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 95 CHIEF ENGINEER REG. III/2 (UNLIMITED)

041-32 – APPLIED HEAT

MONDAY 13 JULY 2015

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' by Mayhew & Rogers (5th edition)

APPLIED HEAT

Attempt SIX questions only.

All questions carry equal marks.

Marks for each part question are shown in brackets.

1. Carbon Dioxide is compressed reversibly in a cylinder according to the law $pV^n = C$.

   The initial pressure, volume and temperature are 1.02 bar, 0.084 m^3 and 30°C respectively.

   The final pressure and temperature are 5.1 bar and 123°C respectively.

   (a) Sketch the p-V and T-s diagrams. (3)

   (b) Calculate EACH of the following:

   (i) the index of compression; (2)

   (ii) the work transfer; (3)

   (iii) the heat transfer; (3)

   (iv) the change in entropy. (5)

   Note: For CO_2 $\gamma = 1.33$, Relative atomic masses C=12,O=16
   the universal constant $R_o = 8.3145$ kJ/kmolK

2. An air standard dual combustion cycle operates with a minimum pressure and temperature of 1 bar and 300 K respectively. The volume compression ratio is 23:1.

   The maximum pressure is 100 bar and the maximum temperature is 1800 K.

   (a) Sketch the cycle on p-V and T-s diagrams. (2)

   (b) Calculate EACH of the following:

   (i) the temperatures and pressures at the cardinal points in the cycle; (6)

   (ii) the specific work output; (6)

   (iii) the cycle efficiency. (2)

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

3. A fuel with a volumetric analysis of 75% Methane CH_4 and 25% Ethane C_2H_6 is completely burned in 50% excess air.

(a) Formulate the complete combustion equation in kmol per kmol of fuel. (8)

(b) Calculate the gravimetric analysis of the exhaust gases. (4)

(c) Comment on the effect of the excess air on the combustion process and the exhaust gases. (4)

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

4. A regenerative steam power cycle operates between temperatures of 450°C and 34°C. The maximum pressure is 20 bar. The optimum mass of bled steam at 3 bar is used to heat the feed water in a surface heat exchanger.

The heater drain is returned to the main condenser through a throttle and the feed water leaves the condenser as a saturated liquid.

The turbine expansion and the feed pump work (which cannot be ignored) are both isentropic.

(a) Sketch the cycle on a T-s diagram. (5)

(b) Determine EACH of the following:

(i) the mass flow of bled steam; (8)

(ii) the thermal efficiency. (3)

5. The specific enthalpy drop in the nozzles of a simple impulse turbine is 490 kJ/kg.
The moving blades are symmetrical with a velocity coefficient of 1.
The absolute velocity of the steam at exit from the stage is in an axial direction.
The diagram efficiency is 0.86.

(a) Sketch the velocity vector diagram labelling all the velocities and angles. (6)

(b) Calculate EACH of the following:

(i) the nozzle angle; (6)

(ii) the blade angle; (2)

(iii) the blade work per kg of steam flow. (2)

6. A vapour compression refrigeration cycle operates between evaporation and condensation temperatures -15°C and 35°C respectively.

The refrigerant enters the compressor as a dry saturated vapour and the expansion valve as saturated liquid.

Compression is regarded as isentropic.

Two refrigerants R134a and Ammonia are to be considered. (2)

(a) Sketch the cycle on P-h and T-s diagrams.

(b) Determine EACH of the following:

(i) the specific work and compressor discharge temperature when using R134a; (4)

(ii) the specific work and compressor discharge temperature when using Ammonia; (6)

(iii) which system requires the least work for the same cooling load. (4)

7. Wet steam at a pressure of 60 bar flows through a steel pipe of inside diameter of 34 mm and wall thickness 5 mm.

It is covered with insulation 25 mm thick.

The surrounding air temperature is 27°C and the thermal resistance of the steam film may be ignored.

Determine EACH of the following:

(a) the rate of heat loss per metre run of pipe; (7)

(b) the outside surface temperature of the insulation; (2)

(c) the percentage reductions in the rate of heat transfer if the insulation thickness is increased by 5 mm. (7)

Note: the thermal conductivity of the steel is 52 W/mK.
the thermal conductivity of the insulation is 0.05 W/mK.
the outside surface coefficient is 14 W/m^{2}K

8. At the beginning of compression in a single stage, single acting reciprocating air compressor, the air is at a pressure of 0.98 bar and a temperature of 24°C.

When the delivery valve opens the pressure is 5.5 bar and the temperature is 145°C.

The cylinder has a diameter of 270 mm and the stroke is 300 mm. The clearance volume is 5% of the swept volume and the compressor runs at a speed of 500 Rev/min.

(a) Sketch the process on a p-V diagram. (2)

(b) Calculate EACH of the following:

(i) the index of compression; (2)

(ii) the volumetric efficiency; (3)

(iii) the indicated power. (5)

(c) Explain how the polytropic index influences the quantity of air delivered. (4)

9. Dry saturated steam at 30 bar enters a convergent divergent nozzle and expands isentropically to 10 bar. The expansion follows the law $pv^{1.19}$ = constant.

The mass flow of steam is 8.2 kg/s.

(a) Determine EACH of the following:

(i) the throat area; (6)

(ii) the exit area. (6)

(b) Impulse turbine nozzles have a convergent-divergent form while reaction turbine nozzles are normally convergent. Explain how this relates to the critical pressure ratio and nozzle exit velocity. (4)

Note: $$\frac{P_c}{P_0} = \left(\frac{2}{n+1}\right)^{\left(\frac{n}{n-1}\right)}$$