Final Examination Paper

Answer the following questions:

1-a Derive an expression for the boundary work for an adiabatic process. (4 Marks)

1-b Carbon dioxide contained in a piston–cylinder device at a pressure of 200 kPa and volume of 0.3 m³ is compressed isothermal to 0.1 m³. Then it expands to a final volume of 1 m³ according to the relation P = CV^2. Calculate the work done during this process. (6 Marks)

2-a Water at 1 bar and 20°C enters a mixing chamber at a rate of 1 kg/s where it is mixed steadily with steam entering at 1 bar and 140°C. The mixture leaves the chamber at 1 bar and 80°C, and heat is lost to the surrounding air at a rate of 2 kW. Neglecting the changes in kinetic and potential energies, determine the exit mass flow rate. (9 Marks)

2-b A well-insulated rigid tank contains 5 kg of a saturated liquid–vapor mixture of water at 100 kPa. Initially, three-quarters of the mass is in the liquid phase. An electric resistor placed in the tank is connected to a 110-V source, and a current of 8 A flows through the resistor when the switch is turned on. Determine how long it will take to vaporize all the liquid in the tank. Also, show the process on a T-v diagram with respect to saturation lines. (6 Marks)

3-a Explain the second law of thermodynamic statements. (4 Marks)

3-b Steam enters an adiabatic turbine steadily at 7 MPa, 500°C, and 45 m/s, and leaves at 100 kPa and 75 m/s. If the power output of the turbine is 5 MW, determine (a) the mass flow rate of steam through the turbine, (b) the temperature at the turbine exit, and (c) the rate of entropy generation during this process. (11 Marks)

With Best Wishes
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Model

1-a) \( PV = c \) \( \square \)

\[ W_b = \int P \, dv \] \( \square \)

\[ P = \frac{c}{V^\gamma} = c \, V^{-\gamma} \]

\[ W_b = \int c \, V^{-\gamma} \, dv = c \int V^{-\gamma} \, dv \]

\[ W_b = c \, \left[ \frac{V^{-\gamma+1}}{-\gamma+1} \right] = c \, \left[ \frac{V_2^{-\gamma} - V_1^{-\gamma}}{1-\gamma} \right] \] \( \square \)

\[ C = P_1 \, V_1^\gamma = P_2 \, V_2^\gamma \]

\[ W_b = \frac{P_2 \, V_2^\gamma \, V_2^{-\gamma} - P_1 \, V_1^\gamma \, V_1^{-\gamma}}{1-\gamma} \]

\[ W_b = \frac{P_2 \, V_2 - P_1 \, V_1}{1-\gamma} \] \( \square \)
\[
\begin{align*}
W_b &= \frac{W_b}{1-\varepsilon} + \frac{W_b}{2-3} \\
W_b &= P_1 V_1 \left( \frac{V_2}{V_1} \right) \left( \frac{0.1}{0.3} \right) = (200)(0.3) h \left( \frac{0.1}{0.3} \right) = -65.91 \text{ kslb} \tag{1}
\end{align*}
\]

\[
W_b = \frac{P_3 V_3 - P_2 V_2}{1-\varepsilon} \tag{1} \quad \varepsilon = 2
\]

\[
P = CV^2
\]

\[
P_1 V_1 = \frac{MRT}{MRT} \frac{V_1}{V_2}
\]

\[
P_2 = P_1 \frac{V_1}{V_2} = (200) \left( \frac{0.3}{0.1} \right) = 600 \text{ kps} \tag{1}
\]

\[
P_3 = \frac{P_2 V_2^2}{P_3 V_3^2} = \left( \frac{V_2}{V_3} \right)^2 = (600) \left( \frac{0.1}{1} \right)^2
\]

\[
P_3 = 6 \text{ kps} \tag{1}
\]

\[
W_b = \frac{P_3 V_3 - P_2 V_2}{1-\varepsilon} = \frac{(6)(1) - (600)(0.1)}{1-2}
\]
\[ \therefore W_b = 54 \text{ kJ/kg} \]

\[ W_b = -11.91 \text{ kJ/kg} \]

\[ = -11.91 \text{ kJ/kg} \]
Apply mass balance:
\[ m_{\text{exit}} = 1 + m_2 \]

Apply 1st Law:
\[ \dot{Q} + h_1 + \sum m_i (h_i + \frac{V_i^2}{2} + \frac{\rho_i}{2} \dot{V}_i) = \dot{Q}_{\text{in}} + \dot{Q}_{\text{out}} + \sum m_i (h_e + \frac{V_e^2}{2} + \frac{\rho_e}{2} \dot{V}_e) \]

\[ m_1 h_1 + m_2 h_2 = \dot{Q}_{\text{in}} + m_e h_e \]

@ \( T = 20^\circ C \) & \( P = 16 \text{ bar} \):
\[ \Rightarrow T_{\text{sat}} = 99.63 ^\circ C \]
\[ \Rightarrow P_{21 \text{ bar}} \Rightarrow T_{\text{sat}} = \text{Compressed liquid} \]
\[ \Rightarrow T < T_{\text{sat}} \]
\[ \Rightarrow \text{Assume state: liquid} @ T = 20^\circ C \]
\[ h_1 = 83.96 \quad \text{kJ/kg} \quad \text{(use Table A-4)} \]

\[ @ \rho = 1 \text{bar} \quad & T = 140^\circ \text{C} \]

\[ T \text{ inlet} \Rightarrow \text{superheated} \]

