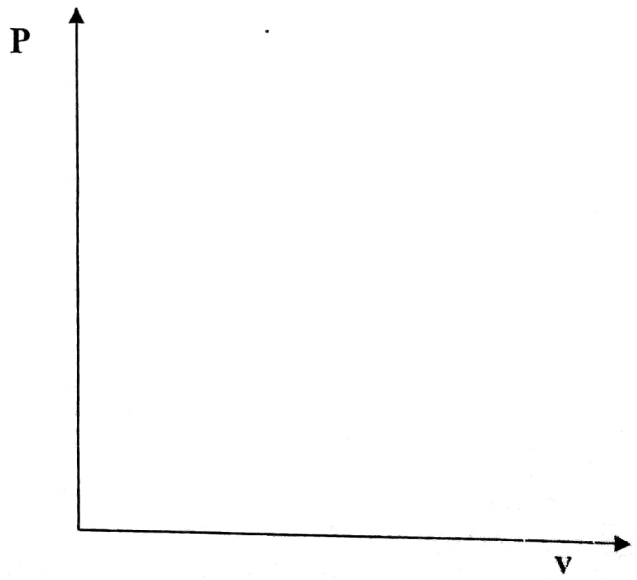
Biomedical Engineering Program
Midterm Exam in Thermodynamics 2016-2017
Time Allowed 60 minutes (20 total marks)

Name : .....

(For air : C_p=1005 J/kg.K , C_v= 718 J/kg.K, R = 287 J/kg.K)

Question (1) : A closed system contains air at a pressure 1 bar, temperature 300 K and volume 0.02 m^3. This system undergoes a thermodynamic cycle consisting of the following three processes in series : (i) Constant volume heat addition till pressure becomes 5 bar, (ii) Constant pressure cooling, ***Sketch the cycle on P-v diagram and determine :*** **(10 marks)**

(i) Temperature at the end of constant volume heat addition.(ii) Heat and work for each process. (iii)The net work done and heat transferred during the cycle.



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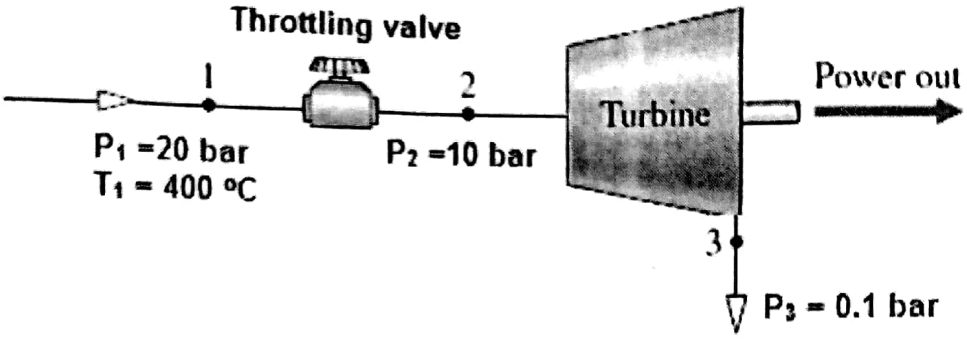
Question (2) Steam at 20 bar and 400 °C is throttled to 10 bar and then it flows steadily through a adiabatic turbine (isentropic). After throttling, the pressure and velocity of steam are 20 bar and 50 m/s respectively. At the turbine exit the steam is at 0.1 bar and a velocity of 20 m/s . If the mass flow rate of the steam is 10 kg/s. calculate : (10 marks)

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

(iii) The area at inlet and exit of turbine.



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Model Answer
Midterm Exam in Thermodynamics 2016-2017

(For air : C_p=1005 J/kg.K , C_v= 718 J/kg.K, R = 287 J/kg.K)

Question (1) : A closed system contains air at a pressure 1 bar, temperature 300 K and volume 0.02 m^3. This system undergoes a thermodynamic cycle consisting of the following three processes in series : (i) Constant volume heat addition till pressure becomes 5 bar, (ii) Constant pressure cooling, and (iii) Isothermal process to initial state. ***Sketch the cycle on P-v diagram and determine :***
(a)Temperature at the end of constant volume heat addition.(b) Heat and work for each process. (c)The net work done and heat transferred during the cycle.

