Name Pat M

Circle one (ME EN 2300) CH EN 2300

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

answer right 2
explanation correct 6

8 a) saturated mixture –
Because enthalpy between the sat liquid & sat. vapor

answer 2 explanation 5

7 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 1000K. 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

$\Delta \bar{u} = \int \bar{c}_v dT = \int_{T_1}^{T_2} (\bar{c}_p - R_u) dT$

$R_u = 8.31447\ kJ/kmol\ K$

$= \int_{T_1}^{T_2} [(a - R_u) + bT + cT^2 + dT^3] dT$

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

For NO:

$a = 29.34$, $b = -0.09395 \times 10^{-2}$ $c = 0.9747 \times 10^{-5}$ $d = -4.187 \times 10^{-9}$

$\Delta \bar{u} = (a - R_u) 500 + \frac{b}{2}(250{,}000) + \frac{c}{3}(8.75 \times 10^{8}) + \frac{d}{4}(9.375 \times 10^{11})$

$= [10512 - 117 + 2842 - 979]\ kJ/kmole$

$= 12258\ kJ/kmole$

$M_{NO} = 14 + 16 = 30\ kg/kmole$

$\Delta u = \frac{12258}{30} = 409\ kJ/kg$

$du = C_v dT$ 1

$\Delta u = \int \bar{c}_v dT$ 2

$\bar{c}_v = \bar{c}_p - R_u$ 2

integral set up 7

integral evaluate 7

molar → mass conversion

$c_v = \frac{\bar{c}_v}{M}$ 2

M evaluation 2

R_u 1

all correct 1

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:

$A_1 = 0.1\ m^2$

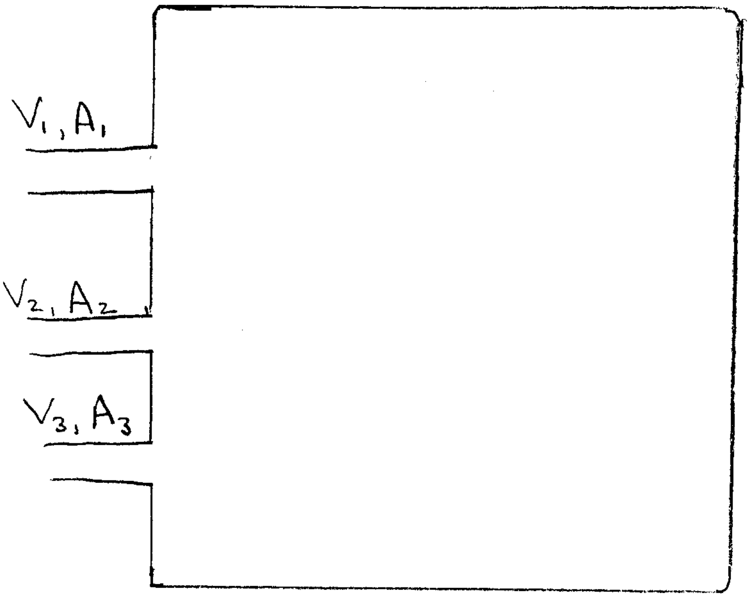
$A_2 = 0.2\ m^2$

$A_3 = 0.18\ m^2$

$V_1 = 1.3$ m/s (into mixing chamber)

$V_3 = -0.8$ 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?



2 $\sum \dot{m}_{in} = \sum \dot{m}_{out}$

2 $\dot{m} = \rho A V$

2 $\dot{m}_1$

2 $\dot{m}_3$

4 compare $\dot{m}_1$ $\dot{m}_3$ to get $\dot{m}_2$ correctly

2 $\dot{m}_2$ direction

1 all correct

Steady $\Rightarrow \sum \dot{m}_{in} = \sum \dot{m}_{out}$

at ① flow is in ∴ $\dot{m} = \rho A_1 V_1 = \rho(.1)m^2(1.3)m/sec$

$= .13\rho$ in kg/sec

at ③ flow is out

∴ $\dot{m}_3 = \rho A_3 V_3 = \rho(.18)m^2(.8\ m/sec) = .144$

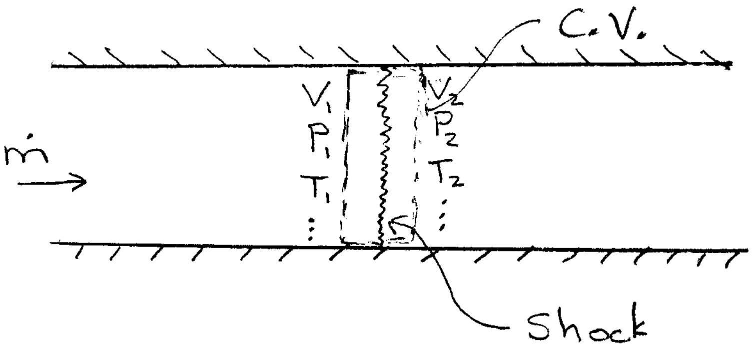
So for $\sum \dot{m}_{in} = \sum \dot{m}_{out}$

