

Thermodynamics
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Lecture 50
Tutorial Problem Part-3

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A frictionless piston-cylinder assembly contains steam having a volume of 0.2 m^3 , mass 0.6 kg and pressure 0.5 MPa . The steam is heated to 300°C at constant pressure. Calculate the work done and the heat transferred.



$V_1 = 0.2 \text{ m}^3$
 $m_1 = 0.6 \text{ kg}$
 $p_1 = 0.5 \text{ MPa}$
 $v_1 = \frac{V_1}{m} = \frac{0.2}{0.6} = 0.33 \text{ m}^3/\text{kg}$
 $v_f = \frac{0.4624 + 0.3156}{2} \Rightarrow v_f = 0.389 \text{ m}^3/\text{kg}$
 $v_g = \frac{0.001084 + 0.001181}{2} \Rightarrow v_g = 0.001132 \text{ m}^3/\text{kg}$
 $x = v_f + x(v_g - v_f) \Rightarrow x = \frac{v_1 - v_f}{v_g - v_f} = 0.827$
 $T_2 = 300^\circ\text{C}$
 $p = C \Rightarrow p_2 = 0.5 \text{ MPa}$
 $m_1 = m_2 = m = 0.6 \text{ kg}$
 $N_2 = ?$
 $Q_2 = ?$
 $300^\circ\text{C} > T_{sat} @ 0.5 \text{ MPa}$



Figure 1.

$W_2 = m(h_2 - h_1)$
 $W_2 = p(v_2 - v_1) = p m (v_2 - v_1) = 0.5 \times 10^6 \times 0.6 \times (0.4250 - 0.33)$
 $W_2 = 28 \text{ kJ}$
 $\Delta U = m(u_2 - u_1)$
 $Q_2 = W_2 + \Delta U$



$v_2 = 0.4250 \text{ m}^3/\text{kg}$
 $h_2 = 2855.8 \text{ kJ/kg}$
 $h_1 = h_f + x(h_g - h_f)$
 $h_1 = h_f + x h_{fg}$
 $h_f = \frac{601.7 + 670.6}{2}$
 $h_{fg} = \frac{2136.5 + 2085.7}{2}$
 $h_1 = 637.55 + 0.827 \times 2109.6$
 $h_1 = 2424.38 \text{ kJ/kg}$



Properties of Saturated Water											
Saturated Vapor				Saturated Liquid				Saturated Vapor			
Temp	Pressure	Specific Volume	Enthalpy	Temp	Pressure	Specific Volume	Enthalpy	Temp	Pressure	Specific Volume	Enthalpy
t	P	v_g	h_g	t	P	v_f	h_f	t	P	v_g	h_g
0.01	0.000611	206.136	2536.92	0.01	0.000611	0.000999	2536.92	0.01	0.000611	206.136	2536.92
5	0.000870	167.290	2555.00	5	0.000870	0.000998	2555.00	5	0.000870	167.290	2555.00
10	0.001235	137.734	2570.92	10	0.001235	0.000997	2570.92	10	0.001235	137.734	2570.92
15	0.001751	114.829	2585.00	15	0.001751	0.000996	2585.00	15	0.001751	114.829	2585.00
20	0.002455	97.867	2597.50	20	0.002455	0.000995	2597.50	20	0.002455	97.867	2597.50
25	0.003383	83.533	2608.75	25	0.003383	0.000994	2608.75	25	0.003383	83.533	2608.75
30	0.004581	71.833	2619.00	30	0.004581	0.000993	2619.00	30	0.004581	71.833	2619.00
35	0.006094	62.896	2628.50	35	0.006094	0.000992	2628.50	35	0.006094	62.896	2628.50
40	0.008070	55.845	2637.50	40	0.008070	0.000991	2637.50	40	0.008070	55.845	2637.50
45	0.010580	49.832	2646.00	45	0.010580	0.000990	2646.00	45	0.010580	49.832	2646.00
50	0.013780	44.624	2654.25	50	0.013780	0.000989	2654.25	50	0.013780	44.624	2654.25
55	0.017830	40.081	2662.25	55	0.017830	0.000988	2662.25	55	0.017830	40.081	2662.25
60	0.022890	36.081	2670.00	60	0.022890	0.000987	2670.00	60	0.022890	36.081	2670.00
65	0.029120	32.512	2677.50	65	0.029120	0.000986	2677.50	65	0.029120	32.512	2677.50
70	0.036680	29.244	2684.75	70	0.036680	0.000985	2684.75	70	0.036680	29.244	2684.75
75	0.045830	26.244	2691.75	75	0.045830	0.000984	2691.75	75	0.045830	26.244	2691.75
80	0.056840	23.391	2698.50	80	0.056840	0.000983	2698.50	80	0.056840	23.391	2698.50
85	0.069990	20.664	2705.00	85	0.069990	0.000982	2705.00	85	0.069990	20.664	2705.00
90	0.085560	18.136	2711.25	90	0.085560	0.000981	2711.25	90	0.085560	18.136	2711.25
95	0.103940	15.779	2717.25	95	0.103940	0.000980	2717.25	95	0.103940	15.779	2717.25
100	0.125610	13.570	2723.00	100	0.125610	0.000979	2723.00	100	0.125610	13.570	2723.00



