

# Tutorial on Thermodynamic Properties of Substances:

(1) State whether the following statements are true or false:

- (a) All ideal gases have the same  $C_p$ .
- (b) For an ideal gas,  $C_v$  changes with pressure.
- (c) The relationship  $h = u + RT$  is valid for both ideal gases and real gases.
- (d) If a given amount of ideal gas undergoes a process during which  $PV^2 = \text{constant}$ , then it is also true that  $T/\sqrt{P}$  remains constant as well.
- (e) To use  $\Delta u = \int C_v dT$  for an ideal gas, it has to undergo a constant-volume process.
- (f) If a saturated liquid undergoes an isothermal expansion, some of the liquid will vapourise.

(2) For hydrogen,  $C_v = 10.2 \text{ kJ/kg} \cdot \text{K}$  and  $\gamma = 1.4$ . Assume that hydrogen behave as an ideal gas. Identify the nearest to correct value (listed **A**, **B**, **C** and **D**) of the required quantity.

- (a) The specific internal energy change of hydrogen when the temperature of hydrogen is raised from  $300^\circ\text{C}$  to  $500^\circ\text{C}$ :  
(A)  $4825 \text{ kJ/kg} \cdot \text{K}$       (B)  $2040 \text{ kJ/kg} \cdot \text{K}$       (C)  $4825 \text{ kJ/kg}$       (D)  $2040 \text{ kJ/kg}$
- (b) The specific gas constant  $R$  of hydrogen:  
(A)  $8.314 \text{ kJ/kg} \cdot \text{K}$       (B)  $4.1 \text{ kJ/kg} \cdot \text{K}$       (C)  $4.1 \text{ kJ/kmol} \cdot \text{K}$       (D) not enough data
- (c) The specific heat at constant pressure  $C_p$  of hydrogen:  
(A)  $18.5 \text{ kJ/kg} \cdot \text{K}$       (B)  $4.1 \text{ kJ/kg} \cdot \text{K}$       (C)  $14.3 \text{ kJ/kg} \cdot \text{K}$       (D) not enough data

(3) For air,  $R = 287 \text{ J/kg} \cdot \text{K}$  and  $\gamma = 1.4$ ; For helium,  $R = 2080 \text{ J/kg} \cdot \text{K}$  and  $\gamma = 1.667$ . Identify the nearest to correct value (listed **A**, **B**, **C** and **D**) of the required quantity.

- (a) The specific internal energy change of 10 g of helium when heated by  $100^\circ\text{C}$   
(A)  $312 \text{ kJ/kg}$       (B)  $5.20 \text{ MJ}$       (C)  $3.12 \text{ MJ}$       (D)  $7.28 \text{ kJ/kg}$
- (b) Specific heat at constant volume  $C_v$  for air  
(A)  $718 \text{ J/kg} \cdot \text{K}$       (B)  $5.20 \text{ kJ/kg}$       (C)  $0.718 \text{ kJ}$       (D)  $1005 \text{ J/kg} \cdot \text{K}$
- (c) The volume of 0.1 kg of air at 100 kPa and  $300^\circ\text{C}$   
(A)  $1.64 \text{ m}^3$       (B) 607 litres      (C) 164 litres      (D)  $1.04 \text{ m}^3$
- (d) 0.1 kg of air expands from 100 kPa and 300 K to 100 kPa and 350 K. Its internal energy increases by  
(A) 718 J      (B) 3.59 kJ      (C) 35.9 kJ      (D) 5.02 kJ
- (e) When 0.1 kg of helium is heated from 100 kPa and 300 K to 100 kPa and 350 K, its specific enthalpy increases by  
(A) 2.6 kJ      (B) 104 J/kg      (C) 260 kJ/kg      (D) 156 kJ/kg
- (f) When 40 g of helium is heated from 100 kPa and 280 K to 100 kPa and 330 K its enthalpy increases by  
(A) 10.4 J      (B) 4.15 J      (C) 10.4 kJ      (D) 6.23 kJ
- (g) The specific volume of 40 g of helium at 150 kPa and  $300^\circ\text{C}$  is  
(A)  $7.95 \text{ m}^3/\text{kg}$       (B) 317 ml      (C) 7.95 l      (D)  $0.317 \text{ m}^3$
- (h) A certain amount of helium at 100 kPa and  $100^\circ\text{C}$  when heated at constant volume to  $150^\circ\text{C}$  required 5 kJ of heat. The mass of helium is  
(A) 32.1 kg      (B) 32.1 g      (C) 19.3 g      (D) 3.22 mol

(4) Extracted values from a Steam Table is given below:

$p$ (bar)	$t$ (°C)	$v_g$ (m <sup>3</sup> /kg)	$u_f$ (kJ/kg)	$u_g$ (kJ/kg)	$h_f$ (kJ/kg)	$h_g$ (kJ/kg)	$s_f$ (kJ/kg·K)	$s_g$ (kJ/kg·K)
1.013	100.0	1.673	-	-	419.1	2675.8	1.307	7.355
5	151.8	0.3748	639	2562	640	2749	1.860	6.82
7	165.0	0.2728	696	2573	697	2764	1.992	6.709

Using the table above, determine the following:

