Answers for the
Tutorial on Thermodynamic Properties of Substances:

(1) (a) All ideal gases do not have the same C_p.

(b) For an ideal gas, C_v is only a function of temperature. Therefore, it does not change with pressure.

(c) The relationship $h = u + RT$ is valid only for ideal gases. For any other substance, $h = u + Pv$.

(d) A given amount of ideal gas is said to undergo a process during which $PV^2 =$ constant. Replacing V of the given relationship, using the ideal gas equation of state, $PV = nRT$, we get $P(nRT/P)^2 =$ constant. Since n and R are constants for a given amount of ideal gas, it is true that $T/\sqrt{P}$ remains a constant as well.

(e) Since u and C_v of an ideal gas are only functions of temperature, $\Delta u = \int C_v \, dT$ for an ideal gas is applicable to any process.

(f) When a saturated liquid undergoes an isothermal expansion, it moves into the saturated vapour-liquid region in the phase diagram. Therefore, it is true that some of the liquid will vapourise.

(2) (a) (**B**) 2040 kJ/kg·K (b) (**B**) 4.1 kJ/kg·K (c) (**C**) 14.3 kJ/kg·K

(3) (a) (**A**) 312 kJ/kg (b) (**A**) 718 J/kg·K (c) (**C**) 164 litres (d) (**B**) 3.59 kJ
(e) (**C**) 260 kJ/kg (f) (**C**) 10.4 kJ (g) (**A**) 7.95 m^3/kg (h) (**B**) 32.1 g

(4) (a) Superheated steam

(b) A mixture of saturated water and saturated steam (which is industrially known as wet steam)

(c) 1316.6 kJ/kg

(d) The table shows, at 7 bar, the saturation temperature is 165.0°C, therefore we have compressed water at 7 bar and 100°C. Since the properties of compressed water is relatively insensitive to the pressure, the compressed water specific enthalpy h at 7 bar and 100°C can be approximated to h_f, the saturated water specific enthalpy, at 100°C. The table above shows that h_f at 100°C is 419.1 kJ/kg, and therefore h at 7 bar and 100°C can be approximated to 419 kJ/kg. Similarly, the compressed water specific internal energy u at 7 bar and 100°C can be approximated to u_f at 100°C, which is in fact not provided in the table above. Let us first calculate u_f at 100°C using $u_f = h_f - p\,v_f$, where $h_f = 419.1$ kJ/kg, $p = 1.013$ bar and v_f may be taken as 1/1000 m^3/kg, which gives $u_f \approx 419$ kJ/kg. Therefore, u at 7 bar and 100°C can be approximated to 419 kJ/kg.

(5) (a) Superheated steam. Dryness fraction has no meaning at the superheated vapour state. $u =$ 2445 kJ/kg.

(b) Superheated steam. Dryness fraction has no meaning at the superheated vapour state. $u =$ 2585 kJ/kg.

(c) Compressed water state. Dryness fraction has no meaning at the compressed water state. Compressed water specific internal energy u at 3 bar and 120°C can be approximated to the saturated water specific internal energy u_f at 120°C, which is about 505 kJ/kg as can be read from Saturated Water and Steam Table.

(d) Mixture of saturated steam and saturated water. Dryness fraction is 0.70. $u = 1879$ kJ/kg.

(6) (a) Superheated steam. Dryness fraction has no meaning at the superheated vapour state. $h =$ 3473 kJ/kg.

(b) Superheated steam. Dryness fraction has no meaning at the superheated vapour state. $h =$ 2779 kJ/kg.

(c) Compressed water state. Dryness fraction has no meaning at the compressed water state. Compressed water specific enthalpy h at 0.75 bar and 80°C can be approximated to the saturated water specific enthalpy h_f at 80°C, which is about 334.9 kJ/kg as can be read from Saturated Water and Steam Table.

(d) Mixture of saturated steam and saturated water. Dryness fraction is 0.786. h = 2000 kJ/kg.

(7) (a) (**C**) has $x = 0.81$ (b) (**B**) at 225^{o}C (c) (**C**) 256.5 kJ

(8) (a) (**C**) 2615 kJ/kg (b) (**C**) 649 kJ (c) (**D**) 195 litres
(d) (**A**) 0.663 kg (e) (**B**) 342 kJ (f) (**B**) 2103 kJ/kg

(9)

Property	Set 1	Set 2	Set 3	Set 4	Set 5
t, °C	280.8	*300*	500	*295.0*	*311.0*
p, bar	*65*	7	*65*	80	100
m, kg	1	2	1.3	3.5	3
v, m^3/kg	*0.02972*	0.3714	*0.0524*	*0.0191*	*0.0143*
V, m^3	*0.02972*	*0.7428*	*0.0681*	*0.0668*	*0.0428*
Moisture, %	*0*	-	-	20	*22.8*
h, kJ/kg	2779	*3060*	*3415.5*	*2470*	*2425*
u, kJ/kg	*2586*	*2800*	3077	*2317*	*2282*
s, kJ/kg·K	*5.851*	*7.298*	*6.8375*	*5.237*	5.100

(10)

Property	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6
t, °C	425	200	*285.8*	*284.1*	*212.4*	*404*
p, bar	160	20	70	5	*20*	*30*
v, m^3/kg	*0.01573*	*0.001*	*0.0158*	*0.5073*	*0.0651*	0.1
x, %	-	-	*55.35*	-	65	-
h, kJ/kg	*3051*	*852*	2100	*3032*	*2137.5*	*3240*
u, kJ/kg	*2799*	*850*	*1990*	*2779*	2008	2940
s, kJ/kg·K	*5.968*	*2.331*	*4.612*	7.4	*4.978*	*6.934*