Concepts of Thermodynamics
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Lecture – 32
Supplementary Lecture: Problem Solving with the Aid of a Computer

Hello and welcome to this session in which we will consider another problem on the transients of the first law of thermodynamics.

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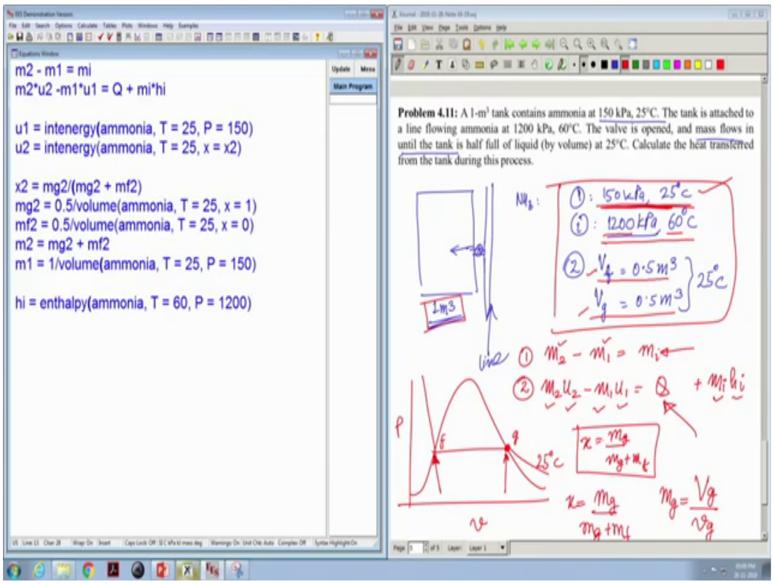

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m2 - m1 = mi
m2*u2 -m1*u1 = Q + mi*hi

u1 = intenergy(ammonia, T = 25, P = 150)
u2 = intenergy(ammonia, T = 25, x = x2)

x2 = mg2/(mg2 + mf2)
mg2 = 0.5/volume(ammonia, T = 25, x = 1)
mf2 = 0.5/volume(ammonia, T = 25, x = 0)
m2 = mg2 + mf2
m1 = 1/volume(ammonia, T = 25, P = 150)

hi = enthalpy(ammonia, T = 60, P = 1200)
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Problem 4.11: A 1-m³ tank contains ammonia at 150 kPa, 25°C. The tank is attached to a line flowing ammonia at 1200 kPa, 60°C. The valve is opened, and mass flows in until the tank is half full of liquid (by volume) at 25°C. Calculate the heat transferred from the tank during this process.

In this particular problem we have been given that we have a 1 meter cube tank of ammonia. So, the initial state is given as 150 kPa and 25 degree Celsius, the tank is attached to a line in which ammonia is flowing let us put a valve over here ok. So, the line pressure is given as 1200 kPa at 60 degree Celsius. So, ammonia flows from the line to the tank because, the pressure in the line exceeds that of the tank. Once the valve is opened mass flows into the tank and until half of the tank is filled with ammonia with liquid ammonia.

So, at state 2 volume of liquid is equal to 0.5 meter cube because the whole tank is 1 meter cube and volume of the vapour or V g, let us use the subscripts V f for the liquid fluid and V g for the vapour gas is also 0.5 meter cube and both these states are at equilibrium at 25 degree Celsius. So, we have to find out the heat transfer from the tank during the process.

Let us first write down the conservation of mass so; obviously, m 2 minus m 1 is equal to m i minus m e is still valid, but here there is no exit thus m e vanishes. So, this is the conservation of mass these are all the states. So, the second thing is to write down the conservation of energy. So, m 2 u 2 minus m 1 u 1 is equal to Q minus w plus m i h i minus m e h e given that there is no exit. So, this term vanishes and also given there is no work done by the system or on the system the work done vanishes.

