3

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 JULY 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 with molar mass 44 kg/kmolK and mass 0.021 kg is compressed isothermally at 281 K to ¼ of its original volume. It is then further compressed according to $PV^{1.25}=C$ to ½ of its secondary volume.

   (a) Calculate the specific gas constant. (2)

   (b) Find the work done during the isothermal compression. (2)

   (c) Determine the heat transferred of the initial compression. (1)

   (d) Calculate EACH of the following:

      (i) the final temperature; (2)

      (ii) the polytropic work done; (2)

      (iii) the change in entropy in each process. (4)

   (e) Draw pV and Ts diagrams. (3)

   Note: Ro= 8.314 kJ/kmolK and Cv= 630 J/kgK

2. A gas turbine plant operates on the ideal air standard Joule cycle. The min pressure and temperature are 1 bar and 335 K.

   The max pressure and temperature are 8 bar and 1020 K.

   (a) Sketch the processes on p-V and T-s diagrams. (2)

   (b) Calculate EACH of the following:

      (i) the temperature at all points; (5)

      (ii) the heat supplied per kg; (2)

      (iii) the net work output per kg; (5)

      (iv) the thermal efficiency. (2)

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

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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 1.06 bar and 15°C and has a volume compression ratio of 3.5 for EACH stage according to the law $pV^{1.25}=C$.

(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: For air Cp= 1.005 kJ/kgK Cv=0.718 kJ/kgK

4. A Carnot cycle uses saturated water and steam as the working fluid and operates between pressures of 0.045 bar and 44 bar.

An ideal Rankine Cycle using steam operates between the same pressures as the Carnot cycle above. The steam is dry saturated at the beginning of expansion, and saturated liquid leaves the condenser.

(a) Determine the Carnot thermal efficiency of the cycle. (2)

(b) Sketch the Rankine cycle on a T-s diagram. (2)

(c) Determine the Rankine cycle thermal efficiency (12)

5. A vapour compression cycle using ammonia has compressor suction and discharge of 3.413 bar and 11.67 bar respectively.

The vapour enters the compressor in a dry saturated state and leaves at a temperature of 105°C. The liquid refrigerant has 4 K of subcooling at the entry to the expansion valve.

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

(b) Determine 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. A copper wire of diameter 5 mm carries an electric current, and EACH metre length generates 6.5 watts of heat. The surrounding air is at 12°C and the surface heat transfer coefficient is 13 W/m^2K.

(a) Determine the temperature of the wire. (6)

(b) The wire is to be covered with insulation 1.5 mm thick and k=0.1 W/mK. The outer heat transfer coefficient may be assumed to remain the same.

Calculate the reduced temperature of the wire. (10)

7. A Natural gas consists of the following volumetric composition:

Nitrogen (N_2) (1.8%); Methane (CH_4) (88.6%); Ethane(C_2H_6) (3.5%) and Ethene (C_2H_4) (0.9%); Sulphur (S)(5.2%).

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

Note: the composition of air by volume is 21%O_2 and 79% N_2

8. (a) Explain the difference between impulse and reaction turbines. (1)

(b) In a 50% reaction turbine stage, the steam leaves the fixed blades with a velocity of 300 m/s. The axial velocity component is 145 m/s and the blade velocity is 200 m/s.

Determine EACH of the following:

(i) the blade inlet and outlet angles; (7)

(ii) the blade work per kg of steam; (4)

(iii) the diagram efficiency. (4)

9. (a) A jet of fresh water 50 mm diameter issues under a head of 24.4 m and strikes a fixed flat plate.

Find the force exerted on the plate when:

(i) the plate is perpendicular to the jet; (4)

(ii) the plate is inclined at 30 degrees to the axis of the jet. (2)

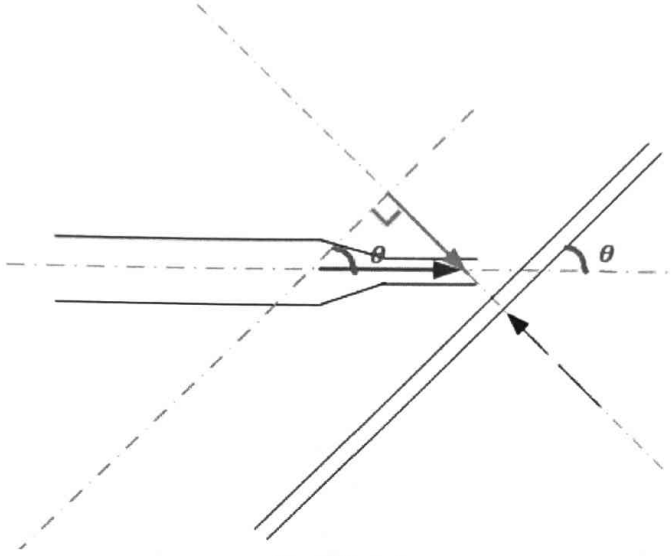

Fig Q9 (a)

(b) Oil of density 900 kg/m^3 flow through a pipe from point A to point B.

At point A the diameter is 125 mm and pressure is 160 kPa and at point B, which is 2 m below the diameter is 250 mm and pressure is 210 kPa.

Determine EACH of the following:

(i) the velocity of the oil at point A; (8)

(ii) the mass flow rate of the oil. (2)