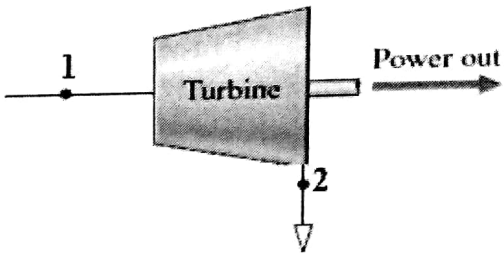
Biomedical Engineering Program
Midterm Exam in Thermodynamics 2017-2018
Time Allowed 60 minutes (20 total marks)

Name : ..... **sec:** .....

Question (1) : *(10 marks) 0.5 m^3 of air at 500 K and 10 bar is heated at constant pressure to 1.5 m^3. It is then expanded adiabatic (isentropic) and further compressed isothermally so as to reach the condition from where it started. Sketch the cycle on P-v diagram and determine :(i) Temperature at the end of constant pressure heating.(ii) Heat and work for each process. (iii) Net work done and heat transferred during the cycle. (Take C_p = 1005 J/kg.K and C_v = 718 J/kg.K.)*

Question (2): *(7 marks) Steam at 80 bar , 500 °C and 50 m/s flows steadily through a adiabatic turbine (isentropic). At the turbine exit the steam is at 0.1 bar and a velocity of 10 m/s . If the mass flow rate of the steam is 10 kg/s and no significant change in potential energy. calculate :*



(i) The temperature at the turbine inlet. (i) The power output from the turbine. (iii) The area at inlet of the turbine.

Question (3): *(5 marks) An ideal (reversed Carnot) refrigerator has a C.O.P of 3. If the low temperature is raised 10 %, what is the new C.O.P keeping the same high temperature?*

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Model answer
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Question (1) *: (10 marks) 0.5 m^3 of air at 500 K and 10 bar is heated at constant pressure to 1.5 m^3. It is then expanded adiabatic and further compressed isothermally so as to reach the condition from where it started. Sketch the cycle on P-v diagram and determine :(i) Temperature at the end of constant pressure heating.(ii) Heat and work for each process. (iii) Net work done and heat transferred during the cycle. (Take C_p = 1005 J/kg.K and C_v = 718 J/kg.K.)*

