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, 4 APRIL 2016

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:

Candidates 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 0.02 m^3 of air at a pressure and temperature of 1.05 bar and 15°C respectively is heated at constant volume until the pressure is 4.2 bar. It is then cooled at constant pressure to the initial temperature.

   (a) Sketch the processes on a Temperature-specific entropy diagram. (3)

   (b) Calculate EACH of the following:

   (i) the net heat flow; (8)

   (ii) the net change in entropy. (5)

   Note: for air R = 0.287 kJ/kgK and γ = 1.4

2. A Morse test was carried out on a 4 cylinder, 4 stroke compression ignition engine and the following data was noted.

Engine speed 3000 rev/min,
Full load brake torque 255 Nm.
Air fuel ratio by mass 30:1,

Morse test result				
Cylinder cut out	1	2	3	4
Brake Power kW	57.77	57.40	57.11	57.90

Data Table						
	Flow rate Litres/ min	specific heat capacity kJ/kg,	inlet temperature °C	outlet temperature °C	Density kg/m^3	Calorific values MJ/kg
cooling water	9.87	4.18	48	80	1000	
lubricating oil	46.21	2.1	40	48	850	
Air			45			
Gas		1.15		450		
Fuel	0.344				720	43

(a) Calculate EACH of the following:

(i) the indicated power; (3)

(ii) the brake specific fuel consumption; (3)

(iii) the indicated thermal efficiency. (2)

(b) Draw up an energy balance as a percentage of the total energy supplied. (8)

3. A fuel of mass analysis 84% carbon and 16% hydrogen is completely burned in air. The dry flue gas analysis shows they contain 81% nitrogen by volume.

(a) Determine, using molar volumes, the full combustion equation for 1 kg of fuel. (8)

(b) Calculate EACH of the following:

(i) the air fuel ratio by mass; (2)

(ii) the mass of water condensed per kg of fuel when the flue gas is at 1.01 bar and 20°C. (6)

Note: Relative atomic masses H =1, C =12, N =14, O =16
Air contains 21% oxygen by volume.
The Molar mass of air may be taken as 29 kg/kmol.

4. In a regenerative steam power plant, steam enters the turbine at a pressure and temperature of 30 bar and 450°C respectively.
It then expands isentropically to a dry saturated condition at which point some steam is bled off to a direct contact feed heater.
The feed water leaves the heater 4.5 K below the saturation temperature of the bled steam pressure.
The remainder of the steam expands isentropically to a condenser pressure of 0.035 bar.
There is no under cooling in the condenser and the feed pump work may be ignored.

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

(b) Determine EACH of the following:

(i) the mass flow rate of bled steam per kg of steam flowing; (5)

(ii) the specific work output; (4)

(iii) the thermal efficiency of the cycle. (3)

5. The first stage of an impulse turbine is velocity compounded with two rows of moving blades.

The steam leaves the nozzles with an absolute velocity of 800 m/s at an angle of 17° to the plane of rotation.

The mean blade diameter is 750 mm and the exit angle from the first row of moving blades, the fixed blades and the second row of moving blades are 22°, 28° and 36° respectively.

The blade velocity coefficient is 0.92 over each of the three rows of blades.

The mass flow rate of steam is 6 tonne/hour and the turbine shaft speed is 3500 rev/min.

Determine EACH of the following:

(a) the fixed and moving blade inlet angles; (8)

(b) the power developed; (4)

(c) the axial thrust acting on the rotor. (4)

6. In a vapour compression refrigeration cycle Ammonia is compressed between saturation temperatures of -12°C and +22°C.
The refrigerant is dry saturated at entry to the compressor and leaves the condenser with 4 degrees of under-cooling.
The cooling load is 1.5 MW and the isentropic efficiency of the compressor is 82%.

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

(b) Determine EACH of the following:

(i) the co-efficient of performance; (6)

(ii) the compressor power in kW; (2)

(iii) the Carnot co-efficient of performance between the same pressure limits. (4)

7. An annular cooling water jacket surrounds a 75 mm mean diameter pipe carrying a hot gas, in a counter flow arrangement.
The hot gas enters the cooler at 350°C and leaves at 100°C. The cooling water enters the cooler at 10°C.
The flow rate of the gas is 200 kg/hour and that of the water is 1400 kg/hour.
The wall thickness of the pipe may be ignored.

Calculate EACH of the following:

(a) the exit temperature of the water; (4)

(b) the log mean temperature difference; (6)

(c) the length of the cooler. (6)

Note: for cooling water c = 4.19 kJ/kgK
for the hot gas c_p *= 1.13 kJ/kgK*
the inner surface heat transfer coefficient = 0.3 kW/m^2*K*
the outer surface heat transfer coefficient = 1.5 kW/m^2*K*

8. In a single acting two stage reciprocating air compressor, air is compressed from an inlet pressure and temperature of 0.9 bar and 20°C respectively to a delivery pressure of 12 bar.

The low pressure cylinder has a bore of 250 mm, stroke of 160 mm and the clearance volume is 2.5% of the swept volume.

The air enters the second stage at a pressure and temperature of 3 bar and 35°C respectively.

The compressor speed is 300 rev/min.
The index of compression and expansion in both stages is 1.25.
The mechanical efficiency is 0.85.

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

(b) Calculate EACH of the following:

(i) the free air delivered per hour at free air conditions of 1 bar and 15°C; (6)

(ii) the input power required to drive the compressor; (5)

(iii) the heat removed in the inter-cooler. (3)

Note: *for air R = 0.287 kJ/kgK* c_p *= 1.005 kJ/kgK*

9. Steam enters a convergent-divergent nozzle with negligible velocity and expands into a space at 5 bar.

At inlet the pressure is 15 bar and temperature is 400°C.

The process from the inlet to the throat is isentropic with an index of 1.37.

The process from the throat to the exit has an isentropic efficiency of 0.9.

Calculate EACH of the following:

(a) the condition of the steam at the throat; (4)

(b) the velocity of the steam at the throat; (3)

(c) the throat area for a mass flow of 1 kg/s; (4)

(d) the exit velocity. (5)