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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, 18 OCTOBER 2021

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. 0.08 kg of Helium is compressed isentropically from 0.325 m^3, 1.5 bar and 20°C to 4.8 bar.

   It is then heated at constant volume to 680 K.

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

   (b) Calculate EACH of the following:

   (i) the volume and temperature at the end of the initial compression; (5)

   (ii) the net heat; (3)

   (iii) the net work; (3)

   (iv) the total change in entropy. (3)

   Note: Cp=5234J/kgK and Cv=3153J/kgK

2. The compressor in an open gas turbine cycle receives air in at a pressure and temperature of 1.24 bar and 17°C and delivers to the combustion chamber at a pressure of 5 bar and 182°C. The products of combustion leave at a pressure of 4.87 bar and 517°C and enter a turbine where the gas expands to 1 bar.

   The isentropic efficiency of the turbine is 0.899 and the power developed by the plant is 1234 kW.

   (a) Calculate EACH of the following:

   (i) the compressor isentropic efficiency; (4)

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

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

   Note: For hot gas, y= 1.33 Cp= 1.154kJ/kgK.
   For air y= 1.4 and Cp= 1.005kJ/kgK

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3. In a two-stage reciprocating air compressor, the LP suction pressure is 1 bar, the LP delivery and HP suction pressure is 4.32 bar and the HP delivery pressure is 15.43 bar.

The LP suction temperature is 278 K and the HP suction temperature is 305 K. The index of compression and expansion is 1.28.

(a) Sketch the pressure volume diagram - showing intercooling. (3)

(b) Calculate EACH of the following:

(i) the indicated work per kg; (7)

(ii) the heat removed in the intercooler per kg; (2)

(iii) the isothermal efficiency. (4)

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

4. In a steam plant, using reheat, the turbine receives the steam at a pressure and temperature of 40 bar and 350°C respectively. The steam isentropically expands in the first stage until it is just dry saturated. It is then reheated at constant pressure to 300°C and is isentropically expanded in the second stage to a condenser pressure of 1.6 bar.

The feed pump work can be neglected, there is no undercooling in the condenser and the steam flow is 4.86 tonne per hour.

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

(b) Calculate EACH of the following:

(i) the total power output from the turbines; (12)

(ii) the specific steam consumption in kg/kWh. (2)

5. A vapour compression refrigeration system operates between the pressures of 4.233 bar and 9.607 bar.

R12 refrigerant enters the compressor dry saturated and is isentropically compressed. Upon leaving the condenser it is undercooled by 10 K. The mass flow rate is 1867 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. The end of a steel pipe of with a thermal conductivity of 60 W/mK is capped with a hemisphere which has internal diameter 33.2 cm and a thickness of 20 mm.

The pipe contains superheated steam at 245°C and the external temperature without lagging is 244.5°C.

(a) Calculate the resistance of the steel. (4)

(b) To achieve a safe working temperature of 35°C, calculate the minimum thickness of insulation with a thermal conductivity of 0.55 W/mK required, assuming the rate of heat is constant. (10)

(c) Sketch a diagram of the system. (2)

7. An unknown hydrocarbon fuel combusts with dry air, the resulting products have the following dry volumetric products, 12% CO_2, 1.5% CO, 3% O_2 and 83.5% N_2.

(a) Calculate the percentage excess air. (10)

(b) Determine the partial pressure of the water vapour and dew point. (3)

(c) Describe the difference between HCV and LCV values. (3)

Note: Atmospheric Pressure is 1.10325×10^5Pa

8. In a 50% reaction turbine stage, steam leaves the fixed blades with a velocity of 188 m/s, the blade/steam ratio is 0.7 and the fixed blade outlet angle is 28°. The mean blade ring diameter is 0.84 m.

(a) Sketch the combined velocity diagram, labelling all velocities and angles. (2)

(b) Determine each of the following:

(i) the speed of rotation of the turbine rotor in rpm; (4)

(ii) the blade inlet angles; (4)

(iii) the diagram efficiency. (6)

9. A centrifugal pump impeller is 665 mm outside diameter and 300 mm inside diameter and runs at 360 rpm. The radial velocity at the inlet and the outlet is 7.2 m/s.

The velocity of the whirl at the exit is 6.1 m/s, and the volumetric flow rate throughout is 0.1355 m^3/s.

Calculate EACH of the following:

(a) the blade outlet angle; (4)

(b) the blade inlet angle; (4)

(c) the width of the impeller at the inlet and outlet; (4)

(d) the power. (4)

Note: The working fluid is water.