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 0.15 m^3 of a gas is initially compressed from 1.5 bar and 210°C to 20 bar and 0.025 m^3 according to the law $PV^{1.446} = C$. After compression, the pressure is reduced at constant volume to 10 bar.

   Calculate EACH of the following:

   (a) the total specific work done; (6)

   (b) the total specific heat transferred; (6)

   (c) the total change in specific entropy. (4)

   Note: $y=1.3$ $R = 502$ J/kgK, $c_p = 2175.3$ J/kgK, $c_v = 1673.3$,J/kgK

2. In a simple open cycle gas turbine plant, air enters the compressor at 1.013 bar and 350 K and is compressed to 7.2 bar with an isentropic efficiency of 0.90.

   Gas leaves the combustion chamber at 7.2 bar and 1290 K and expands to 1.013 bar in the turbine with an isentropic efficiency of 0.94.

   Determine EACH of the following:

   (a) the actual temperatures at points after the compressor and the turbine; (8)

   (b) the net specific work done; (5)

   (c) the net specific heat energy supplied; (2)

   (d) the thermal efficiency. (1)

   Note: For hot gas, $y = 1.34$, $c_p = 1.14$ kJ/kgK
   For air $y = 1.4$, $c_p = 1.005$ kJ/kgK $c_v = 0.718$ kJ/kgK

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3. A single acting, 2-stage reciprocating air compressor with equal stage pressure ratios is designed with perfect intercooling. The compressor delivers 7.4 m^3/min of air from initial conditions of 0.90 bar and 290 K. The index of both compression and expansion is 1.25 for both stages. The final delivery pressure is 10.50 bar.

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

(b) Calculate EACH of the following:

(i) the indicated power; (9)

(ii) the rate of intercooling. (2)

(c) If the clearance ratio is 0.0025 find the volumetric efficiency. (2)

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

4. A Rankine cycle with superheating and reheating operates between the following temperature and pressure limits:

Boiler pressure 60 bar
Superheating temperature 300°C
Reheating pressure is 40 bar
Reheating temperature 300°C
Condenser pressure 0.025 bar

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

(a) draw the cycle on a T-s diagram; (3)

(b) calculate the thermal efficiency. (13)

5. A vapour compression cycle operates using R12. It enters the compressor at 2.191 bar and 5°C. The refrigerant passes through the compressor which has an isentropic efficiency of 96% to 12.19 bar. The temperature at the outlet of the condenser is undercooled by 5 K.

(a) Determine EACH of the values listed in Table Q5. (11)

h_1 (kJ/kg)	h_2 (kJ/kg)	h_3 (kJ/kg)	h_4 (kJ/kg)
s_1 (kJ/kgK)	T_2 (°C)	T_3 (°C)	x_4

Table Q5

(b) Determine the coefficient of performance. (1)

(c) Draw the p-h, T-s graphs of the cycle. (4)

6. Water at 80°C flows through a internal 50 mm steel pipe with wall thickness 10 mm. The pipe is lagged with 40 mm of felt. The outside air is at 25°C. The inside and outside heat transfer coefficients are 1136 and 9.7 W/m^2K respectively.

(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 per metre length of pipe; (2)

(iii) the interface temperatures. (6)

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

7. 2.9 m^3 Butane C_4H_{10} is completely burned with 21% 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. (3)

(b) Calculate EACH of the following:

(i) the volumetric analysis of the wet exhaust gas; (4)

(ii) the mass analysis of the exhaust dry gas; (6)

(iii) the partial pressure and the dew point of the exhaust gas at 1 bar. (3)

8. 4 kg/s of steam enters an impulse turbine at an angle of 20° with a velocity of 1019.80 m/s. The turbine blades are symmetrical and have a blade coefficient of 0.88 and the blade velocity is 380 m/s.

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

(b) Calculate EACH of the following:

(i) the blade inlet angle; (6)

(ii) the diagram power. (6)

9. A Venturi meter is used in a freshwater pipeline. The meter entrance has an area of 0.00331 m^2 and is at a height of 5 m above the deck.

The meter throat has a diameter of 25 mm and is at a height of 2 m above the deck.

The difference in pressure between the entrance and throat due to flow velocity changes is 120 mm of mercury and the frictional losses are equivalent to 0.85 m of head of fresh water.

Note: $\rho_{water} = 1000\ kg/m^3, \rho_{mercury} = 13600\ kg/m^3, g = 9.81 m/s^2$

Calculate EACH of the following:

(a) the velocity at the entrance; (10)

(b) the volumetric flow rate; (3)

(c) the mass flow rate. (3)