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, 16 JULY 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. Helium, of volume 0.6 m^3, is isentropically compressed from a pressure and temperature of 1.2 bar and 20°C respectively, to a pressure of 12 bar. It is then cooled at constant pressure to the original temperature after which, it expands isothermally to the initial state.

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

   (b) Calculate EACH of the following:

   (i) the net heat transfer; (6)

   (ii) the net work transfer; (6)

   (iii) the maximum change in entropy. (2)

   Note: for Helium c_p = 5.193 kJ/kgK, Molecular mass = 4.003 kg/kmolK
   Universal gas constant R_o = 8.3145 kJ/kmolK

2. In the open cycle gas turbine plant shown in Fig Q2.

Air is compressed from a pressure and temperature of 0.95 bar and 15°C respectively through a pressure ratio of 6 with an isentropic efficiency of 0.8.

The turbine has an entry temperature of 850°C and expands the gas to the original pressure with an isentropic efficiency of 0.88.

A regenerator with a thermal ratio of 0.7 is used to heat the air before it enters the combustion chamber.

The mass flow of fuel may be ignored.

(a) Calculate EACH of the following

(i) the work ratio; (8)

(ii) the thermal efficiency. (4)

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

Note: for air $\gamma = 1.4$ *and* $c_p = 1.005$ *kJ/kgK*

for combustion gas $\gamma = 1.33$ *and* $c_p = 1.15$ *kJ/kgK*

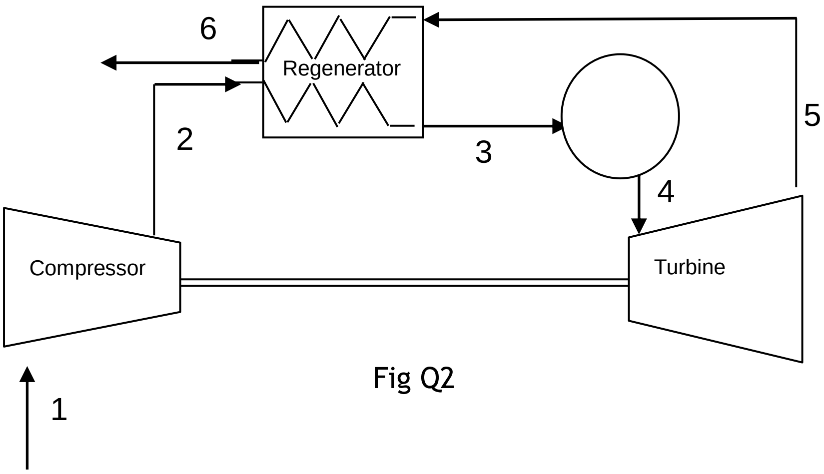

Fig Q2

3. A fuel has a mass analysis of 81.6% carbon and 18.4 % hydrogen.
It is burned at a pressure of 2.5 bar with an air fuel ratio of 14:1. The combustion gasses are then cooled at constant pressure to a temperature of 39°C.

Calculate EACH of the following for 1 kg of fuel:

(a) the volumetric analysis of the combustion gas before cooling; (10)

(b) the mass of water removed from the gas during the cooling process. (6)

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

4. In a regenerative cycle, steam enters the turbine at a pressure and temperature of 40 bar and 350°C respectively.

The steam expands isentropically to a dry saturated state, at which point some is bled off to a direct contact feed heater.

The remainder of the steam expands isentropically to the condenser pressure of 0.05 bar.

The feed water leaves the condenser with 6.2 K of subcooling and leaves the feed heater at the saturation temperature of the bled steam.

Feed pump work can be ignored.

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

(b) Calculate EACH of the following:

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

(ii) the thermal efficiency of the cycle; (8)

(iii) the specific steam consumption. (2)

5. Steam at a rate of 2 kg/s flows through a single row impulse turbine which has a mean blade ring diameter of 956 mm and runs at 4000 rev/min.

The nozzles are set at 25° to the plane of rotation and reduce the specific enthalpy of the steam by 320 kJ/kg.

The blades have a velocity coefficient of 0.8 with inlet and outlet angles selected to give zero axial thrust.

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

(b) Determine EACH of the following:

(i) the blade inlet and outlet angles; (3)

(ii) the driving force on the blades; (3)

(iii) the diagram power; (2)

(iv) the diagram efficiency. (3)

6. A vapour compression refrigeration system operates between the pressures of 2.68 bar and 10.34 bar. It produces 2 tonnes/hour of ice at -8°C from water at 25°C.

The ammonia refrigerant enters the compressor at a temperature of 13°C. It leaves the compressor with 100 K superheat.

The mass flow rate is 750 kg/hour.

(a) Calculate EACH of the following:

(i) the dryness fraction of the refrigerant entering the evaporator; (5)

(ii) the degree of undercooling in the condenser; (3)

(iii) the compressor power; (2)

(iv) the coefficient of performance. (2)

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

Note: for water specific heat capacity = 4.2 kJ/kgK
for ice specific heat capacity = 2.1 kJ/kgK,
latent heat of fusion = 334 kJ/kg

7. A steam pipe with a bore of 120 mm and wall thickness of 10 mm is 100 m long. It is insulated with two materials each of 50 mm thickness.

Dry saturated steam at a pressure of 14 bar enters the pipe at a rate of 576 kg/hour.

The atmospheric temperature is 15°C.

Calculate EACH of the following:

(a) the heat loss from the steam per hour; (6)

(b) the dryness fraction of the steam leaving the pipe; (5)

(c) the insulation interface temperature; (2)

(d) the outer surface temperatures. (3)

Note: inner heat transfer coefficient may be ignored
thermal conductivity of steel = 55 W/mK
thermal conductivity of the inner insulation = 0.05 W/mK
thermal conductivity of the outer insulation = 0.15 W/mK
outer heat transfer coefficient = 15 W/m^{2}K

8. A four stage reciprocating air compressor is designed for minimum work and has perfect intercooling. The inlet pressure and temperature are 0.958 bar and 17°C respectively.

The discharge pressure is 245.28 bar.
The index of expansion and compression in all the stages is 1.22.
The air delivery is 2 m^3/s at free air conditions of 1.015 bar and 15°C.
The mechanical efficiency of the compressor is 82%.

(a) Calculate EACH of the following:

(i) the interstage pressures; (3)

(ii) the air delivery temperature; (2)

(iii) the power input; (4)

(iv) the total heat removed by the intercoolers. (4)

(b) Sketch the cycle on a pressure Volume diagram indicating the intermediate pressures. (3)

Note: For air R = 287 J/kgK, γ = 1.4

9. A centrifugal pump runs at 600 rev/min and discharges sea water at the rate of 7 m^3/min against a head of 14 m.

The impeller has an outer diameter of 500 mm and exit width of 30 mm.

The vanes are backward facing at an angle of 40° from the impeller tangent.

There is no whirl at inlet and the thickness of the vanes may be ignored.

(a) Sketch the blade tip velocity vector diagram identifying the velocities. (4)

(b) Calculate EACH of the following:

(i) the radial velocity of the fluid; (2)

(ii) the whirl velocity at exit; (3)

(iv) the absolute velocity of the fluid at exit; (2)

(v) the theoretical head; (3)

(vi) the manometric efficiency. (2)