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, 31 MARCH 2025

1315 - 1615 hrs

Materials to be supplied by examination centres

Candidate's examination workbook Graph paper Thermodynamic and Transport Properties of Fluids (5^{th} 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

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APPLIED HEAT

Attempt SIX questions only.

All questions carry equal marks.

Marks for each part question are shown in brackets.

1. In a non-flow process 0.4 m^3 of a gas is initially compressed from 3 bar and 250°C to 25 bar and 0.2 m^3 according to the law $PV^n = C$. Then the volume of the gas is reduced isothermally to 0.09 m^3.

   Calculate EACH of the following:

   (a) the temperature after the initial compression; (2)

   (b) the final pressure; (2)

   (c) the specific work done in the initial compression; (2)

   (d) the total specific heat transfer; (6)

   (e) sketch the process on p-V and T-s graphs. (4)

   Note: γ=1.32, n=3.06, $c_p = 2058.4$ J/kgK $c_v = 1559.4$ J/kgK

2. The ratio of compression of an engine working on the constant volume cycle is 9.3:1. At the beginning of compression the temperature is 32°C and at the end of heat supply the temperature is 1205°C.

   Determine EACH of the following:

   (a) the temperatures at the end of compression and expansion; (4)

   (b) the specific net work and thermal efficiency; (6)

   (c) If V_1 = 0.1 m^3 and P_1 = 1 bar find the volume and pressure at each point in the cycle. (6)

   Note: For air $\gamma = 1.4$, $c_v = 0.718$ *kJ/kgK*

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3. A three-stage reciprocating air compressor onboard a tanker. The compressor is perfectly intercooled and has a clearance ratio of 3.5%. The air properties at induction are 1 bar and 20°C and the compressor delivers 25 m^3/min at these conditions

The discharge pressure of the compressor is 15.50 bar. The stage pressure ratios are equal, and the index of compression and expansion is 1.34 for all stages.

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

(b) Calculate EACH of the following:

(i) calculate the indicated power of the compressor; (8)

(ii) the volumetric efficiency. (4)

Note: For Air $c_p = 1005$ J/kgK, $c_v = 718$ J/kgK

4. In a steam plant, using reheat, the turbine receives the steam at a pressure and temperature of 20 bar and 400°C respectively. The steam expands isentropically in the first stage until it is just dry saturated.

It is then reheated at constant pressure to 400°C and is expanded isentropically in the second stage to a condenser pressure of 0.04 bar.

The feed pump work cannot be neglected, there is no undercooling in the condenser and the steam flow rate is 4.86 tonne per hour.

Calculate EACH of the following:

(a) The power output; (14)

(b) The specific steam consumption. (2)

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5. A vapour compression refrigeration cycle uses R134a as a refrigerant. The refrigerant enters the compressor at 1.0637 bar and -15°C, where it undergoes isentropic compression until it reaches 11.595 bar.

The condenser undercools the refrigerant by 25 K.

(a) Sketch the p-h and T-s graphs of the cycle. (4)

(b) Determine the following points:

(i) the enthalpy and entropy at the compressor inlet; (2)

(ii) the temperature and enthalpy at the compressor outlet; (4)

(iii) the enthalpy and entropy at the evaporator inlet; (3)

(iv) coefficient of performance COP. (3)

6. A steel pipe of 25 mm bore and 5 mm wall thickness carries water at a temperature of 80°C. The outside temperature of the air is 30°C. The inner and outer heat transfer coefficients are 100 W/m²K *and* 10 W/m²K.

Calculate EACH of the following:

(a) the heat rate transferred across the pipe; (6)

(b) the temperature between the water the inner surface of steel and between the outer surface of steel and the air; (4)

(c) the thickness of Felt required to reduce the outer temperature to 35°C assuming the rate of heat transfer is unchanged. (6)

Note: $k_{Steel} = 60$ W/mk, $k_{Felt} = 0.038$ W/mK

7. A gas containing carbon 75%, hydrogen H_2 24%, and sulphur 1% by volume is burnt completely with 23% excess air. Air is 21% Oxygen & 79% Nitrogen by volume.

