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, 16 OCTOBER 2023

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 gas with molar mass 46 kg/kmolK and mass 0.056 kg is cooled at constant volume of 0.0046 m^3 from 281 K to 1/2 its original pressure. It is then isentropically compressed according to $PV^{\gamma} = C$ to ½ of its original volume.

(a) Sketch PV and Ts diagrams. (2)

(b) Calculate the specific gas constant. (2)

(c) Find the heat transfer during the initial process. (5)

(d) Calculate EACH of the following:

(i) the final temperature; (4)

(ii) the isentropic work done. (3)

Note: Ru= 8.314 kJ/kmolK and Cv= 451 J/kgK

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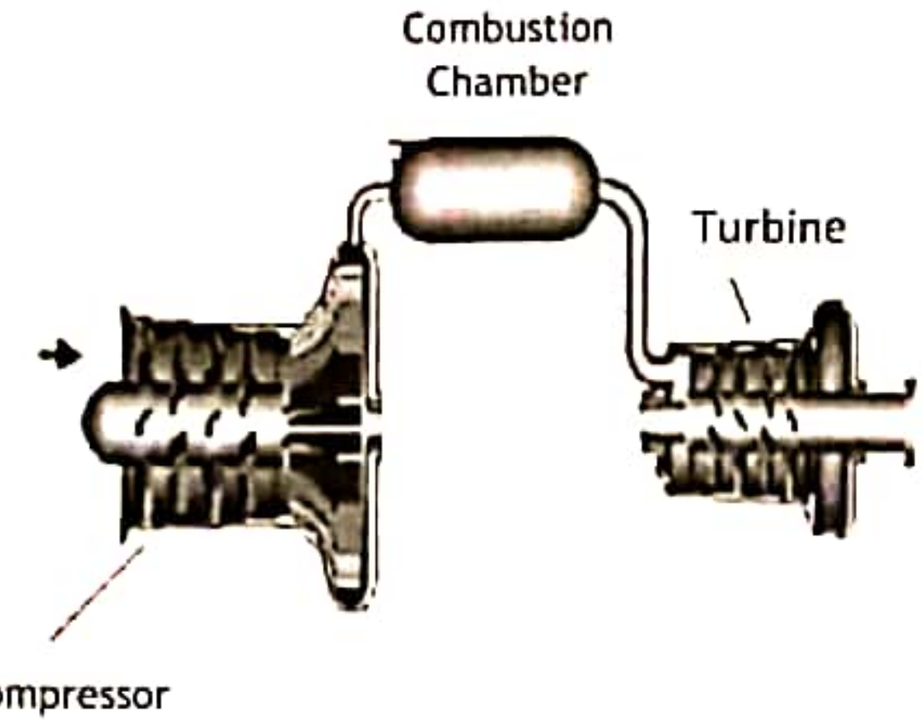
2.



The compressor in an open gas turbine cycle receives air in at a pressure and temperature of 1.054 bar and 17°C and delivers to the combustion chamber at a pressure of 5.8 bar and 210°C.

The products of combustion leave at a pressure of 4.97 bar and 517°C and enter a turbine where the gas expands to 1 bar. The isentropic efficiency of the turbine is 0.8 and the power developed by the plant is 134 kW.

Calculate EACH of the following:

(a) the compressor isentropic efficiency; (4)

(b) the mass flow rate of air; (8)

(c) the thermal efficiency of the cycle. (4)

Note: For hot gas, y= 1.33 and Cp= 1.154 kJ/kgK.
For air y= 1.4 and Cp= 1.005 kJ/kgK

3. In a two-stage reciprocating air compressor, the LP suction pressure is 1.04 bar, the LP delivery and HP suction pressure is 8.32 bar and the HP delivery pressure is 24.1 bar. The LP suction temperature is 274 K and the HP suction temperature is 328 K.

The index of compression and expansion is 1.26.

(a) Sketch the pressure volume diagram - showing intercooling. (3)

(b) Calculate EACH of the following:

(i) the indicated work per kg; (7)

(ii) the heat removed in the intercooler per kg; (2)

(iii) the isothermal efficiency. (4)

Note: Cp 1.005 kJ/kgK and Cv=0.718kJ/kgK

4. In a steam plant, using superheat, the turbine receives the steam at a pressure and temperature of 40 bar and 350°C respectively. The steam is isentropically expanded to condenser pressure of 1.6 bar.

The feed pump work cannot be neglected, there is no undercooling in the condenser and the steam flow is 5 tonne per hour.

(a) Sketch the T-s diagram for the cycle. (2)

(b) Calculate EACH of the following:

(i) the total power output from the turbine; (7)

(ii) the thermal efficiency of the cycle. (7)

5. A vapour compression refrigeration system operates between the pressures of 2.465 bar and 4.295 bar.

R717 refrigerant enters the compressor dry saturated and is isentropically compressed. Upon leaving the condenser it is undercooled by 4 K. The mass flow rate is 687 kg/hour.

(a) Sketch the cycle on pressure-specific enthalpy and temperature specific entropy diagrams. (2)

(b) Calculate EACH of the following:

(i) the dryness fraction of the refrigerant entering the evaporator; (3)

(ii) the temperature leaving the compressor; (5)

(iii) the compressor power; (4)

(iv) the coefficient of performance. (2)

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6. Sea water is to be used to cool engine cooling water in a single pass shell and tube heat exchanger. The cooling water enters the tubes at a temperature of 85°C and to be cooled to 24°C.

The flow rate of cooling water will be 2.3 kg/s. The sea water will enter at a temperature of 7°C and its flow rate will be 6.5 kg/s.

The specific heat capacities of both cooling water and sea water may be taken as 4.2 kJ/kgK. The overall heat transfer coefficient is expected to be 3000 W/ m^2K, based on the outside surface area of the tubes.

The tube outside diameter is to be 90 mm.

Calculate EACH of the following:

(a) the outlet temperature of the seawater; (2)

(b) for counter flow the log mean temperature difference and area required; (6)

(c) for parallel flow the log mean temperature difference and length of tube required. (8)

7. A Natural gas consists of the following volumetric composition, Propane (C_3H_8)(2.7%), Methane (CH_4) (88.6%), Ethene (C_2H_4) (3.5%) and Sulphur (S_2) (5.2%).

Determine the Stoichiometric volume analysis of air, for the complete combustion of $1m^3$. (16)

8. In a 50% reaction turbine stage, steam enters the fixed blades with a velocity of 288 m/s, the blade to steam ratio is 0.75 and the inlet angle is 24°. The mean blade ring diameter is 0.4 m.

(a) Sketch the combined velocity diagram, labelling all velocities and angles. (2)

(b) Determine EACH of the following:

(i) the speed of rotation of the turbine rotor; (4)

(ii) the blade inlet angles; (4)

(iii) the diagram efficiency. (6)

9. (a) A jet of fresh water is 80 mm diameter under a head of 54.4 m and strikes a fixed flat plate.

Find the force exerted on the plate when:

(i) the plate is perpendicular to the jet; (4)

(ii) the plate is inclined at 17° to the axis. (2)

(b) Oil of density 900 kg/m^3 flow through a pipe from point A to point B.

At point A the diameter is 225 mm and pressure is 160 kPa. At point B, which is 2 m below, the diameter is 355 mm and pressure is 210 kPa.

Determine EACH of the following:

(i) the velocity of the oil at point A; (8)

(ii) the mass flow rate of the oil. (2)