CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY
MARINE ENGINEER OFFICER

EXAMINATIONS ADMINISTERED BY THE
SCOTTISH QUALIFICATIONS AUTHORITY
ON BEHALF OF THE
MARITIME AND COASTGUARD AGENCY

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

040-32 - APPLIED HEAT

MONDAY, 10 DECEMBER 2018

1315 - 1615 hrs

Examination paper inserts:

Notes for the guidance of candidates:

1. Non-programmable calculators may be used.
2. All formulae used must be stated and the method of working and ALL intermediate steps must be made clear in the answer.

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

APPLIED HEAT

Attempt SIX questions only

All questions carry equal marks

Marks for each part question are shown in brackets

1. Air at a pressure and temperature of 5.5 bar and 1300 K respectively is cooled at constant volume until the pressure is 1.35 bar.

   The air is then revesibly compressed acording to the law $pV^{1.28}$= constant back to the original pressure.

   (a) Sketch the sequence of process on pressure-Volume and Temperature-specific entropy diagrams. (2)

   (b) Calculate EACH of the following for 1 kg of air:

   (i) the work transfer; (4)

   (ii) the total change in internal energy; (3)

   (iii) the net heat transfer; (4)

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

   Note: for air $R = 0.287$ kJ/kgK and $c_v = 0.718$ kJ/kgK

2. In an air standard dual combustion cycle the volume compression ratio is 20:1.

   The minimum pressure and temperature are 2.0 bar and 47°C respectively.

   The maximum pressure is 200 bar and the maximum temperature is 1685°C.

   (a) Sketch the cycle on pressure-Volume and Temperature-specific entropy diagrams. (3)

   (b) Calculate EACH of the following:

   (i) the pressure and temperature at each point in the cycle; (5)

   (ii) the percentage of the total heat added at constant volume; (5)

   (iii) the cycle thermal efficiency. (3)

   Note: for air $\gamma = 1.4$ and $R = 0.287$ kJ/kgK

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3. A pure hydrocarbon fuel is burned in air.

The mass analysis of the dry combustion products is 5.13 kg of CO_2, 1 kg CO, 1.8 kg O_2, 25.23 kg N_2.

Calculate EACH of the following:

(a) the mass analysis of the fuel; (8)

(b) the percentage excess air by mass; (4)

(c) the molecular mass of total combustion products. (4)

Note: atomic mass relationships H = 1, C = 12, O = 16, N = 14.
air contains 23.3% oxygen by mass.

4. Steam at a pressure of 20 bar and a specific volume of 0.1511 m^3/kg enters a convergent divergent nozzle with a negligible velocity.

The steam expands isentropically according to law $pV^{1.3}$= constant into a space at a pressure of 3 bar.

The diameter of the throat is 10 mm and the specific enthalpy drop in the divergent section is 295.5 kJ/kg.

Calculate EACH of the following:

(a) the critical pressure; (2)

(b) the specific volume of the steam at the throat; (3)

(c) the mass flow rate of steam; (5)

(d) the diameter of the nozzle at exit. (6)

Note: for the nozzle $p_c = p_o\left(\frac{2}{n+1}\right)^{\frac{n}{n-1}}$ $c_c = (n\, p_c v_c)^{\frac{1}{2}}$

5. Steam, at a pressure and temperature of 4 bar and 200°C respectively, leaves the fixed blades of a 50% reaction turbine stage.

The moving blade inlet and outlet angles are 50° and 35° respectively.

The mean blade speed is 170 m/s.

The blade height is 10% of the blade ring mean diameter.

The mass flow rate of steam through the stage is 14 kg/s.

Calculate EACH of the following:

(a) the blade height; (5)

(b) the stage power; (4)

(c) the percentage increase in the moving blade relative velocity; (4)

(d) the stage specific enthalpy drop. (3)

6. A vapour compression refrigeration plant uses R134a and operates between pressures of 1.0637 bar and 10.163 bar.

The refrigerant enters the compressor at a temperature of -25°C and leaves at a temperature of 55°C.

The refrigerant leaves the condenser with 10 K of subcooling.

At these conditions the power input to the plant is 117 kW with a mechanical efficiency of 90%.

(a) Sketch the cycle on pressure-specific enthalpy and Temperature-specific entropy diagrams. (4)

(b) Calculate EACH of the following:

(i) the isentropic efficiency of the compressor; (6)

(ii) the cooling load; (4)

(iii) the plant coefficient of performance. (2)

7. An air cooled heat exchanger has 9 tubes each 40 mm mean diameter in a single pass, parallel flow arrangement.

Fresh water flows through the tubes with a velocity of 0.2 m/s. It enters at a temperature of 85°C, and leaves at a temperature of 75°C.

The air enters the cooler at a temperature of 4°C and has a mass flow of 9 kg/s.

(a) Calculate EACH of the following:

(i) the rate of heat transfer from the water; (3)

(ii) the log mean temperature difference for the cooler: (5)

(iii) the length of EACH cooler tube. (5)

(b) Sketch the cooler temperature distribution (profile) diagram. (3)

Note: for air c_p 1.005 kJ/kgK
for water c = 4.2 kJ/kgK
heat transfer coefficient for air side of the tube = 8.84 kW/m^{2}K
heat transfer coefficient for water side of the tube = 13.74 kW/m^{2}K

8. A single acting, three stage reciprocating compressor, is designed for minimum work with perfect intercooling.

It delivers 8 kg/min of air from initial conditions of 1.15 bar and 25°C and has a volumetric efficiency of 0.88 at a speed of 360 rev/min.

The clearance volume in each stage is 5% of the respective swept volume.

Compression and expansion processes take place according to the law $pV^{1.25}$= constant.

(a) Calculate EACH of the following:

(i) the stage delivery pressures; (5)

(ii) the indicated power; (3)

(iii) the toal heat removed in the intercoolers. (4)

(b) Sketch the cycle on a pressure-Volume diagram, indicating the stage pressures. (4)

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

9. A reducing bend is fitted in a horizontal section of a fresh water system as shown in Fig Q9. It turns the flow through an angle of 90° anticlockwise to the direction of flow.

The system pressure and fluid velocity at inlet are 8 bar and 1.5 m/s respectively.

The bend has diameters of 300 mm at inlet and 150 mm at outlet.

The friction loss in the bend may be ignored.

Calculate EACH of the following:

(a) the system pressure at the bend outlet; (4)

(b) the forces acting in the X and Y direction due to the change in diameter; (3)

(c) the forces acting in the X and Y direction due to the change in momentum; (3)

(d) the magnitude of the resultant force acting on the bend; (4)

(e) the direction of the resultant force. (2)

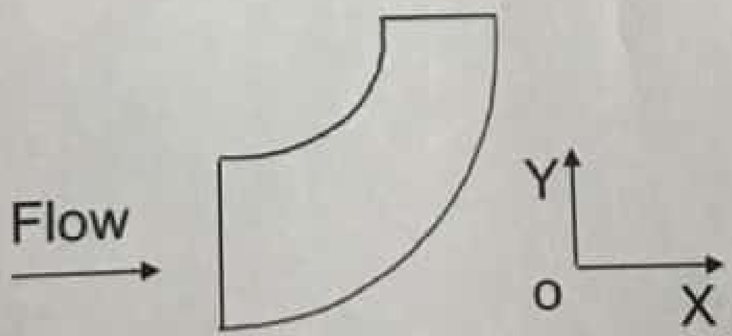

Fig Q9