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

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

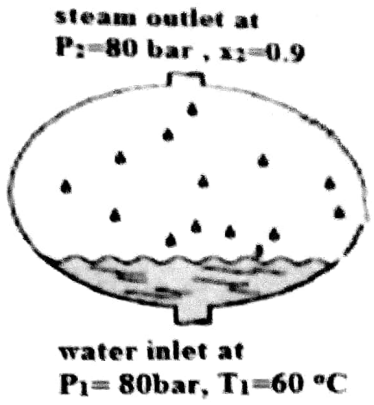
Question (1) : (9 marks)

0.1 m^3 of air at 300 K and 1 bar is compressed polytropic ($pv^{1.3}=c$) to 8 bar. It is then cooled at constant pressure to initial temperature. Sketch two processes on P-v diagram and determine : (i) Temperature at the end of polytropic compression. (ii) Volume at end the constant pressure cooling. (iii) Heat and work for each process.(Take C_p = 1005 J/kg.K and C_v = 718 J/kg.K.)

Scanned by CamScanner

***Question (2)*: (6 marks)**

Water is supplied to the boiler at 80 bar and 60°C and steam is generated from boiler at the same pressure at 0.9 dryness fraction. If the mass flow rate of the steam is 100 kg/s and no significant change in potential energy and kinetic energy. Determine the rate of heat added to the steam in passing through the boiler.



***Question (3)*: (5 marks)**

Heat pump is used to warm house. Its heating load is 20 kW. The temperature of the house is a maintained at 22 °C, while the outdoor temperature is 5 °C.

(a) What is maximum possible COP for a heat pump operating between these temperatures?

(b) What must be the minimum power of the electric motor driving the heat pump?

(c) In reality, the COP of the heat pump will be only 40% of the ideal value. What is the actual power of the electric motor driving the heat pump?

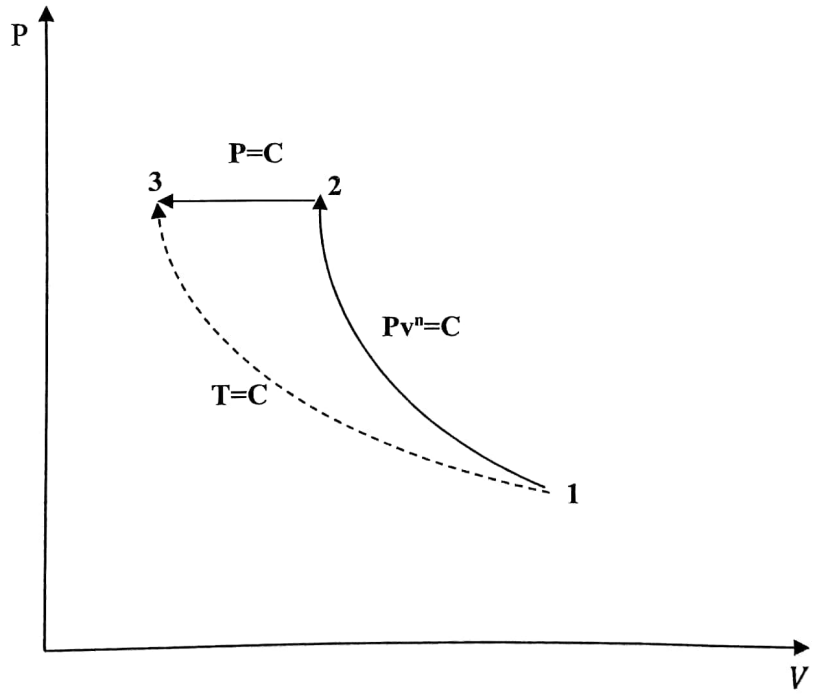
Scanned by CamScanner

Model answer

Question (1) : (9 marks)

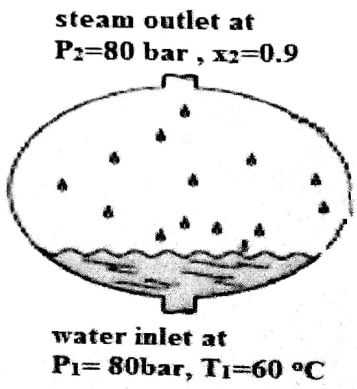
0.1 m^3 of air at 300 K and 1 bar is compressed polytropic ($pv^{1.3}=c$) to 8 bar. It is then cooled at constant pressure to initial temperature. Sketch two processes on P-v diagram and determine : (i) Temperature at the end of polytropic compression. (ii) Volume at end the constant pressure cooling. (iii) Heat and work for each process.(Take C_p = 1005 J/kg.K and C_v = 718 J/kg.K.)

$P_1 V_1 = mRT_1$ $m = \frac{1 \times 10^5 \times 0.1}{287 \times 300} = 0.116\ kg$ **Process (1-2) $Pv^n=c$** $\frac{T_2}{T_1} = (\frac{P_2}{P_1})^{(n-1)/n}$ $T_2 = 484.76\ K$ $W_{1-2} = \frac{mR(T_1 - T_2)}{n-1} = -20503.43J = -20.5kJ$ $Q_{1-2} = W_{1-2} + mC_v(T_2 - T_1) = -5136.57\ J$ $= -5.136kJ$	**Process (2-3) P=c** $T_3=T_1= 300K$ $P_3 V_3 = mRT_3$ $V_3 = \frac{mRT_3}{P_3}$ $V_3= 0.0124\ m^3$ $W_{2-3} = mR(T_3 - T_2)$ $= -6151.03J$ $= -6.15\ kJ$ $Q_{2-3} = mC_p(T_3 - T_2)$ $= -21539.32J$ $= 21.54kJ$



Question (2): (6 marks)

Water is supplied to the boiler at 80 bar and 60°C and steam is generated from boiler at the same pressure at 0.9 dryness fraction. If the mass flow rate of the steam is 100 kg/s and no significant change in potential energy and kinetic energy. Determine the rate of heat added to the steam in passing through the boiler.



Scanned by CamScanner

Solution:

From steam tables No. 3
at P_1= 80bar and T_1= 60 °C we get h_1= 257.8 kJ/kg

From steam tables No. 2
at P_2=80 bar we get h_f=1317.2 , h_g=2615.63 kJ/kg
$h_2 = h_f + x_2 (h_g - h_f)$=2374.06 kJ/kg
h_2=h_f= 251.5 kJ/kg

$$Q_{add} = m_s(h_2 - h_1) = 100(2615.36 - 257.8) = 235783kW$$

Question (3): (5 marks)
Heat pump is used to warm house. Its heating load is 20 kW. The temperature of the house is a maintained at 22 °C, while the outdoor temperature is 5 °C.
(a) What is maximum possible COP for a heat pump operating between these temperatures?
(b) What must be the minimum power of the electric motor driving the heat pump?
(c) In reality, the COP of the heat pump will be only 40% of the ideal value. What is the actual power of the electric motor driving the heat pump?

$$COP_{HP,Carnot} = COP_{max} = \frac{22 + 273}{22 - 5} = 17.35$$

$$COP_{HP,Carnot} = COP_{max} = \frac{Q_H}{W_{min}} = 17.35 = \frac{20}{W_{min}}$$

$$W_{min} = 1.15\ kW$$

$$COP = 0.4 \times COP_{HP,Carnot} = 6.94 = \frac{Q_H}{W} = \frac{20}{W}$$

W=2.88 kW

Scanned by CamScanner