Thermodynamics
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Lecture 47
Tutorial Problems (2 numbers)

Let's look at few tutorial problems on steam and water mixtures. It is recommended to have a hardcopy of steam tables.

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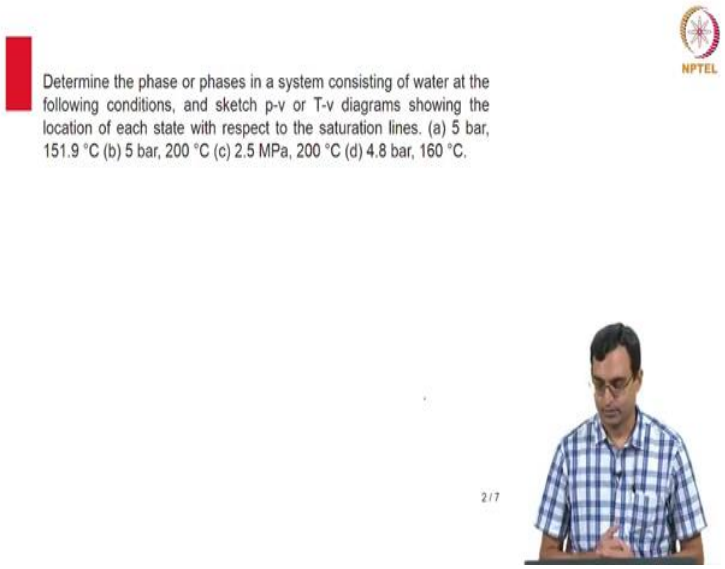

Figure 1.

Solution of the problem in Fig. 1:

(a) 5 bar, 151.9 ℃

Let's go to the steam tables listed by pressure. We don't have a value of 5 bar or 0.5 MPa in the tables. We will find the properties by linear interpolation. The properties at 0.5 MPa are the average of those at 0.4 MPa and 0.6 MPa. After taking average, saturation temperature at 5 bar is 151.2 ℃. Since the given temperature, 151.9 ℃, is greater than 151.2 ℃, the state at 5 bar and 151.9 ℃ lies in the superheated zone. The intersection of the isotherm T=151.9 ℃ and the isobar p=5 bar represents the state asked in the problem on a p-v diagram as well as on the T-v diagram. Figure 2 shows the state (point a) on a p-v and T-v diagram.

(b) 5 bar, 200 ℃

At 5 bar, the saturation temperature is T_{sat} = 151.2 ℃. The given temperature is greater than T_{sat}. Hence, the state corresponding to 5 bar and 200 ℃ lies in the superheated zone. Figure 3 shows the state (point b) on a p-v and T-v diagram. The degree of superheat is more in the case b than a. Degree of superheat equals the difference between the saturation temperature and the actual temperature of the superheated vapour.

(c) 2.5 MPa, 200 ℃

The pressure 2.5 MPa is not listed in the pressure table. Let's look at a temperature table.

At 200 ℃, the saturation pressure is p_{sat} = 1.55 MPa. The given pressure is higher than p_{sat}. Hence, the state lies in the compressed liquid region. Figure 3 shows the state (point c) on a p-v and T-v diagram.

(d) 4.8 bar, 160 ℃

Let's look at the table listed by temperature.

At 160 ℃, the saturation pressure is p_{sat} = 0.6182 MPa = 6.182 bar. The given pressure, 4.8 bar, is less than p_{sat}. Hence, the point lies in the superheated region. Figure 3 shows the state (point d) on a p-v and T-v diagram.

Within the liquid-vapour dome, the pressure and temperature are not independent. Hence, to locate the state on a p-v or T-v diagram within the liquid-vapor dome, along with pressure or temperature some other property such as internal energy, specific volume, specific enthalpy or specific entropy needs to be given.

