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, 17 JULY 2017

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:

Candidates examination workbook
Graph paper
'Thermodynamic and Transport Properties of Fluids' by Mayhew & Rogers (5^{th} edition)

APPLIED HEAT

Attempt SIX questions only.

All questions carry equal marks.

Marks for each part question are shown in brackets.

1. In a reversible cycle 1.5 kg of air is heated at constant volume, from a pressure and temperature of 1 bar and 25°C respectively to a pressure of 7 bar. It is then isothermally expanded to the original pressure and finally it is cooled at constant pressure to the initial volume.

   (a) Sketch the cycle on Pressure-Volume and Temperature-specific entropy diagrams. (4)

   (b) Calculate EACH of the following:

      (i) the net work transfer; (4)

      (ii) the thermal efficiency for the cycle; (3)

      (iii) the efficiency of a Carnot cycle operating between the same temperature limits. (3)

   (c) Sketch the Carnot cycle on a Temperature-specific entropy diagram. (2)

   Note: for air c_p = 1.005 kJ/kgK and c_v = 0.718 kJ/kgK

2. Air enters an open cycle gas turbine at an atmospheric temperature and pressure of 15°C and 1.013 bar respectively. The compressor operates on a pressure ratio of 8.5:1 with an isentropic efficiency of 0.78.

The temperature of the gas leaving the combustion chamber is 925°C and it expands through the turbine to atmosphere with an isentropic efficiency of 0.83. The net power output of the plant is 1800 kW.
The mass flow of fuel may be ignored.

(a) Sketch the cycle on a Temperature-specific entropy diagram. (2)

(b) Calculate EACH of the following:

(i) the temperature at the end of compression; (3)

(ii) the temperature at the end of expansion; (3)

(iii) the mass flow rate of air through the plant; (3)

(iv) thermal efficiency; (3)

(v) the work ratio. (2)

Note: for air c_p = 1.005 kJ/kgK and c_v = 0.718 kJ/kgK

3. A fuel of mass analysis 84% carbon and 16% hydrogen is completely burned in air.

The dry flue gas analysis shows that they contain 14% CO_2 by volume. (8)

(a) Determine the air supply in molar volumes for 100 kg of fuel.

(b) Calculate EACH of the following:

(i) the air fuel ratio by mass; (4)

(ii) the percentage excess air by volume. (4)

Note: Relative atomic masses H =1, C =12, N =14, O =16
Air contains 21% oxygen by volume.

4. A bend of constant cross sectional area which turns the flow through 75° is shown in Fig Q4.
It is fitted in a horizontal section of a 600 mm diameter fresh water cooling system.

The cooling system pressure at this point is 3 bar and the flow rate is 0.85 m^3/s.
The pressure loss due to the bend is negligible.

Calculate EACH of the following:

(a) the net force acting on the axis ox; (8)

(b) the net force acting on the axis oy; (4)

(c) the magnitude of the resultant force acting on the bend; (2)

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

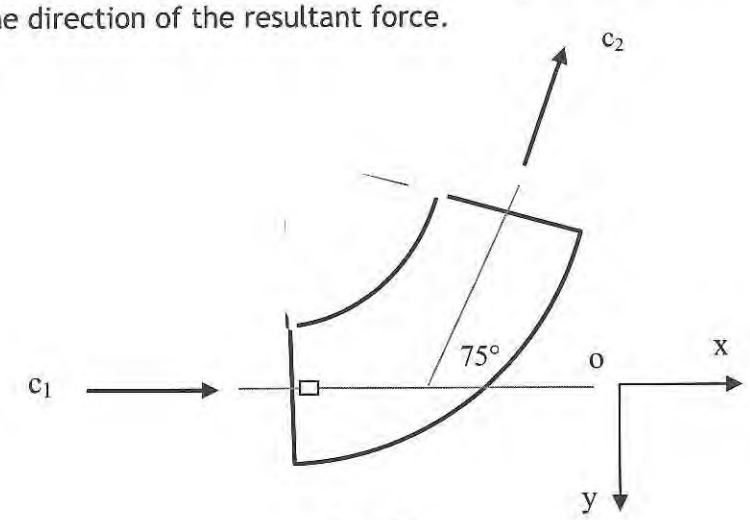

Fig Q4

5 Steam at a pressure and temperature of 40 bar and 400°C respectively is expanded in the nozzles of a two row velocity compounded impulse turbine to a pressure of 15 bar.

