To receive full credit on problems you must clearly indicated the equations you are using (if you use equations) and make clear your steps in simplifying the equations. Do not plug in any numbers until the last step or until necessary.

1. (15) The enthalpy of water at 100 C is 2300 kJ/kg.
   a) What is the phase of the water? Explain
   b) What is the phase of the water if the temperature is raised 3 C while keeping the pressure constant. Explain

   a) Saturated mixture
      Because enthalpy between the sat. liquid & sat. vapor

   b) Superheated vapor
      If a mixture temp can only rise after all liquid has been converted to vapor. So if temp rises by any amount at all, it must be superheated.
2. (25) The temperature of nitric oxide gas is raised from 500 K to 1000 K. Using the most accurate method at your disposal. Determine the change in internal energy, in kJ/kg of the nitric oxide for this temperature rise.

\[
du = C_v dT
\]

most accurate is polynomial expression

\[
\Delta u = \int_{T_i}^{T_f} C_v dT = \int_{T_i}^{T_f} (C_p - R_u) dT
\]

\[
= \int_{T_i}^{T_f} \left[ (a - R_u) + b T + c T^2 + d T^3 \right] dT
\]

\[
= \left[ (a - R_u) (T_2 - T_1) + \frac{b}{2} (T_2^2 - T_1^2) + \frac{c}{3} (T_2^3 - T_1^3) + \frac{d}{4} (T_2^4 - T_1^4) \right]
\]

For NO:

\[
a = 29.34, \quad b = -0.0939 x 10^{-3}, \quad c = 0.9747 x 10^{-5}, \quad d = -4.187 x 10^{-9}
\]

\[
\Delta u = \left[ (a - R_u) (T_2 - T_1) + \frac{1}{2} (20.09) + \frac{c}{3} (9.75 x 10^{-3}) + \frac{d}{4} (9.375 x 10^{-9}) \right]
\]

\[
= \left[ 10512 - 117 + 28.17 - 9.19 \right] \text{kJ/kg mole}
\]

\[
= 12258 \text{ kJ/kg mole}
\]

\[M_{NO} = 14 + 16 = 30 \text{ kJ/kg mole}\]

\[\Delta u = \frac{12258}{30} = 409 \text{ kJ/kg}\]
3. (15) Consider the mixing chamber shown below where flow enters/exits uniformly through three openings. The density is a constant. The following is given:

\[ A_1 = 0.1 \text{ m}^2 \]
\[ A_2 = 0.2 \text{ m}^2 \]
\[ A_3 = 0.18 \text{ m}^2 \]
\[ V_1 = 1.3 \text{ m/s (into mixing chamber)} \]
\[ V_3 = -0.8 \text{ m/s (out of mixing chamber)} \]

If the flow is steady, what is the velocity \( V_2 \)? Is this in or out of the control volume?

\[
\begin{align*}
\Sigma m_{in} &= \Sigma m_{out} \\
2 &\times m = \rho \times A_1 \times V_1 \\
2 &\times m_1 \\
2 &\times m_3 \\
4 \text{ compare } m_1, m_3 \text{ to get } m_2 \text{ correctly} \\
2 \text{ in, 2 out direction} \\
1 &\text{ all correct}
\end{align*}
\]

\[
\text{Steady } \implies \Sigma m_{in} = \Sigma m_{out}
\]

at 1 flow in \( m = \rho \times A_1 \times V_1 = \rho \times (0.1) \text{ m}^2 \times (1.3) \text{ m/sec} = 1.3 \rho \text{ kg/sec} \)

at 2 flow is out \( m_2 = \rho \times A_2 \times V_2 = \rho \times (0.18) \text{ m}^2 \times (-0.8) \text{ m/sec} = -1.44 \rho \)

so for \( \Sigma m_{in} = \Sigma m_{out} \)

\[ \text{Flow through 2 must be } m_2 = 1.44 \rho \]

\[ \therefore V_2 = \frac{1.44 \rho}{A_2} = \frac{0.0414}{0.2} \text{ m/sec} \]

\[ \therefore V_2 = 0.07 \text{ m/sec} \]
4. (20) A shock is a very thin region in a flow where velocity, temperature, pressure, density, etc. have large jumps in their values. Consider a shock formed in a pipe. There is no heat transfer, the mass flow rate is \( \dot{m} \), and the flow is steady. Draw a control volume around the shock and reduce the energy equation (1st law) to its simplest appropriate form to relate properties on either side of the shock. Since the flow is horizontal, there are no potential energy changes across the shock.

\[ \text{1st law for C.V.} \]

In the rate form:

\[ \frac{dE}{dt}_{\text{C.V.}} = Q - W_{\text{out}} + \dot{m}_1 (h_1 + \frac{V_1^2}{2} + g z_1) - \dot{m}_2 (h_2 + \frac{V_2^2}{2} + g z_2) \]

\[ \frac{dE}{dt} = 0 \quad \text{because steady} \]

\[ Q_{\text{in}} = 0 \quad \text{because problem states no heat} \]

\[ W_{\text{out}} = 0 \]

no potential

So left with

\[ \dot{m}_1 (h_1 + \frac{V_1^2}{2}) - \dot{m}_2 (h_2 + \frac{V_2^2}{2}) = 0 \]

but \( \dot{m}_1 = \dot{m}_2 \) (steady)

So

\[ h_1 + \frac{V_1^2}{2} = h_2 + \frac{V_2^2}{2} \]

Other form O.K. like

\[ (h_2 - h_1) + \frac{(V_2^2 - V_1^2)}{2} = 0 \]
5) (25) Air at 30°C enters a diffuser with area \( A_1 = 0.1 \text{ m}^2 \). The air exits at \( A_2 = 0.2 \text{ m}^2 \) at a temperature of 20°C. Assume the density remains a constant value of 1.0 kg/m³ through this process. This is a steady flow problem with a mass flow rate of 10 kg/s.

A) Compute the rate of heat transfer into or out of the system. Indicate the direction of heat transfer. You can neglect any changes in potential energy.

\[
\dot{Q} = \rho \dot{m} \left( h_2 - h_1 \right) + \frac{V_1^2 - V_2^2}{2}
\]

\[
\dot{m}_1 = \dot{m}_2 = \rho \dot{V}_1 A_1 = \rho \dot{V}_2 A_2
\]

So \( \dot{V}_1 = \frac{\dot{m}}{\rho A_1} = \frac{10 \text{ kg/s}}{1 \text{ kg/m}^3 \times 0.1 \text{ m}^2} = 100 \text{ m/s} \)

\( \dot{V}_2 = \frac{\dot{m}}{\rho A_2} = \frac{10 \text{ kg/s}}{1 \text{ kg/m}^3 \times 0.2 \text{ m}^2} = 50 \text{ m/s} \)

\( h_1 \) for air \( @ 30°C \approx 303 \text{ kJ/kg} \)

\( h_2 \) for air \( @ 20°C \approx 227 \text{ kJ/kg} \)

\[
\dot{Q} = \frac{10 \times 303 \times 293}{\text{sec}} + \frac{50^2 - 100^2}{2} = -1375 \text{ kJ/sec}
\]

\[
\omega = \frac{\dot{Q}}{\dot{m}} = -1375 \text{ kJ/kg}
\]