$$P_1 V_1 = mRT_1$$

$$m = \frac{10 \times 10^5 \times 0.5}{287 \times 500} = 3.484\ kg$$

Process (1-2) P=c

$$\frac{T_2}{T_1} = \frac{V_2}{V_1}$$

$$T_2 = 500 \times \frac{1.5}{0.5} = 1500\ K$$

$$W_{1-2} = mR(T_2 - T_1) = 999908J = 999.9kJ$$

$$Q_{1-2} = mC_P(T_2 - T_1) = 3501420\ J = 3501.42kJ$$

Process (2-3) S=c

$T_3 = T_1 = 500K$

$$\frac{P_3}{P_2} = \left(\frac{T_3}{T_2}\right)^{\gamma/(\gamma-1)}$$

P_3= 0.21 bar

$$W_{2-3} = \frac{mR(T_2 - T_3)}{\gamma - 1} = 2499770J = 2499.77\ kJ$$

$$Q_{2-3} = 0$$

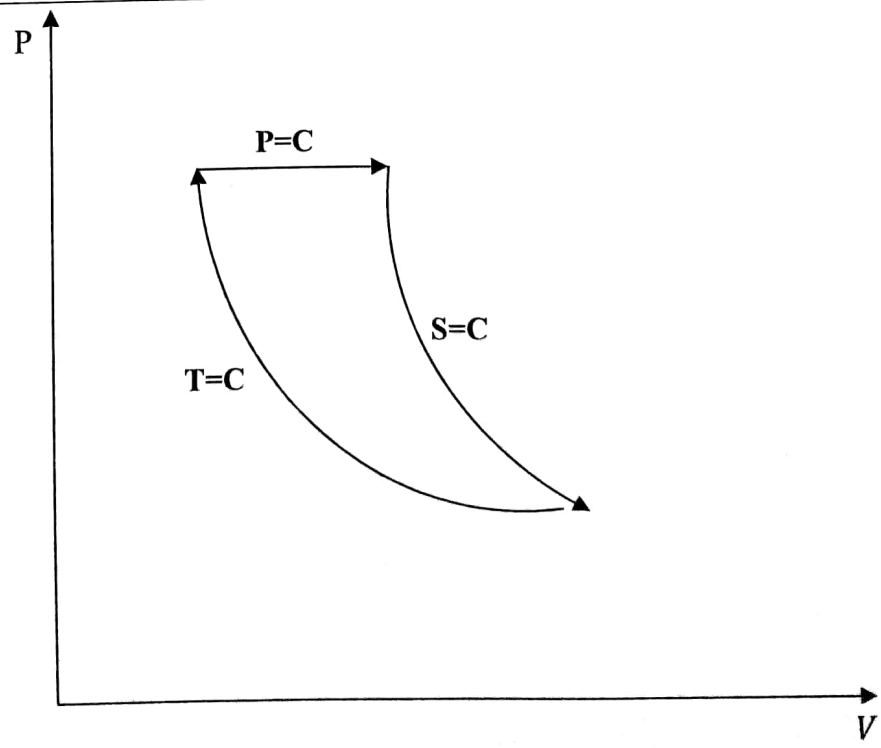
Process (3-1) T=C

$$Q_{2-3} = W_{2-3} = mRT_3 ln\left(\frac{P_3}{P_1}\right) = -1931438.712\ J = -1931.438kJ$$

$$\sum W = 999.9 + 2499.77 - 1931.438 = 1568.232kJ$$

$$\sum Q = 3501.42 + 0 - 1931.438 = 1569.98kJ$$

CHECK $\sum Q \cong \sum W$



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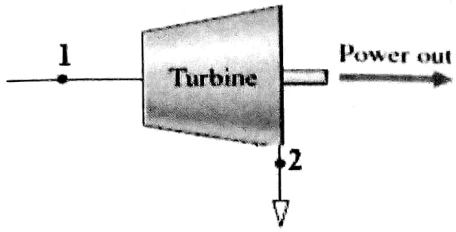
***Question (2)**: (7 marks) Steam at 80 bar , 500 oC and 50 m/s flows steadily through a adiabatic turbine (isentropic). At the turbine exit the steam is at 0.1 bar and a velocity of 10 m/s . If the mass flow rate of the steam is 10 kg/s. calculate :*



(i) The temperature at the turbine exit. (i) The power output from the turbine. (iii) The area at inlet of the turbine.

Given: P_1=80 bar , T_1 500 °C, C_1=50 m/s , P_2=0.1 bar , C_2=10 m/s, m=10kg/s

Required: T_2 , Power $\dot{W}$ and A_1

Solution:

From steam tables No.3

at P_1=80 bar , T_1 500 °C h_1= 3398.8 kJ/kg , v_1 =0.0417 m^3/kg, S_1=S_2=6.7262 kJ/kg.°C

From steam tables No.2

at P_2=0.1 bar S_f = 0.6493 kJ/kg. °C, S_g=8.1511 kJ/kg. °C

h_f = 191.8 kJ/kg, h_g=2584.8 kJ/kg, T_2=45.83 °C

$$S_2 = 6.7262 = 0.6493 + x_2(8.1511 - 0.6493)$$

$$x_2 = 0.81$$

$$h_2 = 191.8 + 0.81 \times (2584.8 - 191.8) = 2130.13 \ kJ/kg$$

$$\dot{Q} - \dot{W} = \dot{m}\left[(h_2 - h_1) + \left(\frac{C_2^2 - C_1^2}{2}\right) + g(z_2 - z_1)\right]$$

$$0 - \dot{W} = 10\left[(2130.13 - 3398.8) \times 1000 + \left(\frac{10^2 - 50^2}{2}\right) + 0\right]$$

$$\dot{W} = 12698700 \ Watt = 12.6987 \ MW$$

$$m = \frac{A_1 C_1}{v_1}$$

$$10 = \frac{A_1 50}{0.0417}, \quad A_1 = 0.00834 \ m^2$$

***Question (3)**: (5 marks) An ideal (reversed Carnot) refrigerator has a C.O.P of 3. If the low temperature is raised 10 %, what is the new C.O.P keeping the same high temperature?*

Given: $C.O.P = 3$

$$C.O.P_R = \frac{T_L}{T_H - T_L} = 3 = \frac{1}{\frac{T_H}{T_L} - 1}$$

$$\frac{T_H}{T_L} = \frac{1}{3} + 1 = 1.333$$

$$C.O.P_{R,new} = \frac{1}{\frac{T_H}{1.1T_L} - 1} = \frac{1}{\frac{1.333}{1.1} - 1} = \frac{1}{0.2118} = 4.721$$

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