The steam enters the first row of moving blades with an absolute velocity of 700 m/s.

The outlet angles from the nozzles, first row of moving blades, fixed blades and the second row of moving blades are 18°, 21°, 26° and 35° respectively.

The blade velocity coefficient is 0.9 over each of the three rows of blades.

The turbine shaft speed is 3000 rev/min and the mean blade diameter is 750 mm.

(a) Determine the condition of the steam leaving the nozzles. (5)

(b) Draw the velocity diagram for each row to a scale of 1 mm = 5 m/s. (8)

(c) Determine the diagram efficiency; (3)

6. A vapour compression refrigeration cycle using Ammonia has compressor suction and discharge pressures 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 sub-cooling at entry to the expansion valve.

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

(b) Determine EACH of the following:

(i) the percentage of dry vapour entering the evaporator; (3)

(ii) the specific work done; (3)

(iii) the coefficient of performance; (2)

(iv) the isentropic efficiency of the compressor. (4)

7. An exhaust gas economiser has a total of 60 tubes in a single pass, counterflow arrangement.

Each tube has an inner diameter of 20 mm, wall thickness 2.4 mm and a length of 3 m.

The feed water enters the tubes at a temperature of 90°C and leaves at 106°C.

The exhaust gas enters the shell at a rate of 47 tonne/hour and temperature of 350°C, it leaves at a temperature of 280°C.

The heat lost to the surroundings is negligible.

Calculate EACH of the following:

(a) the rate of heat transfer; (2)

(b) the mean velocity of the feed water in the tubes; (5)

(c) the log mean temperature difference; (4)

(d) the overall heat transfer coefficient, based on the tube outer surface area. (5)

Note: for feed water c = 4.2 kJ/kgK and density 1000 kg/m^3
for exhaust gas c_p = 1.1 kJ/kgK

8. A single acting, two stage reciprocating air compressor, takes in air at a pressure and temperature of 0.95 bar and 15°C respectively and delivers it at 30 bar.

The low pressure cylinder has a bore of 300 mm and a stroke of 450 mm with a volumetric efficiency of 82%.

The air enters the second stage at a pressure and temperature of 6 bar and 25°C respectively.

The compressor speed is 200 rev/min.

The index of compression and expansion in both stages is 1.3.

(a) Sketch the process on a Pressure-Volume diagram. (2)

(b) Calculate EACH of the following:

(i) the compressor power; (4)

(ii) the heat removed in the inter-cooler; (4)

(iii) the heat removed by the cooling water in the low and high pressure cylinders. (6)

Note: for air R = 0.287 kJ/kgK c_p = 1.005 kJ/kgK

9. In a mixture of methane (CH_4) and air there are three volumes of oxygen to one volume of methane.

The mixture is isentropically compressed through a volume ratio of five to one from initial conditions of 1 bar and 102°C.

Calculate EACH of the following:

(a) the gravimetric analysis of the mixture; (4)

(b) the molecular mass of the mixture; (2)

(c) the adiabatic index of the mixture; (4)

(d) the work done per unit mass of the mixture. (6)

Note:
The universal gas constant = 8.3145 kJ/kmolK.
For each constituent gas the values of c_p at 375 K are:
Oxygen = 0.934 kJ/kg, Methane = 2.442 kJ/kgK,
Nitrogen = 1.042 kJ/kgK .
Atomic mass relationships: H =1, C = 12, N = 14, O = 16.
Air contains 21% oxygen by volume.