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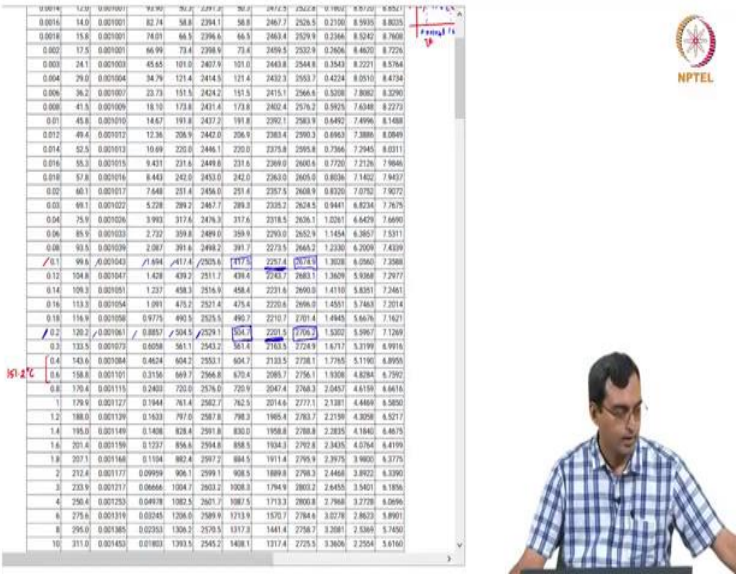

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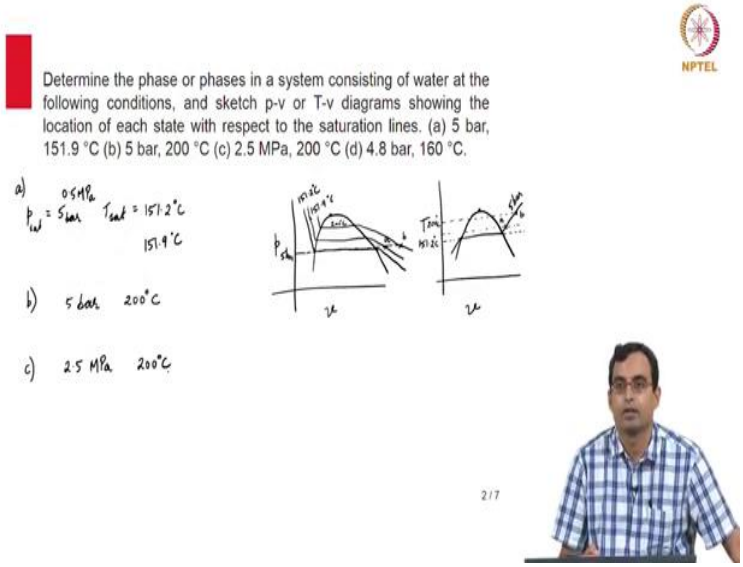

Figure 2.

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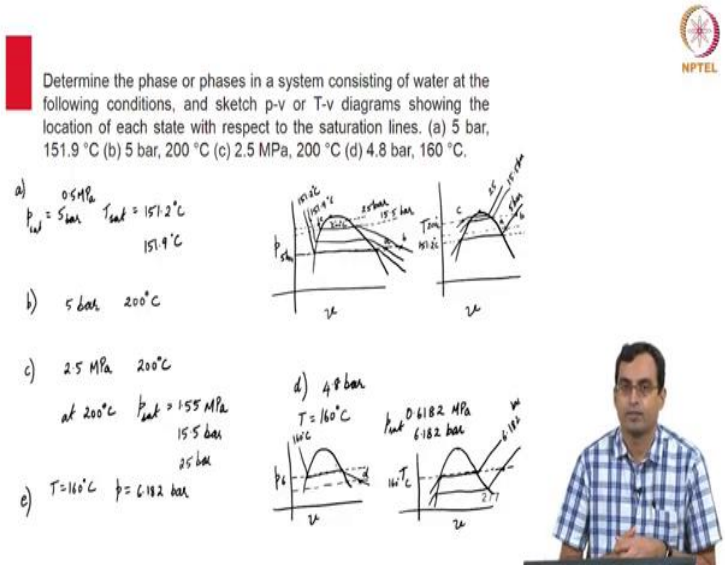
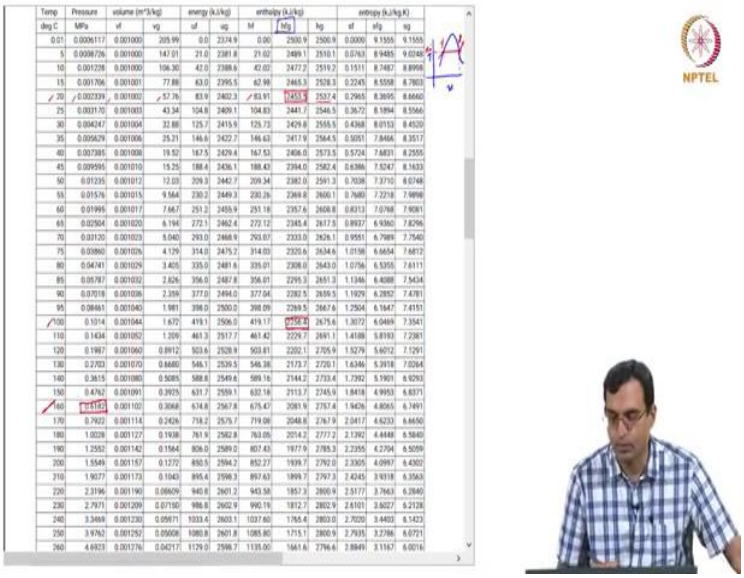


