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 a gas initially expands from 10 bar, 0.005 m^3 and 400 K to 3.75 bar and 0.009 m^3 according to the law $PV^Y = C$. Then the gas expands polytropically to 0.024 m^3, 1 bar and 192 K.

   Calculate EACH of the following:

   (a) the mass of the gas; (3)

   (b) the temperature after the initial expansion; (2)

   (c) the total work; (5)

   (d) the total heat transfer if the change in internal energy in the polytypic process is -1451.32 J; (3)

   (e) the total change in entropy. (3)

   Note: y = 1.67, n = 1.35, c_v = 443.18 J/kgK , Molar mass = 28 kg/kmol

2. A compression ignition engine working on the ideal dual combustion cycle has a compression ratio of 16:1. The pressure and temperature at the beginning of compression are 0.98 bar and 30°C respectively.

   The pressure and temperature at the completion of heat supply are 60 bar and 1300°C.

   Determine EACH of the following:

   (a) T_2, T_3 *and* T_5; (6)

   (b) the net specific heat supplied 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. A single acting, 2-stage reciprocating air compressor is designed with some intercooling. The compressor has equal stage pressure ratios and delivers air from initial conditions of 0.95 bar and 285 K.

At the entrance to the second stage the temperature is 300 K. The index of both compression and expansion is 1.29 and it applies to both stages. The final delivery pressure is 12.90 bar.

(a) Draw the p-V diagram of the compressor. (3)

(b) Calculate EACH of the following:

(i) The specific work required by the compressor; (10)

(ii) The thermal efficiency. (3)

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

4. (a) 2.5 kg/s of water enters a boiler. The water has specific enthalpy of 700 kJ/ and the boiler has a thermal efficiency of 91%. The fuel supplied has a calorific value of 50 MJ/kg at a rate of 0.1 kg/s.

Determine the enthalpy of the steam exiting the boiler. (4)

(b) The steam cycle used on board is Rankine with superheat. The operating pressure of the boiler is 40 bar. The superheat temperature is 300°C. The condenser operating pressure is 0.12 bar.

Assuming all expansions are isentropic, the steam completely condenses, and the pump work CANNOT be ignored:

(i) sketch the T-s diagram of the cycle; (2)

(ii) calculate the isothermal efficiency of the cycle. (10)

5. A vapour compression cycle operates using R717. The refrigerant enters the compressor at 1.196 bar as dry saturated vapour. The refrigerant is isentropically compressed to 8.57 bar. The temperature at the outlet of the condenser is undercooled by 18 K.

(a) Calculate the enthalpy and temperature at the exit of the compressor. (6)

(b) Calculate the entropy at the entrance to the evaporator. (6)

(c) Draw the P-h and T-s graphs to represent the system. (4)

6. A 15 cm diameter hemispheric pipe cap made of steel. The thickness of the cap is 0.35 cm and it is lagged with 2 cm of felt. The inside temperature is at 140°C while the outside air is 27°C. The outside surface film coefficient is 110 W/m^2K and inside surface film coefficient is 9 W/m^2K.

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

(a) Draw a diagram to illustrate the system. (2)

(b) Calculate EACH of the following:

(i) The overall thermal resistance of the system; (6)

(ii) The heat loss per one hour; (2)

(iii) The interface temperatures. (6)

7. 4.2 $m^3 Propane$ C_3H_8 is completely burned with 10% excess air.

Air is 21% Oxygen & 79% Nitrogen by volume.

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

(a) Write the complete balanced combustion reaction equation. (3)

(b) Carry the volumetric analysis of the wet exhaust gas. (4)

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

(d) Taking atmospheric pressure as 1 bar, calculate the partial pressure and the dew point of the exhaust gas. (3)

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 520 kJ/kg. (3)

(b) The turbine has a nozzle entrance angle 21°, the blade velocity is 400 m/s and the blades are symmetrical and have an angle of 33.5°. If the blade velocity coefficient is 0.97 and the mass flow rate of the steam is 2.1 kg/s:

(i) sketch the blade velocity diagram for the turbine; (4)

(ii) calculate the diagram power. (9)

9. An olive oil centrifugal pump has an outer diameter of 650 mm and an outer blade width of 9.5 mm.

It runs at 475 rpm; the outlet radial velocity is 5.5 m/s and the outlet tangential velocity is 6.6 m/s.

(a) Sketch the velocity diagrams of the centrifugal pumps. (6)

(b) Calculate Each of the following:

(i) The blade outlet angle; (4)

(ii) The mass flow rate; (4)

(iii) The power. (2)

Note: $\rho_{olive\ oil} = 920\ kg/m^3$