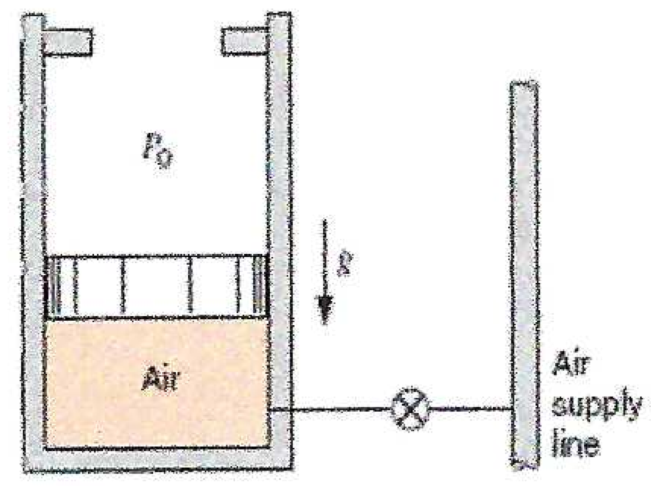
ME 40 Thermodynamics
Spring 2020 Midterm 1 Name: ____________________

1. (50 pts.) A mass-loaded piston/cylinder containing air is at 300 kPa, 17°C with a volume of 0.25 m^3, while at the stops V = 1 m^3. An air-line, at 500 kPa, and 600 K, is connected by a valve that is then opened until a final inside pressure of 400 kPa is reached, at which point T = 350 K. Assumptions are yours to make.



a. Find the air mass that enters, the work, and heat transfer.

POINTS

5 MASS BALANCE $m_2 - m_1 = m_{in}$

15 ENERGY BALANCE

$$m_2 u_2 - m_1 u_1 = m_{in} h_{in} + Q_2 - W$$

5 $P_1 V_1 = m R T_1$ $m_1 = 0.9$ kg

5 $P_2 V_2 = m R T_2$ $m_2 = 3.982$ kg

15 $W = P_1 (V_2 - V_1) = 225$ kJ

5 $Q = 819$ kJ

CONSTANT Cv Cp − 0

TAVE + 2

h, u + 2

~~A~~ With Steam Tables

Each 5pts
- energy eqn
- mass eqn
- h_1
- h_2
- x
- correct answer

- mass (5)
- volume (5)

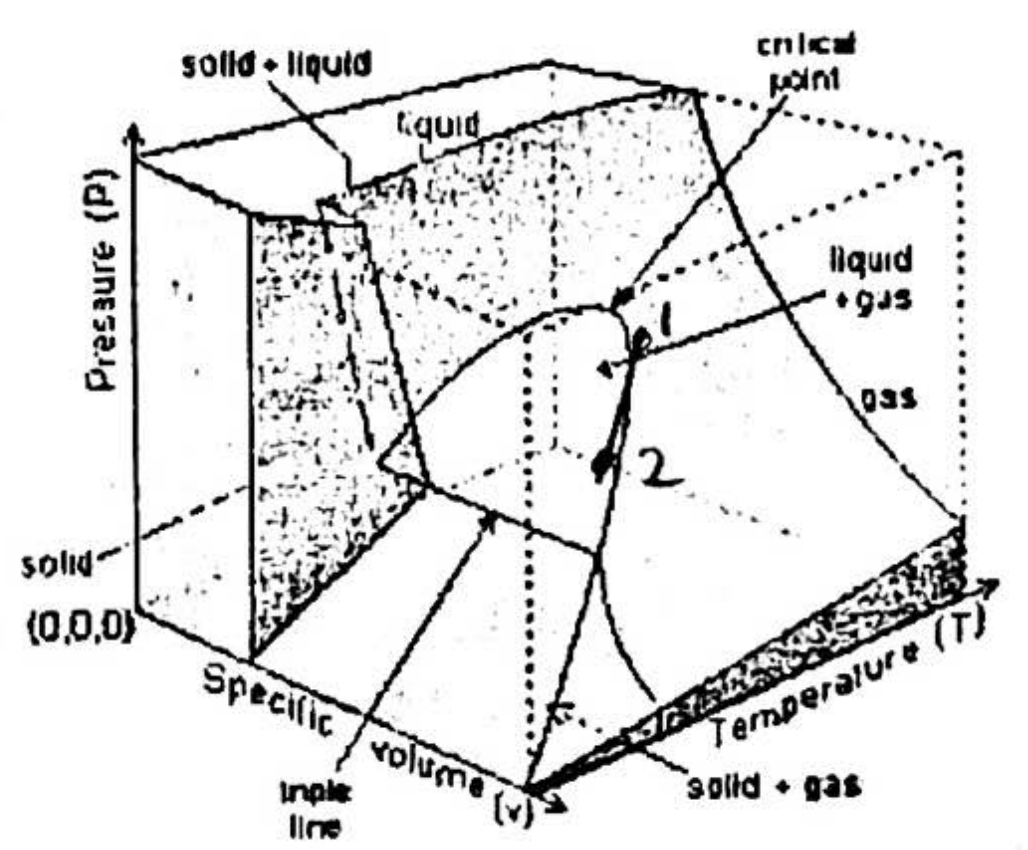
2. (50 pts.) Steam at 0.6 MPa and 200 C enters a nozzle with a velocity of 50 m/s. It leaves at a pressure of 0.15 MPa and a velocity of 600 m/s. The nozzle is assumed adiabatic, i.e. no heat exchange with the environment.