So, you simply have m i h i m 2 u 2 m i m m i m 1 u 1 and Q where, we have implicitly neglected the total contribution from the kinetic energy and the potential energy towards the internal energy and the enthalpy, thus we have simply written u 2 total as u 2, u 1 total as u 1, h i total as h i there we go. So, given that we know exactly what state 1 is we know u 1 and m 1, because we will know what the specific volume corresponding to this state for ammonia is and given that we know the total volume we will know the total mass.

At state 2 we have the volumes of the 2 fluids and if we know the volumes of the 2 fluids we can find out the quality. Because, if we have the dome like this we know the specific volume at 25 degree Celsius this is the isotherm 25 degree Celsius. So, at 25 degree Celsius we know the specific volume of pure vapour and of pure liquid. And, if we know that we can know using the specific volume and the total volume the total masses of the vapour and the liquid.

So, if you know the total mass we can then find out x. So, given this information we can find out what state 2 corresponds to exactly and thus we can know what u 2 is and if and given the volumes and the specific volumes we will know what m 2 is also. So, m 2 m 1 u 2 u 1 unknown m 2 is known m 1 is known. So, m i will be found out using this equation if m i is known and h i is also known because we know the inlet conditions for ammonia which is 1200 kPa at 60 degree Celsius. So, even this will be known and using all this information that Q will also be found out eventually.

So, let us start plugging in these values. So, we have m 2 equal to m 2 minus m 1 is equal to m i, we have m 2 into u 2 minus m 1 into u 1 is equal to Q plus m i into h i, where u 1 is equal to intenergy of ammonia T equal to 25 and P equal to 150. Then we have u 2 equal to intenergy ammonia at T equal to 25, but x equal to x 2, let us find out what x 2 is. So, x 2 is mass of vapour at 2 divided by the total mass where mg 2 is equal to 0.5 which is the volume by the specific volume of ammonia at t equal to 25 and x equal to 1.

Similarly, m fluid 2 is equal to 0.5 by the volume specific volume for ammonia T equal to 25, x equal to 0, here I have made use simply of the fact that if x equal to mg, where mg plus mf then I must know what mg is. So, mg is equal to the volume of the vapour occupied by the specific volume. So, this is the volume of the vapour which is there in the total container and there is this specific volume this is how we find this all. So, this is for the vapour, this is for the fluid x equal to 0 implies fluid the quality x equal to 0 is for fluid. So, this is how you find out x 2 alright so, we know u u 1 u 2 and we also know the masses of the vapours and liquid.

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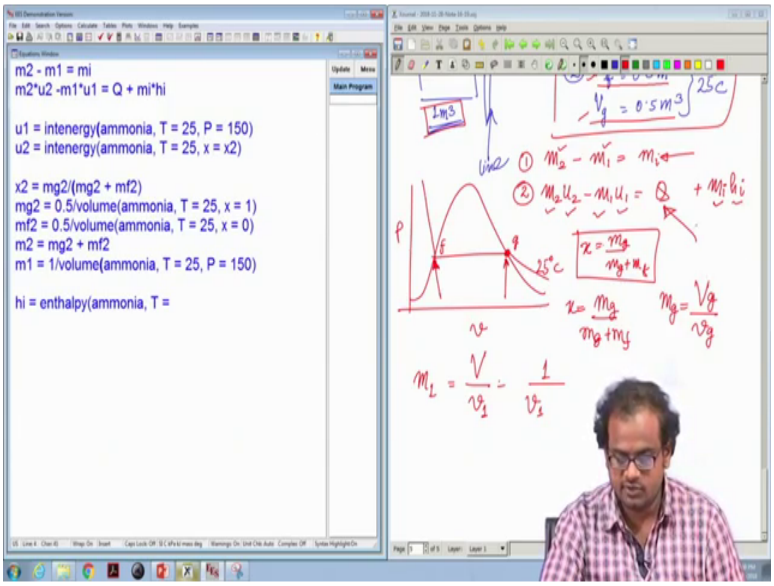