Flow through 2 must be $\dot{m}_2 = .014\rho$ in

∴ $V_2 A_2 = .014 \Rightarrow V_2 = \frac{.014}{.2} = .07$ m/sec

out

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.



3 draw C.V.

6 Correct full energy

reduce

3 $\frac{dE}{dt}=0$

3 $\dot{Q}=0$

3 $\dot{W}=0$

2 all correct

1st Law for C.V.

In the rate form

$$\left.\frac{dE}{dt}\right|_{C.V.} = \dot{Q}_{in} - \dot{W}_{out} + \dot{m}_1\left(h_1 + \frac{V_1^2}{2} + g z_1\right) - \dot{m}_2\left(h_2 + \frac{V_2^2}{2} + g z_2\right)$$

$\frac{dE}{dt} = 0$ because steady

$\dot{Q}_{in} = 0$ because problem states no h.t.

$\dot{W}_{out} = 0$

no potential

So left with $\dot{m}\left(h_1 + \frac{V_1^2}{2}\right) - \dot{m}_2\left(h_2 + \frac{V_2^2}{2}\right) = 0$

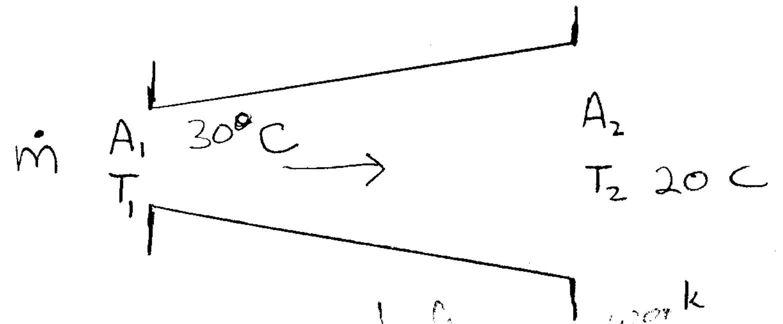
but $\dot{m}_1 = \dot{m}_2$ (steady)

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 $A_1 = 0.1\ m^2$. The air exits at $A_2 = 0.2\ m^2$ at a temperature of 20 C. Assume the density remains a constant value of 1.0 kg/ m^3 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 ~~nozzle~~ diffuser. Indicate the direction of heat transfer. You can neglect any changes in potential energy.



neglect

$$\frac{dE}{dt} = \dot{Q} - \dot{W}_{out} + \dot{m}_1\left(h_1 + \frac{V_1^2}{2} + gz\right) - \dot{m}_2\left(h_2 + \frac{V_2^2}{2} + gz\right)$$

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

$\dot{m}_1 = \dot{m}_2 = \rho V_1 A_1 = \rho V_2 A_2$

so $V_1 = \frac{\dot{m}}{\rho A_1} = \frac{10\ kg/sec}{1\ kg/m^3\ (.1\ m^2)} = 100\ m/sec$

$V_2 = \frac{\dot{m}}{\rho A_2} = \frac{10}{1\ (.2)} = 50\ m/sec$

h_1 for air @ 30 C = 303 K ≈ 303 kJ/kg

@ 20 C = 293 K ≈ 293 kJ/kg

J, not kJ

So $\dot{Q} = \frac{10\ kg}{sec}\left[(293 - 303) + \frac{50^2 - 100^2}{2}\right] =$

$\frac{10\ kg}{sec}\left[-10 \quad -3.75\ kJ\right] = -137.5 = kJ/sec$

or $q = -13.75\ kJ/kg$

8 correct full energy

reduce:

3 $\frac{dE}{dt} = 0$

3 $W = 0$

3 $Q \neq 0$

$V_1 = 2$, $V_2 = 2$ — 3 equat, 1 correct

$h_1 = 2$, $h_2 = 2$ — 3 process, 1 correct

13/18