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, 26 MARCH 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
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. A perfect gas is cooled at constant pressure from a temperature of 1400°C to a temperature of 1000°C. It is further cooled at constant volume until the temperature is 600°C, the change of specific entropy during this process is 1.202 kJ/kgK. After cooling, the gas is compressed isentropically back to the original pressure.

   The temperature of the gas at end of compression is 737°C.

   (a) Sketch the sequence of process on pressure-Volume and Temperature-specific entropy diagrams. (4)

   (b) Calculate EACH of the following:

      (i) the values of c_v, γ, c_p and R for the gas; (4)

      (ii) the change in specific entropy during the constant pressure process; (2)

      (iii) the specific work transfer; (3)

      (iv) the specific heat transfer. (3)

2. In an air standard dual combustion cycle 720 kJ/kg of heat is added at constant volume, the remaining 60% of the total heat supply is added at constant pressure.

   The minimum pressure and temperature in the cycle are 1.05 bar and 311 K respectively.

   The volume compression ratio is 14:1.

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

   (b) Calculate EACH of the following:

      (i) the pressure and temperature at each point in the cycle; (6)

      (ii) the specific work output; (3)

      (iii) the theoretical mean effective pressure. (3)

   Note: for air γ = 1.4 and c_p = 1.005 kJ/kgK

3. A gaseous fuel has a volumetric composition of 60% methane (CH_4) and 40% ethane (C_2H_6) and is completely burned in 20% excess air.

The combustion gases are at a pressure and temperature of 3.346 bar and 400°C respectively and are cooled at constant pressure to 100°C.

(a) Determine the combustion equation in kmols per kmol of fuel. (6)

(b) Calculate EACH of the following:

(i) the mean value of c_p for the dry gas; (4)

(ii) the dew point temperature of the gas; (3)

(iii) the quantity of heat removed from the dry gas per kmol of fuel. (3)

Note: atomic mass relationships H =1, C = 12, O = 16, N = 14
air contains 21% oxygen by volume
Values of c_p: CO_2 = 1.113 kJ/kgK, O_2 = 1.024 kJ/kgK, N_2 = 1.091 kJ/kgK

4. Steam flows through a bank of 20 identical convergent divergent nozzles at the rate of 10 kg/s.

The steam enters each nozzle at 16 bar 400°C with a negligible velocity and expands to an exit pressure of 3 bar.

Expansion in the convergent section is isentropic, whilst in the divergent section the specific entropy increases by 1%.

The nozzles are choked and at this condition, the critical pressure ratio is 0.5625.

Calculate EACH of the following:

(a) the degree of superheat of the steam at the throat; (5)

(b) the throat diameter of each nozzle; (5)

(c) the degree of superheat of the steam at exit; (3)

(d) the exit velocity. (3)

5. In a 50% reaction turbine stage, the steam leaves the fixed blades with a velocity of 400 m/s, the blade speed ratio is 0.7332 and the fixed blade outlet angle is 35°.

The mean diameter of the blade ring is 800 mm.

(a) Sketch the velocity vector diagram, labelling ALL the velocities and angles. (5)

(b) Calculate EACH of the following:

(i) the turbine rotor speed of rotation in rev/min; (3)

(ii) the blade inlet angles; (3)

(iii) the diagram efficiency. (5)

6. A vapour compression refrigeration plant using R 134a is shown in Fig Q6. It has a surface heat exchanger, in the compressor suction line to cool the liquid refrigerant.

The heat exchanger operation may be considered adiabatic.

The compressor suction pressure and temperature are 1.6393 bar and 5°C respectively.

The compressor discharge pressure and temperature are 8.8672 bar and 55°C respectively.

The refrigerant leaves the condenser as a saturated liquid and leaves the evaporator as a dry saturated vapour.

At these conditions the compressor load is 50 kW.

(a) Sketch the cycle on a pressure-specific enthalpy diagram indicating the effect of the heat exchanger. (2)

(b) Calculate EACH of the following:

(i) the mass flow rate of refrigerant; (2)

(ii) the mass flow rate of <u>liquid</u> entering the evaporator; (6)

(iii) the cooling load: (2)

(iv) the heat rejected in the condenser; (2)

(v) the coefficient of performance. (2)

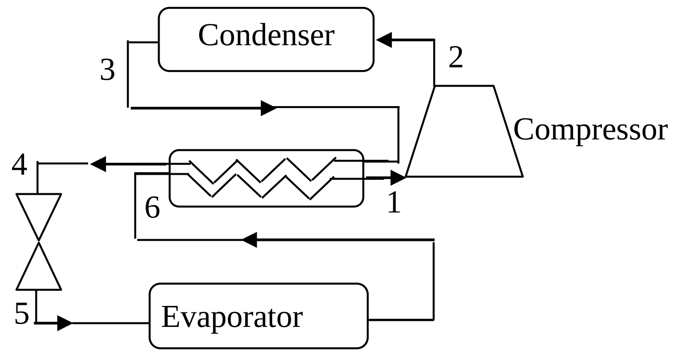

Fig Q6

7. A combustion air heater has 100 tubes each 2.5 m long in a single pass counterflow arrangement.

Exhaust gas from the combustion process enters at 400°C and heats 0.3334 kg/s of air from 25°C to 170°C.

The combustion air to fuel ratio is 20:1 and the overall heat transfer coefficient is 6.391 W/m^{2}K.

(a) Calculate EACH of the following:

(i) the outlet temperature of the exhaust gas; (5)

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

(iii) the mean diameter of the heater tubes. (4)

(b) Sketch the heater temperature distribution (profile) diagram. (2)

Note: for air c_p 1.005 kJ/kgK
for exhaust gas c_p = 1.15 kJ/kgK]

8. In a single acting, single stage reciprocating compressor, air is compressed from free air conditions of 1 bar and 15°C to 9 bar.

The clearance volume is 4% of the swept volume.

Compression and expansion processes take place according to the law $pV^{1.3}$= constant.

Calculate EACH of the following for 1 kg of air delivered:

(a) the volumetric efficiency; (2)

(b) the delivery temperature; (2)

(c) the heat transferred during the compression process; (5)

(d) the heat transferred during the expansion process; (4)

(e) the net work input. (3)

Note: for air R = 287 J/kgK, c_v = 717.5 J/kgK

9. A fresh water cooling system discharges into an observation tank through a 50 mm diameter horizontal pipe.

The flow from the pipe strikes the centre of a flat square plate which is hinged at its upper edge.

The plate has a side length of 150 mm and uniform thickness.

During maintenance the original 1.5 kg plate was replaced with a new plate of the same dimensions but of mass 2 kg.

The effect of friction in the hinge may be ignored.

(a) Sketch the system of forces acting on the plate. (4)

(b) Calculate EACH of the following:

(i) the mass flow rate when the 1.5 kg plate was at an angle of 30° to the vertical; (8)

(ii) the percentage change in mass flow when the 2 kg plate is now at an angle of 30° to the vertical. (4)