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

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

Question (1) : (9 marks)

1.5 m^3 of air at 300 K and 1 bar is heated at constant pressure to 3 m^3. It is then compressed adiabatic (isentropic) to initial volume. Sketch two processes on P-v diagram and determine : (i) Temperature at end of constant pressure heating. (ii) Temperature at end of isentropic compression. (iii) Heat and work for each process.(Take C_p = 1005 J/kg.K and C_v = 718 J/kg.K.)

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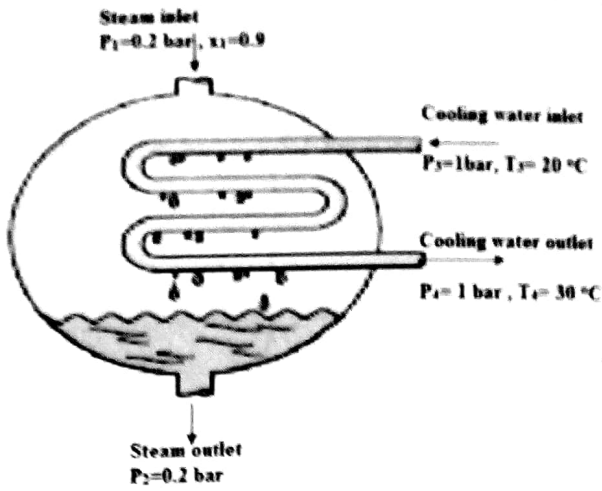
***Question (2)*: (6 marks)**

Steam enters the condenser of a steam power plant at 0.2 bar and a dryness fraction of 0.9 with a mass flow rate of 20,000 kg/h. If the steam is to leave the condenser as saturated liquid at 0.2 bar. It is to be cooled by water from a nearby river by circulating the water through the tubes within the condenser. The cooling water enters the tubes of the condenser at 1bar and 20 °C and leaves at 1 bar and 30 °C. Determine the mass flow rate of the cooling water required.



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

Cold store requires 25 kW as cooling load to maintain its temperature at - 5 °C. The average temperature of the environment outside the store is estimated by 30 °C.

(a) What is maximum possible COP for a cold store operating between these temperatures?

(b) What must be the minimum power of the electric motor driving the cold store?

(c) In reality, the COP of the heat pump will be only 50% of the ideal value. What is the actual power of the electric motor driving the cold store?

