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, 27 MARCH 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. Air at 8.1bar, 0.024 m^3 and 490 K with a mass of 0.138 kg of air is expanded isothermally to 5.2 bar.

   The system is then further expanded polytropically to 2.8 bar and 416 K.

   (a) Calculate EACH of the following:

   (i) the polytropic index of expansion; (3)

   (ii) the net work; (5)

   (iii) the net heat; (3)

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

   (b) Sketch the PV and TS diagrams. (2)

   Note: Cv, Cp and R are 718J/kgK, 1005J/kgK and 287J/kgK respectively.

2. In a Diesel cycle the polytropic compression ratio is 15 and the heat energy supplied at constant pressure is 1 MJ/kg.

   The initial pressure and temperature of the air at the start of compression are 1 bar and 15°C respectively.

   Calculate EACH of the following:

   (a) the temperatures at all points; (6)

   (b) the cycle thermal efficiency. (10)

   Note: For compression: n=1.35, for expansion: n=1.25
   Cv=0.718 kJ/kgK and Cp= 1.005 kJ/kgK R=0.287 kJ/kgK

3. A single acting 3 stage reciprocating compressor is designed for minimum work with perfect intercooling. It delivers 0.11 kg/s of air from initial conditions of 1.10 bar and 15°C and has a volume compression ratio of 2.41 for EACH stage according to the law $pV^{1.38}=C$.

(a) Draw graph pV diagram showing intercooling. (3)

(b) Calculate each of the following:

(i) each stage delivery pressure; (5)

(ii) the total indicated power; (5)

(iii) the total rate of heat removed in the intercoolers. (3)

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

4. A steam turbine isentropically expands steam from a pressure 60 bar and superheated temperature of 415°C to 6 bar. The feed water leaves the condenser with no undercooling, the feed pump work cannot be ignored.

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

(b) Calculate the thermal efficiency of the cycle. (14)

5. A vapour compression cycle using Tetrafluoroethene (R134a) has compressor suction and discharge of 3.4966 bar and 11.595 bar respectively.

The vapour enters the compressor in a dry saturated state and leaves at a temperature of 62°C. The liquid refrigerant has 5 K of subcooling at the entry to the expansion valve.

(a) Sketch Ph and Ts diagrams. (3)

(b) Determine EACH of the following:

(i) the isentropic efficiency of the compressor; (7)

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

(iii) the coefficient of performance. (3)

6. A pipe of diameter 0.3 m carries a fluid, and EACH metre length generates 185 watts of heat. The surrounding air is at 6°C and the surface heat transfer coefficient is 9 W/ m^2K.

(a) Calculate the temperature of the pipe. (6)

(b) The pipe was covered in insulation 2cm thick and a thermal conductivity of 5W/mK. The outer heat transfer coefficient may be assumed to remain the same.

Calculate the new temperature of the pipe. (10)

7. A Natural gas consists of the following volumetric composition, Propane C_3H_8 (50%) and Ethene C_2H_4 (50%).

Determine EACH of the following:

(a) the Stoichiometric volume of air, for the complete combustion of 3.5 m^3; (10)

(b) the percentage volumetric analysis of the exhaust gas products. (6)

8. An impulse turbine has a nozzle at entrance.

(a) Calculate the nozzle exit velocity if the change in enthalpy across the nozzle is 720 kJ/kg. (2)

(b) Sketch a blade velocity diagram labelling all significant angles and velocities. (3)

(c) The nozzle entrance angle is 14°, the blade velocity is 460 m/s, and the blades are symmetrical and have an angle of 38°.

Determine the diagram power if the blade velocity coefficient is 0.98 and the mass flowrate of the steam is 0.6 kg/s. (11)

9. A centrifugal pump impeller is 1.2 m outside diameter and 0.85 m inside diameter and runs at 720 rpm. The radial velocity at the inlet and the outlet is 27.2 m/s. The tangential component is 16.1 m/s, and the volumetric flow rate throughout is 0.5 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 density of water is 1000 kg/m^3