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 25 MARCH 2019

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. Carbon Dioxide expands reversibly according the law $pV^n=C$.

   The initial pressure, volume and temperature are 12 bar, 0.09 m^3 and 400°C respectively.

   The final volume and temperature are 0.457 m^3 and 154°C respectively.

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

   (b) Calculate EACH of the following:

      (i) the polytropic index of expansion; (2)

      (ii) the change in internal energy; (4)

      (iii) the work transfer; (2)

      (iv) the heat transfer; (2)

      (v) the change in entropy. (4)

   Note: *for carbon dioxide $\gamma = 1.33$*
   relative atomic masses C = 12, O = 16
   the universal gas constant $R_o = 8.3145$ kJ/kmolK

2. In an air standard diesel cycle the volume compression ratio is 16:1. The heat addition takes place for 12% of the stroke.

The minimum pressure and temperature in cycle are 1.3 bar and 45°C respectively.

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

(b) Calculate EACH of the following:

(i) the temperatures and pressures at the cardinal points of the cycle; (5)

(ii) the thermal efficiency; (4)

(iii) the mean effective pressure. (5)

Note: for air, $\gamma = 1.4$ and $c_v = 718\ J/kgK$

3. A pressure vessel contains 1 kmol of a stoichiometric mixture of methane CH_4 and air. The mixture is at a pressure and temperature of 1.05 bar and 20°C respectively.

Calculate EACH of the following:

(a) the volumetric analysis of the mixture; (5)

(b) the mass analysis of the mixture; (3)

(c) the volume of the pressure vessel; (3)

(d) the partial pressures of the methane, oxygen and nitrogen. (5)

Note: atomic mass relationships H =1, C = 12, O = 16, N = 14.
universal gas constant = 8.3145 kJ/kmolK.
air contains 21% oxygen by volume.

4. A regenerative steam plant is shown in Fig Q4.

The steam enters the turbine at a pressure and temperature of 60 bar and 500°C respectively and expands to a pressure of 0.1 bar and a dryness fraction of 0.91.

Steam is bled from the turbine at a pressure and temperature of 2 bar and 150°C respectively and supplied to a surface heat exchanger which drains back to the main condenser through a throttle.

The boiler feed water leaves the heater at a temperature of 115.2°C and leaves the condenser with 5.5 K subcooling.

The feed pump work cannot be ignored.

(a) Sketch the cycle on a Temperature-specific entropy diagram. (4)

(b) Calculate EACH of the following per kg of steam flow:

(i) the mass flow rate of bled steam; (4)

(ii) the net work output; (4)

(iii) the heat removed in the condenser. (4)

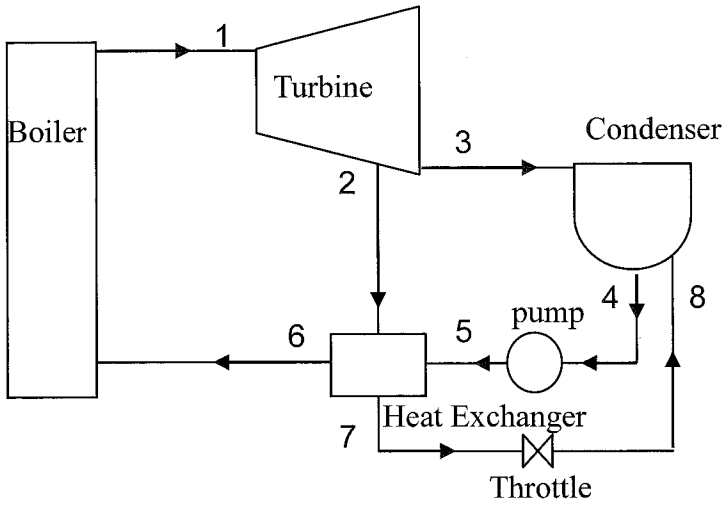

Fig Q4

5. The first stage of an impulse turbine is velocity compounded with two rows of moving blades. The enthalpy drop in the nozzles is 198.5 kJ/kg.

The steam leaves the nozzles at an angle of 20° to the plane of blade rotation and the mean blade speed is 100 m/s.

The axial velocity of the steam remains constant throughout the stage.

A blade velocity coefficient of 0.9 may be assumed for all the blade rows.

(a) Draw the steam velocity vector diagram to a scale of 1 mm = 5 m/s. (6)

(b) Determine EACH of the following:

(i) the blade angles for each row of moving blades; (2)

(ii) the blade angle for the fixed blades; (2)

(iii) the absolute velocity of the steam leaving the stage; (2)

(iv) the diagram power output for 1 kg/s of steam flow; (2)

(v) the diagram efficiency. (2)

6. A vapour compression refrigeration plant uses ammonia and operates between saturation temperatures of -22°C and 30°C.

The refrigerant enters the compressor as dry saturated vapour and leaves at a temperature of 130°C.

The liquid refrigerant enters the expansion valve at a temperature of 22°C.

The cooling load is 200 kW.

The swept volume of the compressor is 0.0266 m^3 with a volumetric 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 compressor power; (5)

(ii) the coefficient of performance; (2)

(iii) the speed of the compressor. (5)

7. A freezer locker has a 200 mm air gap between the inner aluminium lining and a 10 mm thick outer steel shell.

Some of this gap is to be used by coating the inner surface of the steel with a layer of foam insulation which cannot be used below a temperature of 0°C.

The aluminium lining is at a uniform temperature of -20°C and the atmospheric temperature is 35°C.

Calculate EACH of the following per m^2 of surface area:

(a) the rate of heat flow without the insulation; (4)

(b) the maximum thickness of the foam insulation; (8)

(c) the percentage reduction in heat flow when the insulation is used. (4)

Note: thermal conductivity of air = 0.026 W/mK.
thermal conductivity of the foam insulation = 0.013 W/mK
thermal conductivity of steel = 52 W/mK.
outer surface heat transfer coefficient = 8 W/m^2K

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

A total mass of 9 kg/min of air is compressed from a pressure and temperature of 0.9 bar 27°C respectively, through a pressure ratio of 25:1.

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

The polytropic index of expansion and compression in both stages is 1.28.

The compressor speed is 400 rev/min and the mechanical efficiency of the compressor drive is 85%.

(a) Sketch the cycle on a pressure-Volume diagram. (2)

(b) Calculate EACH of the following:

(i) the input power required to drive the compressor; (6)

(ii) the total heat removed by the jacket cooling water. (8)

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

9. During calibration, the flow rate through a horizontal venturi meter is measured using a collecting tank.

The venturi meter has an inlet diameter of 76 mm and a throat diameter of 38 mm.

The differential pressure is measured by a U tube manometer with the branches in contact with the meter fluid.

The level difference in the U tube remains constant at 266 mm of mercury when 2200 kg of fluid is collected in 4 minutes.

Calculate EACH of the following:

(a) the differential pressure in N/m^2; (3)

(b) the fluid velocities at the meter inlet and throat; (8)

(c) the meter coefficient of discharge. (5)

Note: relative density of mercury = 13.6
relative density of venturi fluid = 1.01