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Model answer

Question (1) *: (9 marks)*

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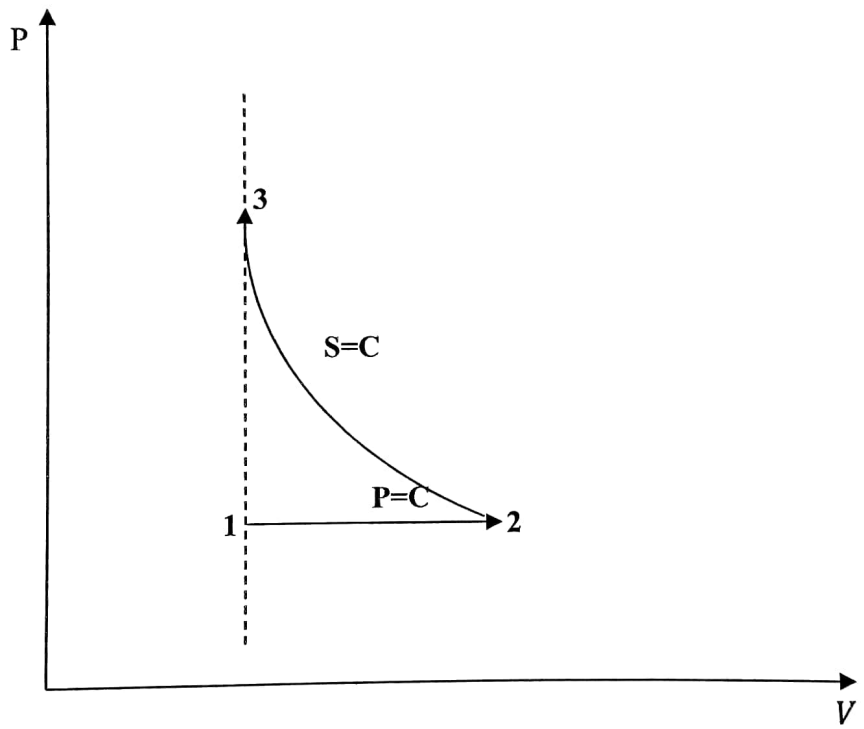
$P_1 V_1 = mRT_1$ $m = \frac{1 \times 10^5 \times 1.5}{287 \times 300} = 1.74\ kg$ **Process (1-2) P=c** $\frac{T_2}{T_1} = \frac{V_2}{V_1}$ $T_2 = 300 \times \frac{3}{1.5} = 600\ K$ $W_{1-2} = mR(T_2 - T_1) = 149814J = 149.814kJ$ $Q_{1-2} = mC_P(T_2 - T_1) = 524610\ J = 524.61kJ$	**Process (2-3) S=c** $V_3 = V_1 = 1.5\ m^3$ $\frac{T_3}{T_2} = (\frac{V_2}{V_3})^{(\gamma-1)}$ T_3= 791.7K $W_{2-3} = \frac{mR(T_2 - T_3)}{\gamma - 1}$ $= -239327.865J$ $= -239.328\ kJ$ $Q_{2-3} = 0$



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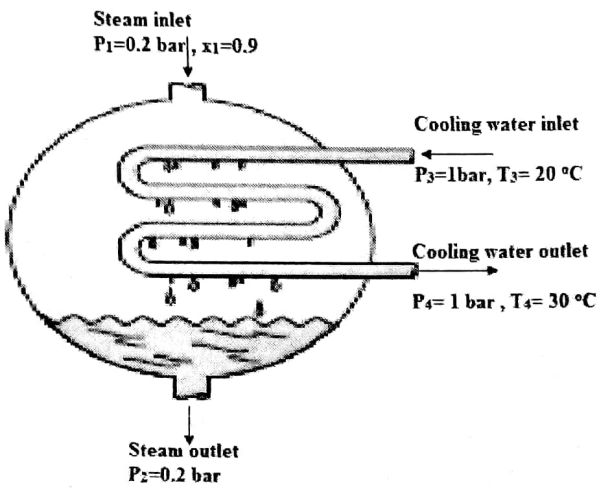

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SOLUTION:

From steam tables No. 3

at P_3= 1bar and T_3= 20 °C we get h_3= 84 kJ/kg

at P_4= 1bar and T_4= 30 °C we get h_4= 125.8 kJ/kg

From steam tables No. 2

at P_1=0.2 bar we get h_f=251.5 h_g=2609.9 kJ/kg

$h_1 = h_f + x_1 (h_g - h_f)$=2374.06 kJ/kg

$h_2 = h_f$= 251.5 kJ/kg

$$Q_s = m_s(h_2 - h_1) = \frac{20000}{3600}(251.5 - 2374.06) = -11792kW$$

$$+Q_w = -Q_s = 11792kW$$

$$Q_w = m_w(h_4 - h_3)$$

$$11792 = m_w(125.8 - 84)$$

$$m_w = 282.105kg/s = 1015578.9kg/hr$$

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$$COP_{R,Carnot} = COP_{max} = \frac{(-5 + 273)}{30 - (-5)} = 7.657$$

$$COP_{R,Carnot} = COP_{max} = \frac{Q_L}{W_{min}} = 7.657 = \frac{25}{W_{min}}$$

$$W_{min} = 3.265\ kW$$

$$COP = 0.5 \times COP_{R,Carnot} = 3.8285 = \frac{Q_L}{W} = \frac{25}{W}$$

W=6.534 kW

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