Using Table (A-6) \[ @ \rho = 1 \text{bar} \quad T = 140^\circ \text{C} \]

\[ h_2 = 2756.36 \quad \text{kJ/kg} \]

for the exit conditions \(\Rightarrow\text{Compressed} \)

Assume sat. byq. (A-4)

\[ h_3 = 334.91 \text{kJ/kg} \]

\[ (1)(83.96) + m_2 (2756.36) = 2 + (1 + m_2)(334.91) \]

\[ 2421.45 \quad 252.95 \]

\[ m_2 (2756.36 - 334.91) = 2 + 334.91 + 83.96 \]

\[ m_2 = 0.104 \quad \text{kg/s} \]

\[ m_{exit} = 1.104 \text{ kg/s} \]
2-b)

$m = 5$ kg  
$p = 100$ kPa

$m_e = 0.75 (5)$  
$m_v = 0.25 (5)$  

Apply 1st L of Thermodynamic

$V = 110 \, V$  
$I = 8 \, A$

$w_{in} = m (u_f - u_i)$

$w_{in} = m (u_f - u_i)$

Time?

$\text{V.I.Time} = m (u_f - u_i)$

$u_i \Rightarrow x_i = \frac{m_v}{m_t} = 0.25$

Using Table (A-5) @ $p = 100$ kPa

$u_i = u_f + x u_{fb}$

$= 417.36 + (0.25)(2088.7)$

$= 939.53 \, kJ$
\[ V_1 = V_y + x V_y \quad @ \text{100 kPa} \]
\[ V_1 = 0.42 \text{ m}^3/\text{s} \quad \boxed{1} \]
\[ V_2 = V_1 \cdot V_y \quad @ \text{49.1 kPa} \]
\[ \Rightarrow U_2 = V_1 \cdot V_y \quad @ \text{49.1 kPa} \]
\[ U_2 = 2556 \text{ kJ/kg} \quad \boxed{1} \]
\[ 110 \times 8 \times \Delta t = 5 (2556 - 939) \]
\[ \frac{\Delta t}{100} = 1.5 \quad \boxed{1} \]
\[ 25.0 = \frac{m}{a} \quad \boxed{1} \]
\[ \Delta V = 9 \quad (\text{R.H. 269}) \]
\[ Q V_1 + f_4 = 0 \]
Apply 1st Law of Thermodynamic

\[
\dot{Q}_{\text{in}} + \dot{W}_{\text{in}} + \Delta \dot{m}_{\text{in}} = \dot{Q}_{\text{out}} + \dot{W}_{\text{out}} + \Delta \dot{m}_{\text{out}}
\]

\[
\dot{Q}_{\text{in}} + \dot{W}_{\text{in}} + \dot{m}_{\text{in}} (h_{\text{in}} + \frac{V_{\text{in}}^2}{2}) = \dot{Q}_{\text{out}} + \dot{W}_{\text{out}} + \dot{m}_{\text{out}} (h_{\text{out}} + \frac{V_{\text{out}}^2}{2})
\]

\[
\dot{m}_{\text{in}} (h_{\text{in}} + \frac{V_{\text{in}}^2}{2}) = \dot{W}_{\text{in}} + \dot{m}_{\text{in}} (h_{\text{out}} + \frac{V_{\text{out}}^2}{2})
\]

\[
h_{\text{in}} @ P_i = 7 \text{ MPa} \text{ & } T_i = 500^\circ \text{C}
\]

Use Table (A-6)

\[
h_{\text{in}} = 3410.3 \text{ KSL/b}
\]

\[
S_{n\text{-in}} = 6.79 \text{ KSL/b-K}
\]

\[
S_{n\text{-in}} = S_e = 6.79
\]

@ \( P_e = 100 \text{ kPa} \) Use Table (A-5)

\[
S_f = 1.3026 \text{ KSL/b-K}
\]

\[
S_g = 7.3596 \text{ KSL/b-K}
\]

\[
\frac{3-b}{2}
\]

\[
P_i = 7 \text{ MPa}
\]

\[
T_i = 500^\circ \text{C}
\]

\[
V_i = 45 \text{ m/s}
\]

\[
\rho_e = 100 \text{ kPa}
\]

\[
V_e = 75 \text{ m/s}
\]

\[
\dot{W}_t = 5 \text{ MW}
\]}
\[ S_e > S_f \]

the point is mix

\[ S = S_f + x (S_f) \]

\[ x = \frac{6.79 - 1.3026}{6.0568} = 0.9059 \]

\[ h_e = h_f + x h_f' \]

\[ = 417.46 + (0.9059)(2258) \]

\[ h_e = 2462.98 \text{ kJ/kg} \]

\[ \dot{m}_{sf} = \frac{5 \times 10^3}{(3410.3 - 2462.98) + \left( \frac{45^2}{2000} - \frac{75^2}{2000} \right)} \]

\[ = 4.75 \text{ kgs} \]

\[ @ \ Pe = 100 \text{ kPa} \]

\[ t_e = 99.63^\circ \text{C} \]

Apply entrap\(_3\) balance

\[ \sum \dot{Q} + \sum \dot{E}_{\text{in}} - \dot{E}_{\text{out}} + \dot{E}_{\text{sep}} = 0 \]

\[ \dot{S} = \dot{m}_s (S_e - S_i) = 0 \]