APPLIED HEAT

Attempt SIX questions only.

All questions carry equal marks.

Marks for each part question are shown in brackets.

1. A mass of 2 kg of carbon dioxide at a pressure and temperature of 12 bar and 800°C respectively, expands in an isentropic process to a pressure of 2 bar. It is then cooled at constant pressure to a temperature of 15°C.

   (a) Sketch the processes on Pressure-Volume and Temperature-specific entropy diagrams. (3)

   (b) Calculate the net-work transfer. (13)

   Note: Atomic mass 44 kg/kmol, Universal gas constant R_o = 8.3145 kJ/kmol K. For Carbon dioxide γ = 1.33

2. In an air standard dual combustion cycle, the initial volume compression ratio is 5:1. The maximum and minimum temperatures are 1350 K and 305 K, respectively.

   The maximum and minimum pressures are respectively 16 bar and 1 bar.

   (a) Sketch the processes on p-V and T-s diagrams. (4)

   (b) Calculate EACH of the following:

   (i) the temperature at all points; (10)

   (ii) the thermal efficiency. (2)

   Note: For air γ= 1.4 and Cp= 1.005 kJ/kgK Cv= 0.718 kJ/kgK

3. A single-acting, two stage reciprocating air compressor is designed for minimum work with perfect intercooling. The compressor delivers 11.2 kg/min of air from an initial condition of 1 bar and 16°C. Air is delivered at is 28 bar.

The index for all compressions and expansions is n= 1.35.

(a) Sketch the pressure volume diagram - showing intercooling. (4)

(b) Calculate EACH of the following:

(i) the indicated power; (6)

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

(iii) the isothermal efficiency. (4)

Note: For air Cp= 1.005 kJ/kgK Cv= 0.718 kJ/kgK

4. A steam turbine isentropically expands steam from a pressure 50 bar and superheated temperature of 415°C to 6 bar.

The feed water leaves the condenser with no undercooling, the feed pump work cannot be ignored.

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

(b) Calculate the thermal efficiency of the cycle. (14)

5. A vapour compression refrigeration system using R134a operates between the pressures of 5.7162 bar and 21.161 bar. The refrigerant enters the compressor and is compressed with 10 K of superheating and compressed through a compressor with an isentropic efficiency of 86%.

No undercooling takes place in the condenser.

(a) Draw the cycle on pressure-specific enthalpy and Temperature-specific entropy diagrams. (2)

(b) Calculate EACH of the following:

(i) the temperature leaving the compressor; (11)

(ii) the coefficient of performance. (3)

6. Hot oil of 0.564 kg/s at 99°C enters a pipe heat exchanger and is cooled to 27°C. The water enters at 5°C and is warmed to 25°C.

(a) Sketch the temperature profile showing counter flow. (2)

(b) Calculate the log mean temperature difference for the counter flow arrangement. (3)

(c) Calculate the rate of heat transfer. (2)

(d) Find the mass flow rate of water. (2)

(e) If the overall heat transfer coefficient is 2500 W/m^2K and the diameter is 50 mm, calculate the length of the tubes. (4)

(f) Explain the relative benefits of counter flow compared to parallel flow. (3)

Note: Cp of hot oil is 2.2 kJ/kgK and water 4.18 kJ/kgK

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%).

Calculate the stoichiometric volume of air, for the complete combustion of $1m^3$.of gas. (16)

Note : Air contain 21%O_2 and 79%N_2 by volume.

8. An impulse turbine has a nozzle at the entrance.

(a) Calculate the nozzle exit velocity if the change in enthalpy across the nozzle is 345 kJ/kg. (2)

(b) Sketch a blade velocity diagram labelling all significant angles and velocities. (3)

(c) The nozzle entrance angle is 16°, the blade velocity is 200 m/s, and the blades are symmetrical and have an angle of 40°. If the blade velocity coefficient is 0.8 and the mass flowrate of the steam is 0.8 kg/s, determine the diagram power. (11)

9. A horizontal pipe has a 180° U-bend with a diameter of 110 mm throughout. It carries a fluid of density 860 m^3/kg at a rate of 0.8 m^3/s. The entrance pressure is 1.2 bar and exit pressure is 0.98 bar.

(a) Sketch the U-bend and label appropriately. (2)

(b) Find the pressure forces at the entrance and exit. (6)

(c) Calculate the velocity of the fluid. (3)

(d) Determine the force exerted by the liquid on the bend. (5)