air has 23% O_2 and 77%N_2

8. A single stage impulse turbine has a mean blade diameter of 2.2 m, and the speed of rotation is 2547 rev/min. The nozzle angle is 20° to the plane of rotation and the steam leaves the nozzles at 1200 m/s.

The blade velocity coefficient is 0.8 and there is no axial thrust. For a steam mass flow rate of 0.55 kg/s.

Calculate EACH of the following:

(a) the velocity of the blades; (2)

(b) the blade inlet angle; (6)

(c) the blade outlet angle; (4)

(d) the power output. (4)

9. A horizontal pipe carrying fresh water tapers from 650 mm diameter at point 1 to 210 mm diameter at point 2, then to 321 mm at point 3.

The volumetric flowrate is 0.4 m^3/s. There is a head loss of 7 m between point 2 and point 3.

Calculate EACH of the following:

(a) The velocities at all points; (6)

(b) Determine the pressure difference between point 1 and 2 and between point 2 and 3. (10)