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m2 = mg2 + mf2
m1 = 1/volume(ammonia, T = 25, P = 150)

hi = enthalpy(ammonia, T =
```

So, m 2 is simply mg 2 plus mf 2 and mass of the initial condition is simply 1 by volume of ammonia T equal to 25 and P equal to 150. This is because the initial condition is this and initially there is one meter cube of ammonia and so, the initial mass m 1 is equal to the initial volume or the other volume which is simply 1 meter cube by the initial specific volume.

So, this is equal to 1 by the specific volume at the initial condition. So, this is 1 divided by the specific volume at the initial condition which is 25 degree Celsius and 150 kPa. So, we have m 1 we have m 2 and we have all the energies except the enthalpy at the inlet line. So, h i is equal to the enthalpy for ammonia. So, what is the inlet condition, let us find out. It is 1200 kilo Pascal at 60 degree Celsius.

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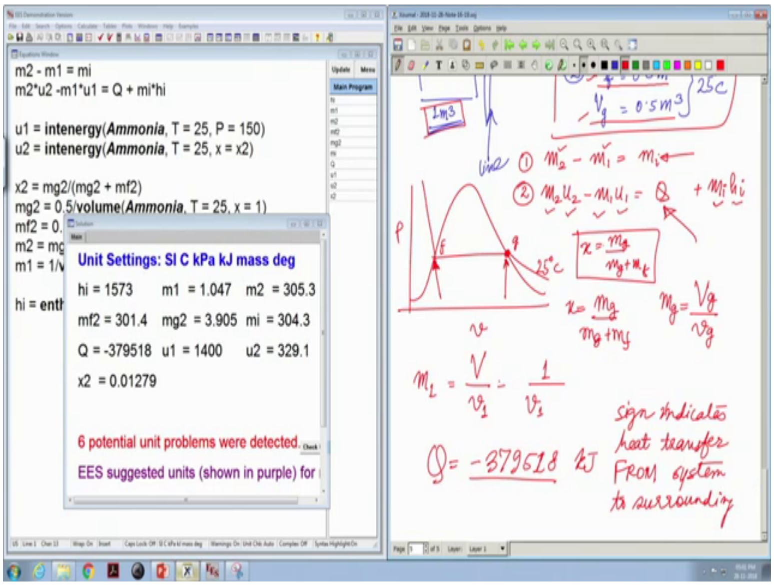

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u2 = intenergy(Ammonia, T = 25, x = x2)

x2 = mg2/(mg2 + mf2)
mg2 = 0.5/volume(Ammonia, T = 25, x = 1)
mf2 = 0.
m2 = mg
m1 = 1/v

hi = enth
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Unit Settings: SI C kPa kJ mass deg
hi = 1573       m1  = 1.047   m2  = 305.3
mf2 = 301.4     mg2  = 3.905  mi  = 304.3
Q = -379518     u1  = 1400    u2  = 329.1
x2  = 0.01279

6 potential unit problems were detected.
EES suggested units (shown in purple) for
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$V_g = 0.5 m^3$ 25C

1m3

line ① $m_2 - m_1 = m_i$

② $m_2 u_2 - m_1 u_1 = Q + m_i h_i$

$x = \frac{m_g}{m_g + m_f}$

$x = \frac{m_g}{m_g + m_f}$ $m_g = \frac{V_g}{v_g}$

$m_1 = \frac{V}{v_1} = \frac{1}{v_1}$

$Q = -379518$ kJ

sign indicates heat transfer FROM system to surrounding

There you go so let us solve this and so the amount of heat transferred from the system we obtain Q as minus 379518 kilo joule that is a huge amount of heat transfer and so the heat this heat the sign indicates it is heat transfer from the system to the surrounding. So, if someone asks what is the heat lost then you will say the heat transferred from the tank is 379.51 mega joule ok, when if you want to go very scientific you will say the heat transfer to the system is minus 379518 kilo joule.

So, with the help of conservation of mass and conservation of energy we were able to solve this problem and the slightly interesting thing was finding out the x using the fact that the final state was given as half volume of liquid. So, the solution says actually the x was 0.01279. So, I hope you will work this problem out on your own you will try to work out all the logic behind the problem and you will be able to solve many more problems of this kind on your own. So, with this we end this session and I will see you next time.

Thank you.