

$$\Delta H = C_v \Delta T$$

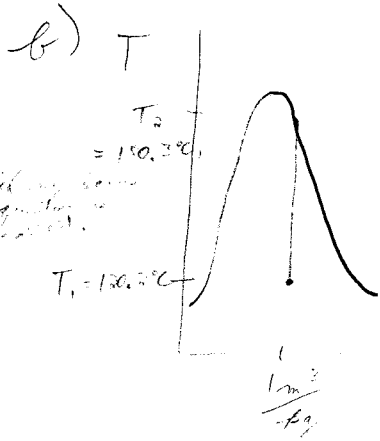
From table A-3, liquid water at 100 kPa has a temperature of 120.2°C (= T₁)
 We want T₂ = 0, and T₂ = 100°C after adding heat.

$$Q_2 = \Delta H + W = 10/20$$

$$= C_v \Delta T$$

Not an
ideal gas.

It would normally use $PV = nRT$
 or $P_1 V_1 = P_2 V_2$ to solve for T₂, but it do
 not have P₂ so it cannot solve for it.
 attempt the usual way for ideal gas.



straight line because volume is constant.

$$u_1 \rightarrow \phi/10$$

$$u_2 \rightarrow \phi/10$$

Baron

T₁ = 120.2°C (a before)
 P₁ = 200 kPa (a before)
 P₂ = 500 kPa

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \Rightarrow \frac{P_1}{T_1} = \frac{P_2}{T_2} \quad \phi/10$$

$$T_2 = \frac{P_2 T_1}{P_1} = \frac{500 \text{ kPa} \cdot 120.2^\circ\text{C}}{200 \text{ kPa}}$$

$$T_2 = 300.5^\circ\text{C}$$

$$Q_2 = C_v \Delta T$$

→ need to know the value of C_v

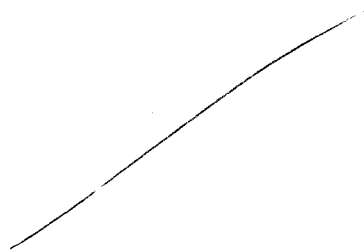
→ At 300°C, C_p = C_v + R, but with the most accurate data we have a value for C_p at

$$T = 300.5^\circ\text{C} \Rightarrow T_2 = 300.5^\circ\text{C} \Rightarrow T = (300.5 + 273.15)^\circ\text{C} = 573.65 \text{ K}$$

→ At this temperature, the value for C_p is 1.87 kJ/kg·K

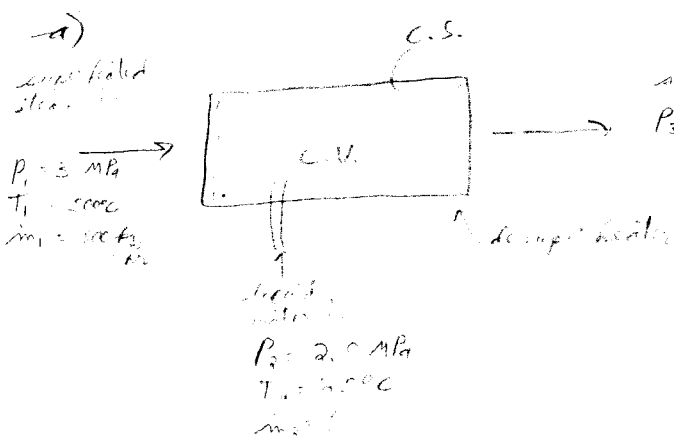
$$\Delta T = 300.5 - 120.2^\circ\text{C}$$

$$\Delta T = 180.3^\circ\text{C}$$



QUESTION 2) It is sometimes necessary to produce saturated steam from superheated steam (which is steam at a temperature higher than the vapour-liquid coexistence temperature for the given pressure). This change can be accomplished in a desuperheater, a device in which just the right amount of liquid water is sprayed into the superheated steam to produce dry, saturated steam. If superheated steam at 3.0 MPa and 500 °C enters the desuperheater at a rate of 500 kg/hr, then at what rate should liquid water at 2.5 MPa and 25 °C be added to the desuperheater to produce saturated steam at 2.25 MPa? Before answering this question you should answer the following:

- Sketch the desuperheater showing the fluid flows entering and leaving the device,
- Determine the enthalpies of the fluids in these flows,
- Determine the quality of the exiting saturated steam at 2.25 MPa (abs), and finally
- Calculate the mass flow rate of liquid water at 2.5 MPa (abs) and 25 °C.



