PROBLEM 2.35

Known: A gas undergoes the five processes shown below.

Find: Show the same processes on P-T and T-V coordinates.

Assumptions: The substance is an ideal gas.

Analysis:

Comments: Understanding how to move from one coordinate system to another is important, as different problems lend themselves to different styles of plots.

\[ PV = RT \]
Known: Piston / Cylinder, M, P1, saturated steam at state 1, T2

Find: W2, DU, DH, W1

Sketch:

Graphs follow solution

Assumptions:
- Pressure is constant
- Fixed mass
- No system kinetic energy
- Negligible change in potential energy
- Quasi-equilibrium process

Analysis: First, define states 1 & 2:

State 1: \( P_1 = 300 \text{kPa} \), \( x_1 = 1.0 \) \( \rightarrow \) From Table D.2
\( V_1 = 0.0576 \text{ m}^3/\text{kg} \)
\( u_1 = 2543.2 \text{ kJ/kg} \)
\( h_1 = 2724.9 \text{ kJ/kg} \)

State 2: \( P_2 = P_1 = 300 \text{kPa} \), \( T_2 = 600 \text{K} \) \( \rightarrow \) From Table D.3 (supercritical water)
\( \rho_2 = 0.7744 \text{ kg/m}^3 \)
\( \sigma_2 = 2829.2 \text{ kJ/kg} \)
\( \lambda_2 = 3124.9 \text{ kJ/kg} \)

Now, we can solve for \( W_2 \):

\[ W_2 = \int_1^2 P \, dV = P \int_{V_1}^{V_2} dV \quad \text{[for constant pressure]} \]
\[ = P(V_2 - V_1) = PM(V_2 - V_1) \]
Problem 5-2 (contd)

\[ W_2 = (300 \times 10^3 \text{Pa}) (0.1 \text{ kg}) (0.9777 - 0.60576 \text{ m}^3/\text{kg}) \]

\[ W_2 = 9.35 \text{ kJ} \]

\[ \Delta u = M(u_2 - u_1) = (0.1 \text{ kg})(2597.2 - 2583.2 \text{ kJ/kg}) \]

\[ \Delta u = 30.6 \text{ kJ} \]

\[ \Delta h = M(h_2 - h_1) = (0.1 \text{ kg})(3124.4 - 2724.4 \text{ kJ/kg}) \]

\[ \Delta h = 39.95 \text{ kJ} \]

To find \( Q_2 \), use the first law of thermodynamics:

\[ Q_2 - W_2 = u_2 - u_1 + \frac{M(V_2^2 - V_1^2)}{2} + Mg(z_2 - z_1) \]

\[ Q_2 = \Delta u + W_2 = 30.6 \text{ kJ} + 9.35 \text{ kJ} \]

\[ Q_2 = 39.95 \text{ kJ} \]

Comments:

Note that for an isochoric process:

\[ Q_2 = W + \Delta V = P(V_2 - V_1) + V_2 - V_1 \]

\[ = (V_2 + P_2 V_2) - (V_1 + P_1 V_1) = H_2 - H_1 \]

\[ R_2 = \Delta H \]
Known: $T_1, V_1, V_2, C_p$

Find: $T_2$

Assumptions:
1) Steady State
2) $Q_{in} = 0$ (adiabatic)
3) $W_{in} = 0$ (no work boundary)
4) No change in potential energy
5) Uniform velocity at inlet and outlet

Sketch:

Analysis: For a control volume, the conservation of energy equation is:

$$\dot{W}_{in} - \dot{W}_{out} = \dot{m} \left[ h_2 - h_1 + \frac{V_2^2 - V_1^2}{2} + \frac{\gamma (P_2 - P_1)}{P_1} \right]$$

$$0 = \dot{m} \left[ h_2 - h_1 + \frac{V_2^2 - V_1^2}{2} \right]$$

$$h_1 - h_2 = \frac{V_2^2 - V_1^2}{2} = \frac{250^2 - 150^2}{2} = 31200 \frac{J}{kg}$$

By definition, $h_2 - h_1 = C_p (T_2 - T_1)$ or $h_1 - h_2 = C_p (T_1 - T_2)$

Therefore: $C_p (T_1 - T_2) = 3120 \frac{kJ}{kg}$.

$$T_2 = T_1 - \frac{3120 \frac{kJ}{kg}}{\frac{1.005}{kJ} \frac{kJ}{kg}}$$

$$T_2 = 300K - 31.04K$$

$$T_2 = 268.96K$$
Problem 5-121 (Cond 4)

From Appendix C:

\[ h_1 \text{ (300K)} = 426.04 \text{ kJ/kg} = h_1 \]

with \( h_1 - h_2 = 31.2 \text{ kJ/kg} \):

\[ h_2 = h_1 - 31.2 = 426.04 \text{ kJ/kg} - 31.2 \text{ kJ/kg} \]

\[ h_2 = 394.84 \text{ kJ/kg} \]

Interpolating to find \( T_2 \):

\[ T_2 = \frac{270 - 260}{395.84 - 385.79} \times (385.79 - 260) + 260 \]

\[ T_2 = 768.79 \]

Comments: The assumption of an average specific heat was valid because the temperature change was so small. Hence, the results from both methods are nearly equal.
Problem 6.84

\((6.45 \quad 7.12 \quad 12.19)\) can be found in the HW solutions

Known: \(\vec{V}_1, \vec{V}_2, m\)

Find: \(\vec{F}\)

Assumptions:
1. Neglect the weight of the heated, and other effects of gravity
2. Steady-state CV
3. The inlet and outlet pressure are atmosphere pressure, so they cancel with each other

Momentum conservation:

\[\sum (m \vec{V})_{in} - \sum (m \vec{V})_{out} + \sum \vec{F} = 0\]

in \(x\) direction,

\[m V_i - [m \cdot (-V_{2,x})] + [-F_x] = 0\]

\[F_x = m(V_i + V_{2,x})\]

\[= 0.2 \quad \text{kg/s} \times (6 + 5.196) \quad \text{m/s}\]

\[= 2.239 \quad \text{N}\]

in \(y\) direction,

\[0 - [m \cdot (-V_{2,y})] + [F_y] = 0\]

\[F_y = mV_{2,y}\]

\[= 0.2 \quad \text{kg/s} \times 3 \quad \text{m/s}\]

\[= 0.6 \quad \text{N}\]

\[\vec{F} = -[F_x \hat{i} + F_y \hat{j}] = -2.239 \hat{i} - 0.6 \hat{j} \quad \text{N}\]

\[\vec{F} = 2.239 \hat{i} + 0.6 \hat{j} \quad \text{N}\]