solution:

$$P_1 V_1 = mRT_1$$

$$m = \frac{10^5 \times 0.02}{287 \times 300} = 0.023\ kg$$

Process (1-2) V=c

$$\frac{T_2}{T_1} = \frac{P_2}{P_1}$$

$$T_2 = 300 \times \frac{5}{1} = 1500\ K$$

$$W_{1-2} = 0$$

$$Q_{1-2} = mC_v(T_2 - T_1) = 19816.8\,J = 19.816\ kJ$$

Process (2-3) P=c

$T_3 = T_1 = 300$ k

$$W_{2-3} = mR(T_3 - T_2) = -7921.2J = -7.921kJ$$

$$Q_{2-3} = mC_P(T_3 - T_2) = -27738J = -27.738kJ$$

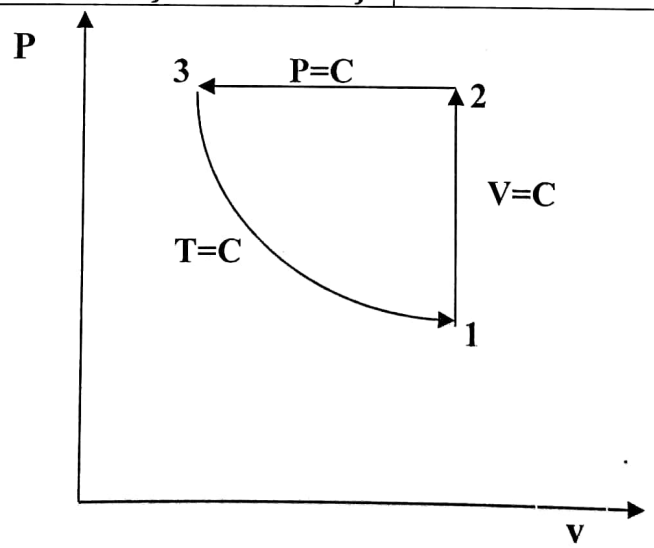
Process (3-1) T=c

$$Q_{2-3} = W_{2-3} = mRT_3 ln\left(\frac{P_3}{P_1}\right)$$
$$= 3187.17\,J$$
$$= 3.187kJ$$

$$\sum W = 0 - 7.921 + 3.187$$
$$= -4.734kJ$$

$$\sum Q = 19.816 - 27.738 + 3.187$$
$$= -4.735kJ$$

CHECK $\sum Q = \sum W$



Question (2) **Steam at 20 bar and 400 °C is throttled to 10 bar and then it flows steadily through a adiabatic turbine (isentropic). After throttling, the pressure and velocity of steam are 20 bar and 50 m/s respectively. At the turbine exit the steam is at 0.1 bar and a velocity of 20 m/s . If the mass flow rate of the steam is 10 kg/s. calculate :**
(i) The temperature at the turbine inlet. (i) The power output from the turbine.
(iii) The area at inlet of turbine.

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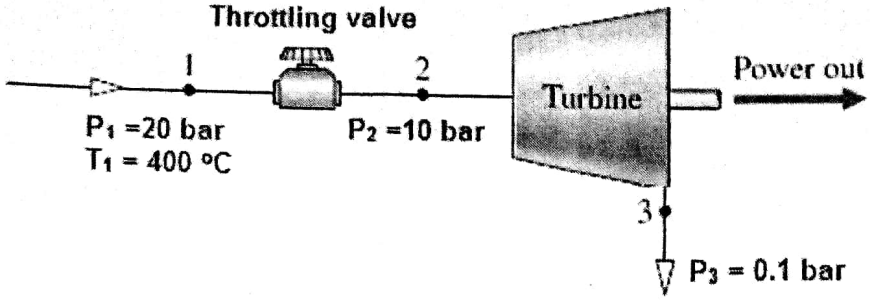

Solution:

From steam tables

Table 3 at P_1= 20 bar and T_1 = 400 °C h_1= 3248.7 kJ/kg = h_2

Table 2 at P_2= 10 bar h_f=762.6 kJ/kg h_g= 2776.2 kJ/kg

$h > h_g$ *superheated steam*

Table 3 at P_2= 10 bar and h_2= 3248.7 kJ/kg

we get T_2=394 °C S_2=7.49 kJ/kg.K, v_2= 0.304 m^3/kg

Turbine

$S_3 = S_2$= 7.49 kJ/kg.K

Table 2 at P_3= 0.1 bar S_f=0.6493 kJ/kg.K S_g= 8.151 kJ/kg .K

h_f=191.8 kJ/kg h_g= 2584.8 kJ/kg

$S_f < S_3 < S_g$ **Wet zone**

$$S_3 = S_f + x_3(S_g - S_f)$$
$$7.49 = 0.6493 + x_3(8.151 - 0.6493)$$

we get $x_3 = 0.9118$

$$h_3 = h_f + x_3(h_g - h_f) = 191.8 + 0.9118(2584.8 - 191.8) = 2373.7374\ \frac{kJ}{kg}$$

$$\dot{Q} - \dot{W} = \dot{m}\left[(h_3 - h_2) + \left(\frac{C_3^2 - C_2^2}{2}\right) + g(z_3 - z_2)\right]$$

Isentropic $\dot{Q} = 0$

$$z_3 = z_2$$

$$\dot{0} - \dot{W} = 10\left[(2373.7374 - 3248.7) \times 10^3 + \left(\frac{20^2 - 50^2}{2}\right) + 0\right]$$

$$\dot{W} = 8760126\ W = 8760.126\ kW$$

$$\dot{m} = \rho_2 A_2 C_2$$
$$10 = \frac{1}{0.304} \times A_3 \times 50$$

we get A_2=0.0608 m^2

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