1. The following data for a simple steam power plant as shown in Fig. 1. **(18%)**

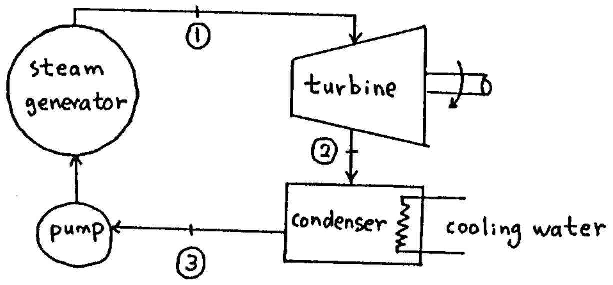

Fig. 1

P_1 = 5.5 MPa, T_2 = 490 °C; P_2 = 10 kPa, x_2 = 0.9, V_2 = 200 m/sec; P_3 = 9 kPa, T_3 = 40 °C;
Rate of steam flow = 25 kg/sec
Pipe diameters:
Steam generator to turbine: 200 mm; Condenser to steam generator: 75 mm;

According to Table 1 and 2, calculate:
(a) Power output of the turbine. (b) Heat transfer rate in the condenser. (c) Flow rate of cooling water through the condenser if the temperature of the cooling water increases from 17.5 °C to 27.5 °C in the condenser.

Table 1: Saturated Steam: Pressure table

P (kPa)	T (°C)	v_f (m^3/kg)	v_g (m^3/kg)	h_f (kJ/kg)	h_g (kJ/kg)
2.0	17.50	0.001001	67.00	73.48	2533.5
3.0	24.08	0.001003	45.67	101.05	2545.5
4.0	28.96	0.001004	34.80	121.46	2554.4
5.0	32.88	0.001005	28.19	137.82	2561.5
7.5	40.29	0.001008	19.24	168.79	2574.8
10.0	45.81	0.001010	14.67	191.83	2584.7

Table 2: Superheated Vapor

	P = 5.0 MPa		P = 6.0 MPa	
T (°C)	v (m^3/kg)	h (kJ/kg)	v (m^3/kg)	h(kJ/kg)
450	0.06330	3316.2	0.05214	3301.8
500	0.06857	3433.8	0.05665	3422.2

2. Air enters a counterflow heat exchanger at 0.5 MPa, 30 °C, and is heated to 100 °C. Call this air stream the cold air. The cold air flow rate is 0.4 kg/sec. Heat is transferred to the cold air from an air stream which enters at 0.1 MPa, 200 °C, and leaves at 95 °C. Call this latter stream the hot air. Both stream pass through the heat exchanger with negligible change in pressure and in kinetic energy. There are no stray heat losses. The temperature of the surrounding atmosphere is 18 °C. Determine the irreversibility per kg of cold air. Assume C_p is constant and equal to 1.0 kJ/kg K. **(12%)**

3. (a) What is the Carnot cycle?

(b) Prove that the Carnot cycle is the most efficient cycle that can operate between two constant temperature reservoirs.

(c) Derive an expression in terms of the reservoir temperatures T_H and T_L for the thermal efficiency of a Carnot cycle using an ideal gas as working fluid. (Don't derive this expression from T-s diagram) (20%)

4. The cycle shown in Fig. 2 has been pro$\overset{\text{po}}{\wedge}$sed for an auxiliary power supply in a spacecraft. The working fluid is argon (ideal gas throughout the cycle). The compressor and turbine processes are both adiabatic and the heater and cooler processes are both constant-pressure. The following data are known:

$P_1 = P_4 = 35$ kPa; $P_2 = P_3 = 140$ kPa; $T_1 = 280$ K; $T_3 = 1100$ K;

$\eta_{turbine} = 80\%$; $\eta_{compressor} = 70\%$;

(a) Show this cycle on a T-s diagram.

(b) Calculate the net work output of the cycle and the thermal efficiency of the cycle. Assume C_p and C_v are both constant. $C_p = 0.52$ kJ/kg K and $C_v = 0.31$ kJ/kg K. (18%)

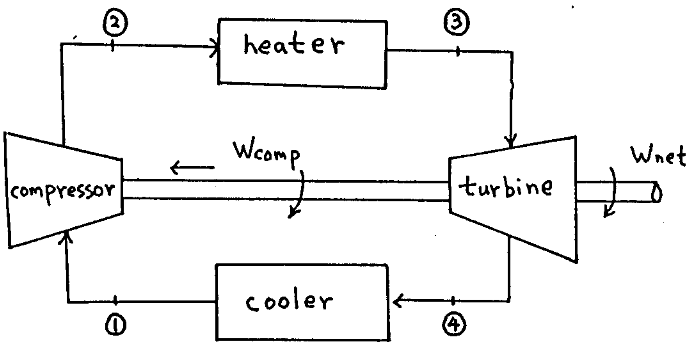

Fig. 2

5. The pressure of the mixture entering and leaving the adiabatic saturator is 0.1 MPa, the entering temperature is 33 °C, and the temperature leaving is 17.5 °C, which is the adiabatic saturation temperature. Calculate the humidity ratio and relative humidity of the air-water mixture entering. (Tables 1 and 2 are the reference tables for the thermodynamic poperties of steam)(12%)

6. van der Waals equation is

$$P = RT/(v-b) - a/v^2$$

Prove:

(a) $v_c = 3b$; $a = 27R^2T_c{}^2/(64P_c)$; $b = RT_c/(8P_c)$

where P_c, T_c and v_c are the pressure, temperature and specific volume at the critical point.

(b) $Z^3 - [P_r/(8T_r) + 1]Z^2 + [27P_r/(64T_r{}^2)]Z - 27P_r{}^2/(512T_r{}^3) = 0$

where Z is the compressibility fator and

$P_r = P/P_c$ reduced pressure; $T_r = T/T_c$ reduced temperature. (20%)