Properties of Saturated Water											
Saturated Vapor				Saturated Liquid				Saturated Vapor			
Temp	Pressure	Specific Volume	Enthalpy	Temp	Pressure	Specific Volume	Enthalpy	Temp	Pressure	Specific Volume	Enthalpy
t	P	v_g	h_g	t	P	v_f	h_f	t	P	v_g	h_g
0.01	0.000611	206.136	2536.92	0.01	0.000611	0.000999	2536.92	0.01	0.000611	206.136	2536.92
5	0.000870	167.290	2555.00	5	0.000870	0.000998	2555.00	5	0.000870	167.290	2555.00
10	0.001235	137.734	2570.92	10	0.001235	0.000997	2570.92	10	0.001235	137.734	2570.92
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35	0.006094	62.896	2628.50	35	0.006094	0.000992	2628.50	35	0.006094	62.896	2628.50
40	0.008070	55.845	2637.50	40	0.008070	0.000991	2637.50	40	0.008070	55.845	2637.50
45	0.010580	49.832	2646.00	45	0.010580	0.000990	2646.00	45	0.010580	49.832	2646.00
50	0.013780	44.624	2654.25	50	0.013780	0.000989	2654.25	50	0.013780	44.624	2654.25
55	0.017830	40.081	2662.25	55	0.017830	0.000988	2662.25	55	0.017830	40.081	2662.25
60	0.022890	36.081	2670.00	60	0.022890	0.000987	2670.00	60	0.022890	36.081	2670.00
65	0.029120	32.512	2677.50	65	0.029120	0.000986	2677.50	65	0.029120	32.512	2677.50
70	0.036680	29.244	2684.75	70	0.036680	0.000985	2684.75	70	0.036680	29.244	2684.75
75	0.045830	26.244	2691.75	75	0.045830	0.000984	2691.75	75	0.045830	26.244	2691.75
80	0.056840	23.391	2698.50	80	0.056840	0.000983	2698.50	80	0.056840	23.391	2698.50
85	0.069990	20.664	2705.00	85	0.069990	0.000982	2705.00	85	0.069990	20.664	2705.00
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95	0.103940	15.779	2717.25	95	0.103940	0.000980	2717.25	95	0.103940	15.779	2717.25
100	0.125610	13.570	2723.00	100	0.125610	0.000979	2723.00	100	0.125610	13.570	2723.00



Solution of the problem in Fig. 1:

$$V_1 = 0.2 \text{ m}^3, m_1 = 0.6 \text{ kg}, p_1 = 0.5 \text{ MPa}, T_2 = 300 \text{ }^\circ\text{C}, m_2 = m_1 = 0.6 \text{ kg}, p_2 = p_1 = 0.5 \text{ MPa}$$

$$v_1 = \frac{V_1}{m_1} = 0.33 \frac{\text{m}^3}{\text{kg}}$$

At 0.5 MPa, $v_g = 0.389 \frac{m^3}{kg}$ and $v_f = 0.001132 \frac{m^3}{kg}$ (These values are the average of those at 0.4 MPa and 0.6 MPa. In the tables provided, 0.5 MPa is not listed. Hence, we did linear interpolation.)

Now, $v_f < v_1 < v_g$. Hence, the state 1 (initial state) is inside the liquid-vapor dome.

$$\text{Now, } x_1 = \frac{v_1 - v_f}{v_g - v_f} = 0.847$$

This is a constant pressure process. At $p_2 = 0.5$ MPa, the temperature is 300°C . Now, $300^\circ\text{C} >$ saturation temperature at 0.5 MPa which is 151.8°C . Hence, the state 2 lies in the superheated zone. We are asked to calculate Q and W.

For a constant pressure process, we know that $Q = \Delta H = m\Delta h = m(h_2 - h_1) \dots \dots (1)$

Also, the work done $W = p\Delta V = pm(v_2 - v_1) \dots \dots (2)$

Now, at state 2, $v_2 = 0.5226 \frac{m^3}{kg}$, $h_2 = 3064.6 \frac{kJ}{kg}$ (from tables for superheated steam)

$$\text{Now, } h_1 = h_f + x_1(h_{fg}) = 2424.38 \frac{kJ}{kg}$$

$$\text{Now, (1) implies } Q = 0.6(3064.6 - 2424.38) = 384.1 \text{ kJ}$$

$$(2) \text{ implies } W = 0.5 \times 10^6 \times 0.6 \times (0.5226 - 0.33) = 57.8 \text{ kJ}$$