   a. (30 pts tot) Determine the final temperature if the steam is superheated in the final state or, the quality and temperature if it is saturated.

   b. (5 pts tot) Draw the process on the diagram at the right and on a two-dimensional projection of the diagram at the right.

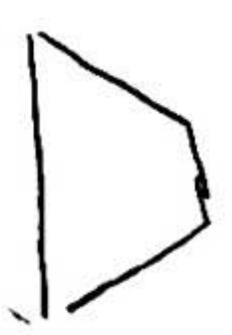
   c. (10 pts tot) If you can, calculate the mass and volume flow rates. If you can't, use what information you have with placeholders in your equation for the information you would need to do so.

   d. (5 pts tot) Is the adiabatic assumption reasonable? Why?



steam

$P_1 = 0.6$ MPa
$t_1 = 200°C$
$V_1 = 50 \frac{m}{s}$



$P_2 = 0.15$ MPa
$V_2 = 600$ m/s

adiabatic

$v_2 > v_1$
$P_1 < P_2$

state 1 superheated

$P_1 = 0.6$ MPa
$t_1 = 200°C$
$h_1 = 2850.6 \frac{kJ}{kg}$

mass

$\dot{m}_{in} = \dot{m}_{out}$

energy

$\dot{m}_1 (h_1 + \frac{1}{2} V_1^2) = \dot{m}_2 (h_2 + \frac{1}{2} V_2^2)$

$h_1 + \frac{1}{2} V_1^2 = h_2 + \frac{1}{2} V_2^2$

$h_2 = h_1 + \frac{1}{2}(V_1^2 - V_2^2)$

$= 2850.6 \frac{kJ}{kg} + \frac{\frac{1}{2}(50 \frac{m}{s}^2 - 600 \frac{m}{s}^2)}{1000}$

$h_2 = 2671.85 \frac{kJ}{kg}$

state 2

$P_2 = 0.15$ MPa

sat mix

$h = 2671.85 \frac{kJ}{kg}$

$T_2 = 111.35°C$ but just need quality

$x = \frac{h - h_f}{h_{fg}} = \frac{2671.85 \frac{kJ}{kg} - 467.13 \frac{kJ}{kg}}{2226 \frac{kJ}{kg}} = 0.99$

$\dot{m}_1 = \frac{A_1 V_1}{v_1}$ $\dot{m}_{in} = \dot{m}_{out}$ so 1 $\dot{m}$

$\dot{m}_1 = \frac{A_1 (50 \frac{m}{s})}{0.3512 \ m^3/kg}$ $v_1 = 0.35212 \ m^3/kg$

or

$\dot{m} = \frac{A(600 \frac{m}{s})}{0.001053 + 0.99(1.1594 - 0.001053)}$ v_2

$\dot{m}_1 = \frac{A(600 \frac{m}{s})}{1.15 \ m^3/kg}$

$\dot{V} = VA = \dot{m}v$

yes adiabatic b/c velocity so fast through nozzle