CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY MARINE ENGINEER OFFICER

STCW 78 as amended MANAGEMENT ENGINEER REG. III/2 (UNLIMITED)

040-32 - APPLIED HEAT

MONDAY, 14 JULY 2025

1315 - 1615 hrs

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

Examination Paper Inserts

Notes for the guidance of candidates:

1. Examinations administered by the SQA on behalf of the Maritime & Coastguard Agency.
2. Candidates should note that 96 marks are allocated to this paper. To pass, candidates must achieve 48 marks.
3. Non-programmable calculators may be used.
4. All formulae used must be stated and the method of working and all intermediate steps must be made clear in the answer.

Maritime & Coastguard Agency

SQA

APPLIED HEAT

Attempt SIX questions only

All questions carry equal marks

Marks for each part question are shown in brackets

1. A mass of 0.9 kg of a gas is heated at constant volume from a pressure and temperature of 2 bar and 30°C respectively to a pressure of 6.5 bar. The gas is then isothermally expanded to its original pressure.

   (a) Calculate EACH of the following:

      (i) the temperature after the initial heating process; (2)

      (ii) the net work transfer; (2)

      (iii) the total heat transfer; (4)

      (iv) the total change in entropy; (4)

   (b) Sketch the process on p-V and T-s graphs. (4)

   Note: $R = 413.9\ J/kgK$, $y = 1.4$, $c_P = 1448.65\ J/kgK$, $c_v = 1034.75\ J/kgK$

2. A compression ignition engine working on the ideal dual combustion cycle has a volume compression ratio of 14:1. The pressure and temperature at the beginning of compression are 1 bar and 27°C respectively. The pressure and temperature at the completion of heat supply are 45 bar and 1275°C.

   Determine EACH of the following:

   (a) all temperatures; (6)

   (b) the net specific heat supply and the net specific work; (8)

   (c) the thermal efficiency. (2)

   Note: For air $y = 1.4$, and $c_P = 1.005\ kJ/kgK$, $c_V = 0.718\ kJ/kgK$

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3. In a two-stage reciprocating air compressor, 4.5 kg of air per minute is compressed from 1.013 bar at 15°C through a pressure ratio of 9 to 1. Both stages have the same pressure ratio, and the law of compression in both stages is $PV^{1.3} = C$. The compressor has perfect intercooling.

(a) Sketch the p-V diagram of the compressor. (4)

(b) Calculate EACH of the following:

(i) the indicated power of the compressor; (6)

(ii) rate of heat loss to the cylinder jacket cooling water; (4)

(iii) the rate of heat loss to the intercooler circulating water. (2)

4. A boiler generates 7500 kg of steam per hour at 40 bar. The steam temperature is 350°C and the feedwater temperature is 20°C. The fuel supplied has a calorific value of 60 MJ/kg and is supplied at a rate of 0.15 kg/s.

On exiting the boiler, the steam is further heated to 600°C before being throttled to 10 bar.

(a) Calculate the boiler efficiency. (9)

(b) Calculate the power required in the superheater. (4)

(c) Draw the process on a pressure enthalpy diagram. (3)

5. A vapour compression refrigeration cycle operates between 2.191 bar and 4.233 bar. Upon leaving the evaporator, R12 is dry saturated vapour and then leaves the compressor with 15 K of superheating. No undercooling takes place.

(a) Determine each of the following in table 5: (13)

	P (bar)	T(°C)	h (kJ/kg)	s (kJ/kgK)
1				
2				
3				
4				

Table 5

(b) Sketch a temperature entropy diagram of the process. (3)

6. 0.12kg/s of hot oil at 71°C with C 2.20 kJ/kgK enters a double pipe heat exchanger and is cooled to 27°C. The water enters at 10°C and is warmed to 21°C.

The outside diameter of the inner tube of the heat exchanger is 25 mm. The overall heat transfer coefficient is 3000 W/m^2 K.

For the given duty, calculate EACH of the following:

(a) the log mean temperature difference for counter current flow; (3)

(b) the rate of heat transfer; (3)

(c) the mass flow rate of water; (4)

(d) the length of the pipe of the heat exchanger. (6)

Note: c_{water} =4.183 kJ/kgK

7. Methane CH_4 is burned with dry air and the volumetric analysis of the products gives 8.2% CO_2, 0.82% CO, 1.48% O_2, 71.48% N_2.and 18.03% H_2O.

For 100 m^3 of flue gas exhaust, calculate EACH of the following:

(a) the mass of air; (8)

(b) determine the mass analysis of the dry flue gas per Table Q7. (8)

Substance	C	H	O	N
GFM (g/mole)	12	1	16	14

Table Q7

Note: Air is 21% Oxygen & 79% Nitrogen by volume

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8. In an impulse turbine the nozzles are inclined at 20° to the blade motion and the blade inlet and outlet angles are 34 and 30 degrees respectively. Steam leaves the nozzles with an absolute velocity of 1000 m/s.

The blade velocity coefficient is 0.88.

(a) Sketch the blade velocity diagram for the turbine. (4)

(b) Determine EACH of the following:

(i) the mean blade speed; (1)

(ii) the absolute velocity of the steam leaving the blades; (6)

(iii) the steam consumption for a power of 20 kW. (5)

9. A horizontal pipe carrying water tapers from 200 mm diameter to 100 mm diameter. The volumetric flowrate is 0.055 m^3/s.

Calculate EACH of the following:

(a) the velocities at both points; (8)

(b) the mass flow rate; (3)

(c) the pressure difference between the two points. (5)

Note: Friction loses can be ignored and $\rho_{fresh\ water} = 1000\ kg/m^3$