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, 12 OCTOBER 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. A volume of 1 m^3 of air at a pressure and temperature of 4 bar and 150°C respectively expands isentropically to 1 bar, after which 120 kJ of heat is added at constant pressure.

   The two processes can be replaced with a single polytropic process operating between the same initial and final states.

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

   (b) Calculate EACH of the following:

   (i) the original total work done; (6)

   (ii) the index of expansion for the single polytropic process; (2)

   (iii) the total change in entropy. (4)

   Note: For air c_p= 1.005 kJ/kgK, R = 0.287 kJ/kgK and γ = 1.4

2. A six cylinder 4 stroke diesel engine has a bore of 230 mm and stroke of 600 mm. The brake mean effective pressure is 8 bar at 900 rev/min and the brake specific fuel consumption is 0.139 kg/kWh when burning a fuel with a calorific value of 46 MJ/kg.
   The air to fuel ratio by mass is 28:1 at atmospheric conditions of 0.95 bar and 17°C.

   (a) Show that the brake mean effective pressure is directly proportional to engine torque and independent of speed. (4)

   (b) Calculate EACH of the following:

   (i) the shaft torque; (2)

   (ii) the brake thermal efficiency; (4)

   (iii) the volumetric efficiency of the engine. (6)

   Note: For air R = 0.287 kJ/kgK

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3. A pure hydrocarbon fuel has the chemical formula C_nH_{2n+2} (where n is a positive integer).
When the fuel is burned in air the dry flue gas analysis shows they contain 10.50% carbon dioxide, 0.95% carbon monoxide, 4.55% oxygen by volume.

Calculate EACH of the following:

(a) the chemical formula of the fuel; (10)

(b) the percentage excess air supplied. (6)

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

4. Steam enters the high pressure stage of a turbine at a pressure and temperature of 60 bar 450°C respectively and expands to 15 bar with an isentropic efficiency of 0.697.
The steam then enters a low pressure stage where it expands to 0.05 bar during which it develops 60% of the total power generated.
There is no under cooling in the condenser and the feed pump work may be ignored.

(a) Determine EACH of the following:

(i) the steam condition at the inlet to the low pressure turbine; (4)

(ii) the steam condition at the outlet from the low pressure turbine; (4)

(iii) the specific steam consumption; (2)

(iv) the thermal efficiency of the cycle. (2)

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

5. The nozzle angle of a two row Curtis wheel is 20º to the plane of rotation and the isentropic enthalpy drop in the nozzle is 222 kJ/kg.

The fixed and moving blade rows are symmetrical each with a velocity coefficient of 0.95.

The mean blade speed is 150 m/s and nozzles have an isentropic efficiency of 90%.

(a) Calculate the nozzle exit velocity. (2)

(b) Draw to a scale of 1 mm = 5 m/s the velocity diagram for each row. (6)

(c) Determine EACH of the following:

(i) the magnitude of the steam velocity entering and leaving each blade; (2)

(ii) the fixed and moving blade angles; (2)

(iii) the total blade work per kg of steam flowing; (2)

(iv) the diagram efficiency. (2)

6. A vapour compression refrigeration cycle using Ammonia operates between saturation temperatures of -24ºC and +20ºC.
The refrigerant enters the compressor as a dry saturated vapour and during compression the specific entropy increases by 2.95 %.
After cooling it enters the expansion valve as a saturated liquid.
The compressor has a stroke of 200 mm and a bore of 100 mm, with a volumetric efficiency of 85% at 300 rev/min.
The mechanical efficiency of the drive is 90%.

(a) Sketch the cycle on P-h and T-s diagrams. (4)

(b) Calculate EACH of the following:

(i) the mass flow of refrigerant; (4)

(ii) the cooling load based on the mass flow obtained Q6b(i); (2)

(iii) the input power; (4)

(iv) the coefficient of performance of the plant, including the mechanical efficiency of the drive. (2)

7. A steel pipe 100 mm bore and 10 mm wall thickness carries dry saturated steam at 12 bar.
It is covered with a 50 mm layer of moulded insulation which in turn, is covered with a 60 mm layer of felt.
This combination gives an outer surface temperature of 30°C.
The felt is to be replaced with a new insulation which will maintain the original heat transfer rate but requires an interface temperature of 82.5°C between the felt and the insulation.

Calculate EACH of the following:

(a) the original rate of heat loss per unit length of pipe; (8)

(b) the change in the moulded insulation thickness to maintain the required condition. (8)

Note: inner surface heat transfer coefficient = 550 W/m^{2}K
thermal conductivity of moulded insulation = 0.07 W/mK
thermal conductivity of felt = 0.09 W/mK

8. In a single acting two-stage reciprocating air compressor with negligible clearance, 30 m^3 of air per minute are compressed through an overall pressure ratio of 16:1.
The initial pressure and temperature are 1 bar and 27°C respectively.
The pressure ratio in each stage is the same.
The polytropic index for each compression process is 1.35.
Inter-cooling is perfect and the mechanical efficiency of the compressor is 0.92.

(a) Sketch the process on a p-V diagram indicating the work saved by inter-cooling. (2)

(b) Calculate EACH of the following:

(i) the power input to the compressor; (4)

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

(iii) the heat transfer to the jacket cooling during compression. (6)

Note: for air R = 0.287 kJ/kgK c_v = 0.718 kJ/kgK

9. A perfect gas at a pressure and temperature of 7 bar and 93°C respectively enters a circular section convergent-divergent nozzle with a negligible velocity.

It expands isentropically into a space at 3.6 bar.

The cross-sectional area of the nozzle throat is 0.196 m^2.

Calculate EACH of the following:

(a) the critical pressure; (4)

(b) the mass flow through the nozzle; (6)

(c) the diameter of the nozzle at exit. (6)

Note : for the gas molecular mass M = 30 kg/kmol, c_v *= 1.383 kJ/kgK*
The universal gas constant = 8.3145 kJ/kmolK