Figure 3.



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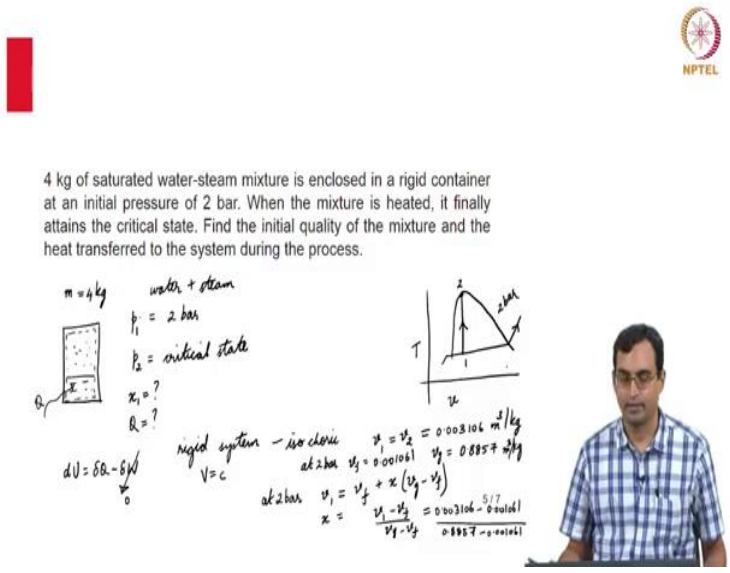


Figure 4.

Solution of the problem given in Fig. 4:

$m_{mix} = 4\ kg, p_1 = 2\ bar, p_2 = p_c$=pressure at the critical point

The system is the mixture inside the container.

Since it is a rigid container, the work done W = 0.

The first law in the integrated form, $\Delta U = Q$ (there are no changes in kinetic and potential energy).

The process is shown on a T-v diagram in Fig. 4. It is a constant volume process. The initial state is the point of intersection of 2 bar isobar and a vertical line passing through the critical point on a T-v diagram.

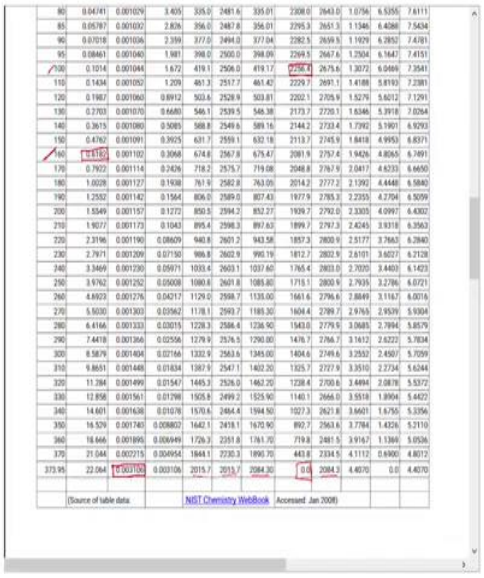
Since the mass is fixed and it is a constant volume process, $v_1 = v_2 = v_c$ = specific volume at the critical point = 0.003106 m^3/kg.

