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, 17 OCTOBER 2022

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 gas is cooled at constant volume from 0.03 m^3, 3.8 bar and 600 K to 382 K. The gas is then allowed to expand polytropically to 0.054 m^3, 1 bar and 283 K.

   (a) Calculate EACH of the following:

   (i) the pressure and mass at the beginning of the polytropic expansion; (5)

   (ii) the polytropic index; (3)

   (iii) the total work; (3)

   (iv) the total heat. (5)

   Note: Cp=1105J/kgK Cv=850 J/kgK 16

2. The compressor of an open gas turbine cycle receives air in at a pressure and temperature of 1.07 bar and 5°C and delivers to the combustion chamber at a pressure of 6 bar and 193°C. The products of combustion leave at 517°C and enter a turbine where the gas expands to 1 bar.

   The isentropic efficiency of the turbine is 0.86 and the power developed by the plant is 900 kW.

   For hot gas, γ= 1.33 and Cp= 1.15 kJ/kgK. For air γ= 1.4 and Cp= 1.005 kJ/kgK

   Calculate EACH of the following:

   (a) the compressor isentropic efficiency; (4)

   (b) the mass flow rate of air; (8)

   (c) the thermal efficiency of the cycle. (4)

[OVER

3. A single acting single stage air compressor runs at 300 rpm and has a clearance volume equal to 3% of the swept volume. The compressor delivers 0.029 m^3/s of air at 1.013 bar and 8°C.

The suction pressure and temperature are 0.98 bar and 26°C respectively, and the discharge pressure and temperature are 6.6 bar and 180°C, respectively.

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

(b) Calculate EACH of the following:

(i) the volume induced per cycle; (5)

(ii) the swept volume; (4)

(iii) the index of compression; (3)

(iv) the indicated power. (2)

Note: Cp=1005J/kgK Cv=718 J/kgK

4. In a steam plant, using reheat, the turbine receives the steam at a pressure and temperature of 30 bar and 500°C respectively. The steam expands in the first stage until it is just dry saturated at 1.5 bar.

It is then reheated at constant pressure to 400°C and is isentropically expanded in the second stage to a condenser pressure of 0.05 bar.

The feed pump work can be neglected and there is no undercooling in the condenser.

(a) Sketch the T-s diagram for the cycle. (2)

(b) Calculate EACH of the following:

(i) the net work from the turbines per kg of steam; (11)

(ii) the thermal efficiency. (3)

5. A vapour compression refrigeration system operates between the pressures of 0.8071 bar and 2.191 bar.

R12 refrigerant enters the compressor dry saturated and is isentropically compressed. Upon leaving the condenser it is undercooled by 5K. The mass flow rate is 1777 kg/hour.

(a) Sketch the cycle on pressure-specific enthalpy and Temperature-specific entropy diagrams. (2)

(b) Calculate EACH of the following:

(i) the dryness fraction of the refrigerant entering the evaporator; (3)

(ii) the temperature leaving the compressor; (5)

(iii) the compressor power; (4)

(iv) the coefficient of performance. (2)

6. Sea water is to be used to cool engine jacket water in a single pass shell and tube heat exchanger. The jacket water enters the tubes at a temperature of 85°C and is to be cooled to 28°C. The flow rate of cooling water will be 2 kg/s.

The sea water will enter at a temperature of 7°C and its flow rate will be 6.5 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 3000 W/ m^2K, based on the outside surface area of the tubes.

The tube outside diameter is to be 50 mm.

Determine EACH of the following:

(a) the outlet temperature of the seawater; (4)

(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. (6)

7. A Natural gas consists of the following volumetric composition, Propane (C_3H_8) (2.7%), Methane (CH_4) (88.6%), Ethane (C_2H_6) (3.5%) and Sulphur (5.2%).

Determine the Stoichiometric volume of air, for the complete combustion of 1m^3. (16)

Note: Air contains 21% O_2 by volume.

8. In a 50% reaction turbine stage, steam enters the fixed blades with a velocity of 288 m/s, the blade to steam ratio is 0.45 and the inlet angle is 24°.

The mean blade ring diameter is 0.65 m.

(a) Sketch the combined velocity diagram, labelling all velocities and angles. (3)

(b) Determine EACH of the following:

(i) the speed of rotation of the turbine rotor; (3)

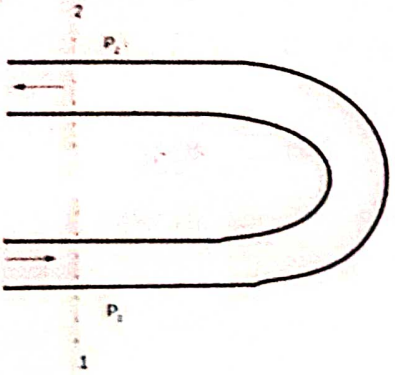
(ii) the blade inlet angles; (4)

(iii) the diagram efficiency. (6)

9. A horizontal pipe has a 180 degrees U-bend with a diameter of 300 mm throughout.

It carries a fluid of density 900 m^3/kg at a rate of $0.8m^3/s$.

The entrance pressure is 1.2 bar and exit pressure is 0.98 bar.



(a) Calculate the pressure forces at the entrance and exit. (6)

(b) Calculate the velocity of the fluid. (3)

(c) Determine the force exerted by the liquid on the bend. (7)