Knowns

$P_1 = 3 \text{ MPa}$
 $T_1 = 500 \text{ }^\circ\text{C}$
 $m_1 = 500 \text{ kg/hr}$
 $P_2 = 2.5 \text{ MPa}$
 $T_2 = 25 \text{ }^\circ\text{C}$
 $m_2 = ?$
 $P_3 = 2.25 \text{ MPa}$

Assumptions

- 1) steady state flow
- 2) mass flow is conserved
- 3) $\Delta H = 0$
- 4) steam acts as an ideal gas
- 5) device is rigid, $\Delta U = 0$
- 6) no heat transfer
- 7) velocity effects are negligible

h₁ (@ 3 MPa, 500°C)
 From Table A4, $h_1 = 2456.5 \frac{\text{kJ}}{\text{kg}}$

h₂ (@ 2.5 MPa, 25°C)
 → for liquids, $h(T, P) \approx h_f(T)$
 so h_2 (@ 25°C), from Table A2, $h_2 = 104.89 \frac{\text{kJ}}{\text{kg}}$

h₃ (@ 2.25 MPa)
 → from Table A3, h_3 (@ 2.25 MPa)
 we need to interpolate

$$\frac{h_3 - h_4}{P_3 - P_4} = \frac{h_5 - h_6}{P_5 - P_6} \rightarrow \frac{2503.1 - 2491.5}{2.5 - 2.0} = \frac{2503.1 - h_3}{2.5 - 2.25} \rightarrow h_3 = 2501.3 \frac{\text{kJ}}{\text{kg}}$$

c) quality of exiting saturated steam @ 0.5 MPa = x = ?

$$h = (1-x)h_f + xh_g$$

→ from before

$$h = h_f + x(h_g - h_f)$$

$$@ 1.2 \text{ MPa, } h_g = 3456.5 \frac{\text{kJ}}{\text{kg}}$$

$$h - h_f = x(h_g - h_f)$$

$$@ P_2 = 0.5 \text{ MPa, } h_g = h_f = 104.89 \frac{\text{kJ}}{\text{kg}}$$

$$x = \frac{h - h_f}{h_g - h_f}$$

$$@ P_2 = 0.5 \text{ MPa, } h_g = h_f = 2801.3 \frac{\text{kJ}}{\text{kg}}$$

$$x = \frac{(2801.3 \frac{\text{kJ}}{\text{kg}}) - (104.89 \frac{\text{kJ}}{\text{kg}})}{(3456.5 \frac{\text{kJ}}{\text{kg}}) - (104.89 \frac{\text{kJ}}{\text{kg}})}$$

$$\therefore x = 0.8045$$

d) Mass flow rate of liquid water at 0.5 MPa and 100°C

$$\dot{Q} = \dot{Q} - \dot{W} + \sum \dot{m}_i (h_i + \frac{V_i^2}{2} + g z_i) - \sum \dot{m}_e (h_e + \frac{V_e^2}{2} + g z_e)$$

$$0 = \dot{m}_1 (h_1 + \frac{V_1^2}{2}) + \dot{m}_2 (h_2 + \frac{V_2^2}{2}) - \dot{m}_3 (h_3 + \frac{V_3^2}{2})$$