Now, $v_1 = \left[v_f + x\left(v_g - v_f\right)\right]_{at\ 2\ bar}$

Hence, $x = \frac{v_1 - v_f}{v_g - v_f} = \frac{0.003106 - 0.001061}{0.8857 - 0.001061} = 0.0023$ (the values of the specific volumes are obtained from the steam tables)

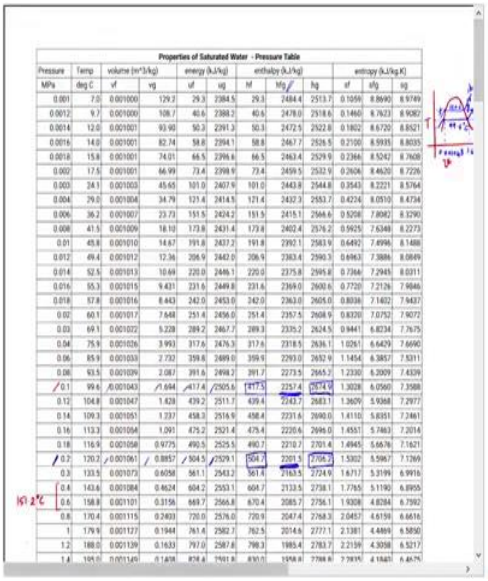
Now, $Q = \Delta U = m\Delta u = m(u_2 - u_1) = m\left[u_c - \left\{u_f + x\left(u_g - u_f\right)\right\}_{2bar}\right] = 4[2015.7 + 0.0023(2529.1 - 504.5)] = 6026.2\ kJ$ ($u_2 = u_c$=specific internal energy at the critical point)

Since Q is positive, the heat is transferred to the system.



Properties of Saturated Water - Pressure Table

Pressure	Temp	volume (m^3/kg)		energy (kJ/kg)		enthalpy (kJ/kg)			entropy (kJ/kg.K)		
MPa	deg C	vf	vg	uf	ug	hf	hfg	hg	sf	sfg	sg
0.001	7.0	0.001000	129.2	29.3	2384.5	29.3	2484.4	2513.7	0.1059	8.8690	8.9749
0.0012	9.7	0.001000	108.7	40.6	2388.2	40.6	2478.0	2518.6	0.1460	8.7623	8.9082
0.0014	12.0	0.001001	93.90	50.3	2391.3	50.3	2472.5	2522.8	0.1802	8.6720	8.8521
0.0016	14.0	0.001001	82.74	58.8	2394.1	58.8	2467.7	2526.5	0.2100	8.5935	8.8035
0.0018	15.8	0.001001	74.01	66.5	2396.6	66.5	2463.4	2529.9	0.2366	8.5242	8.7608
0.002	17.5	0.001001	66.99	73.4	2398.9	73.4	2459.5	2532.9	0.2606	8.4620	8.7226
0.003	24.1	0.001003	45.65	101.0	2407.9	101.0	2443.8	2544.8	0.3543	8.2221	8.5764
0.004	29.0	0.001004	34.79	121.4	2414.5	121.4	2432.3	2553.7	0.4224	8.0510	8.4734
0.006	36.2	0.001007	23.73	151.5	2424.2	151.5	2415.1	2566.6	0.5208	7.8082	8.3290
0.008	41.5	0.001009	18.10	173.8	2431.4	173.8	2402.4	2576.2	0.5925	7.6348	8.2273
0.01	45.8	0.001010	14.67	191.8	2437.2	191.8	2392.1	2583.9	0.6492	7.4996	8.1488
0.012	49.4	0.001012	12.36	206.9	2442.0	206.9	2383.4	2590.3	0.6963	7.3886	8.0849
0.014	52.5	0.001013	10.69	220.0	2446.1	220.0	2375.8	2595.8	0.7366	7.2945	8.0311
0.016	55.3	0.001015	9.431	231.6	2449.8	231.6	2369.0	2600.6	0.7720	7.2126	7.9846
0.018	57.8	0.001016	8.443	242.0	2453.0	242.0	2363.0	2605.0	0.8038	7.1402	7.9437
0.02	60.1	0.001017	7.648	251.4	2456.0	251.4	2357.5	2608.9	0.8320	7.0752	7.9072
0.03	69.1	0.001022	5.228	289.2	2467.7	289.3	2335.2	2624.5	0.9441	6.8234	7.7675
0.04	75.9	0.001026	3.993	317.6	2476.3	317.6	2318.5	2636.1	1.0261	6.6429	7.6690
0.06	85.9	0.001033	2.732	359.8	2489.0	359.9	2293.0	2652.9	1.1454	6.3857	7.5311
0.08	93.5	0.001039	2.087	391.6	2498.2	391.7	2273.5	2665.2	1.2330	6.2009	7.4339
0.1	99.6	0.001043	1.694	417.4	2505.6	417.5	2257.4	2674.9	1.3028	6.0560	7.3588
0.12	104.8	0.001047	1.428	439.2	2511.7	439.4	2243.7	2683.1	1.3609	5.9368	7.2977
0.14	109.3	0.001051	1.237	458.3	2516.9	458.4	2231.6	2690.0	1.4110	5.8351	7.2461
0.16	113.3	0.001054	1.091	475.2	2521.4	475.4	2220.6	2696.0	1.4551	5.7463	7.2014
0.18	116.9	0.001058	0.9775	490.5	2525.5	490.7	2210.7	2701.4	1.4945	5.6676	7.1621
0.2	120.2	0.001061	0.8857	504.5	2529.1	504.7	2201.5	2706.2	1.5302	5.5967	7.1269
0.3	133.5	0.001073	0.6058	561.1	2543.2	561.4	2163.5	2724.9	1.6717	5.3199	6.9916
0.4	143.6	0.001084	0.4624	604.2	2553.1	604.7	2133.5	2738.1	1.7765	5.1190	6.8955
0.6	158.8	0.001101	0.3156	669.7	2566.8	670.4	2085.7	2756.1	1.9308	4.8284	6.7592
0.8	170.4	0.001115	0.2403	720.0	2576.0	720.9	2047.4	2768.3	2.0457	4.6159	6.6616
1	179.9	0.001127	0.1944	761.4	2582.7	762.5	2014.6	2777.1	2.1381	4.4469	6.5850
1.2	188.0	0.001139	0.1633	797.0	2587.8	798.3	1985.4	2783.7	2.2159	4.3058	6.5217
1.4	195.0	0.001149	0.1408	828.4	2591.8	830.0	1958.8	2788.8	2.2835	4.1843	6.4678