Substance	C	H	O	N	S
GFM (g/mole)	12	1	16	14	32

Calculate EACH of the following:

(a) The mass of air per 100 m^3 of the exhaust gas; (5)

(b) The volumetric analysis of the exhaust wet gas; (5)

(c) The mass analysis of the dry exhaust gas. (6)

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8. The velocity of steam leaving the nozzles of an impulse turbine is 900 m/s and the nozzle angle is 20°. The blade velocity is 300 m/s and the blade velocity coefficient is 0.7.

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

(b) For a mass flow of 1 kg/s, and symmetrical blading, calculate EACH of the following:

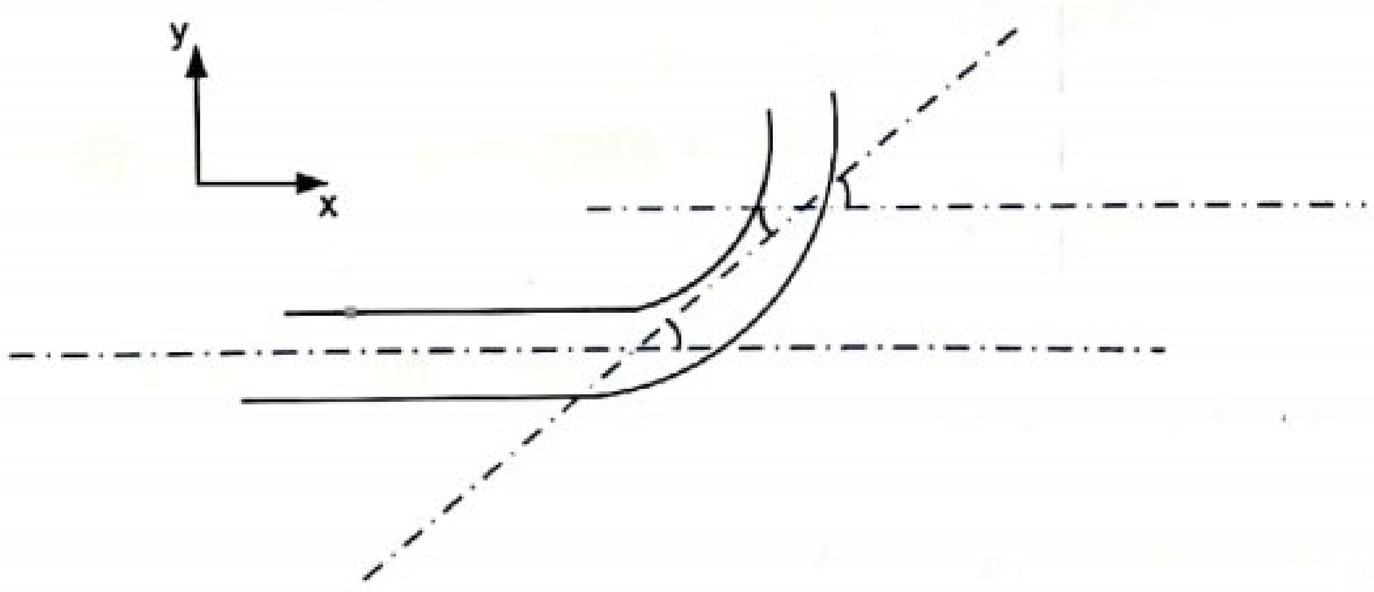
(i) The blade inlet angle; (4)

(ii) The driving force on the wheel; (5)

(iii) The axial thrust. (3)

9. A 70 degree bend is fitted in a horizontal section of a 480 mm diameter fresh water cooling system. The cooling system pressure is 2.95 bar, the flowrate is $0.94\ m^3/s$ and the pressure loss due to the bend is negligible.

Calculate the magnitude of the resultant force acting on the bend. (16)



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