Continuity: $\dot{m}_1 + \dot{m}_2 = \dot{m}_3$

→ same as before

$$0 = \dot{m}_1 (h_1 + \frac{V_1^2}{2}) + \dot{m}_2 (h_2 + \frac{V_2^2}{2}) - (\dot{m}_1 + \dot{m}_2) (h_3 + \frac{V_3^2}{2})$$

$$0 = \dot{m}_1 (h_1 + \frac{V_1^2}{2}) + \dot{m}_2 (h_2 + \frac{V_2^2}{2}) - \dot{m}_1 (h_3 + \frac{V_3^2}{2}) - \dot{m}_2 (h_3 + \frac{V_3^2}{2})$$

$$\dot{m}_2 (h_2 + \frac{V_2^2}{2}) - \dot{m}_2 (h_3 + \frac{V_3^2}{2}) = \dot{m}_1 (h_3 + \frac{V_3^2}{2}) - \dot{m}_1 (h_1 + \frac{V_1^2}{2})$$

$$\dot{m}_2 = \frac{\dot{m}_1 (h_3 + \frac{V_3^2}{2}) - \dot{m}_1 (h_1 + \frac{V_1^2}{2})}{(h_2 + \frac{V_2^2}{2}) - (h_3 + \frac{V_3^2}{2})}$$

$$= \frac{\dot{m}_1 [(h_3 + \frac{V_3^2}{2}) - (h_1 + \frac{V_1^2}{2})]}{(h_2 + \frac{V_2^2}{2}) - (h_3 + \frac{V_3^2}{2})}$$

$$\dot{m}_2 = \dot{m}_1 \frac{h_3 - h_1}{h_2 - h_3}$$

$$= \frac{h_3 - h_1}{h_2 - h_3}$$

$$= \frac{(500 \frac{\text{kg}}{\text{s}}) (3456.5 \frac{\text{kJ}}{\text{kg}}) - (500 \frac{\text{kg}}{\text{s}}) (2801.3 \frac{\text{kJ}}{\text{kg}})}{3456.5 \frac{\text{kJ}}{\text{kg}} - 104.89 \frac{\text{kJ}}{\text{kg}}}$$

$$\therefore \dot{m}_2 = 97.744 \text{ kg/s}$$

CARLETON UNIVERSITY

MIDTERM EXAMINATION
February 26, 2010

DURATION: 75 MINUTES

Number of Students: 90+120

Department: Mechanical & Aerospace Engineering
Course: MAAE 2400 Thermodynamics and Heat Transfer
Instructors: Profs. J. Gaydos and T. Kaya

AUTHORIZED MEMORANDA
Open book, Open Notes

Students **MUST** count the number of pages in this examination question paper **before** beginning to write, and report any discrepancy immediately to a proctor. This question paper has 4 pages.

This examination question paper **MAY NOT** be taken from the examination room.

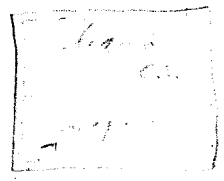
Last Name: HARRINGTON First Name: GREG

Student ID No: 100 76-5093

QUESTION 1) A rigid 1 m³ tank at a pressure of 200 kPa contains a liquid-vapour water mixture. At the beginning, half of the mass inside the tank is in the liquid phase.

- a) Calculate the heat transfer necessary to completely vaporize the water.
 - b) Show the entire process schematically on a temperature-specific volume (T-v) diagram.
- Bonus question: Calculate the heat transfer necessary to raise the pressure to 500 kPa and show the process on the same T-v diagram.

Diagram



Assumptions

- 1) This is a closed system ✓
- 2) $\Delta PE = \Delta KE = 0$ ✓

Known values

$V = 1 \text{ m}^3$ $V_{\text{at}} = \text{liquid}$
 $P = 200 \text{ kPa}$ $V_{\text{at}} = \text{vapor}$
 $Q = ?$

Transfer closed systems: $\Delta E = Q_2 - W_2 = \Delta U + \Delta PE + \Delta KE$

$\Delta U = Q_2 - W_2$ ✓

$Q_2 = \Delta U + W_2$

$W_2 = \int P dV$

0 because container is rigid, also volume is constant ✓