$\kappa = 2.5 \times 10^{-3}$

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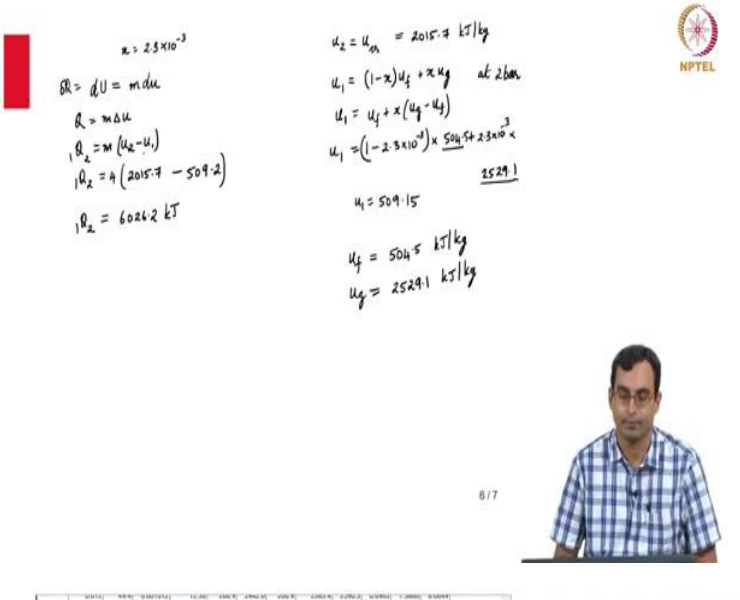

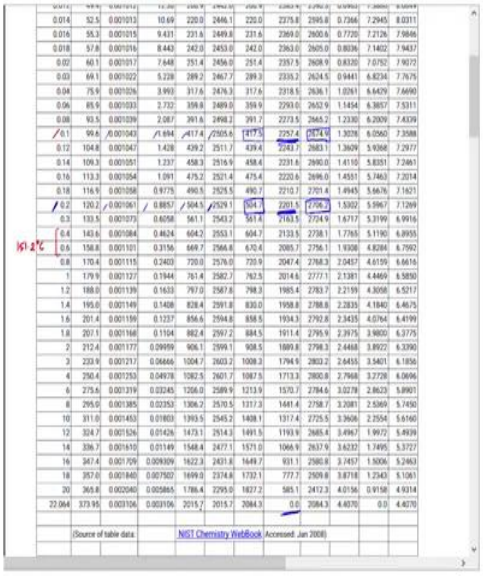

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