- condition of water/steam at 6 bar and  $s = 8.3$  kJ/kg·K
- condition of water/steam at 5 bar and  $u = 2500$  kJ/kg
- specific internal energy at 1.013 bar and  $v = 0.72$  m<sup>3</sup>/kg
- specific enthalpy and specific internal energy at 7 bar and 100°C

(Answers are available also on pages 99 & 100 of *Thermodynamics for Beginners* by R. Shanthini)

(5) Specify the condition of water/steam at the following states along with its dryness fraction wherever applicable, and determine the specific internal energy at that state:

- at 0.05 bar and 50°C
- at 0.75 bar and  $s = 7.75$  kJ/kg·K,
- at 3 bar and 120°C
- at 1 bar and  $h = 2000$  kJ/kg

(Answers are available also on page 101 of *Thermodynamics for Beginners* by R. Shanthini)

(6) Determine the specific enthalpy of water/steam at the following states, and specify the condition of the state along with its dryness fraction wherever applicable:

- at 15 bar and 500°C
- at 0.75 bar and a specific entropy of 7.75 kJ/kg·K
- at 0.75 bar and 80°C
- at 15 bar and 2000 kJ/kg of specific enthalpy

(7) Use the following properties of steam in the tables below and identify the nearest to correct value (listed **A**, **B**, **C** and **D**) of the required quantity.

$p$ (bar)	$t$ (°C)	$v_g$ (m <sup>3</sup> /kg)	$u_f$ (kJ/kg)	$u_g$ (kJ/kg)	$h_f$ (kJ/kg)	$h_{fg}$ (kJ/kg)	$h_g$ (kJ/kg)
5.0	151.8	0.3748	639	2562	640	2109	2749
6.0	158.8	0.3156	669	2568	670	2087	2757

$p$ (bar)	$t$ (°C)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)
5.0	200	0.4252	2644	2857
5.0	250	0.4745	2725	2962

- Steam at 5 bar with a specific enthalpy of 2348 kJ/kg  
(**A**) is superheated (**B**) has  $x = 0.85$  (**C**) has  $x = 0.81$  (**D**) has  $x = 0.19$
- If the specific volume of steam at 5 bar is 0.4498 m<sup>3</sup>/kg, it is  
(**A**) at 175°C (**B**) at 225°C (**C**) at 275°C (**D**) wet
- The internal energy of 0.1 kg of dry saturated steam at 5.5 bar is  
(**A**) 654 kJ/kg (**B**) 2565 kJ/kg (**C**) 256.5 kJ (**D**) 65.4 kJ

(8) Properties of steam at 2 bar are given in the tables below and identify the nearest to correct value (listed **A**, **B**, **C** and **D**) of the required quantity.

$T_{sat}$ (°C)	$v_g$ (m <sup>3</sup> /kg)	$u_f$ (kJ/kg)	$u_g$ (kJ/kg)	$h_f$ (kJ/kg)	$h_{fg}$ (kJ/kg)	$h_g$ (kJ/kg)
120.2	0.886	504.5	2530	504.7	2202	2707

$T$ (°C)	$v$ (m <sup>3</sup> /kg)	$u$ (kJ/kg)	$h$ (kJ/kg)
160	0.992	2592	2790
200	1.086	2654	2870

- (a) The specific internal energy of 0.25 kg steam at 2 bar and 175°C is  
(A) 654 kJ (B) 2630 kJ/kg (C) 2615 kJ/kg (D) 658 kJ
- (b) The enthalpy of 0.25 kg of steam at 2 bar with dryness fraction 0.95 is  
(A) 2092 kJ (B) 523 kJ (C) 649 kJ (D) 2597 kJ/kg
- (c) The volume of 0.25 kg of steam of 0.88 dryness fraction at 2 bar is  
(A) 0.222 m<sup>3</sup> (B) 0.78 m<sup>3</sup> (C) 0.886 m<sup>3</sup> (D) 195 litres
- (d) The mass of 0.5 m<sup>3</sup> of steam of 0.9 dryness fraction at 2 bar is  
(A) 0.663 kg (B) 1.59 kg (C) 0.80 kg/m<sup>3</sup> (D) 0.886 m<sup>3</sup>/kg
- (e) The enthalpy of 0.15 kg saturated water at 2 bar converted to steam at 2 bar and 160°C increases by  
(A) 12.5 kJ (B) 342 kJ (C) 2285 kJ (D) 330 kJ/kg
- (f) The specific internal energy of 0.15 kg saturated water at 2 bar converted to steam at 2 bar and 170°C increases by  
(A) 315 kJ (B) 2103 kJ/kg (C) 2202 kJ/kg (D) 330 kJ

(9) With the help of a Steam Table, fill in the blank spaces in the following table:

Property	Set 1	Set 2	Set 3	Set 4	Set 5
$t, ^\circ\text{C}$	280.8		500		
$p, \text{bar}$		7		80	100
$m, \text{kg}$	1	2	1.3	3.5	3
$v, \text{m}^3/\text{kg}$		0.3714			
$V, \text{m}^3$					
Moisture, %				20	
$h, \text{kJ/kg}$	2779				
$u, \text{kJ/kg}$			3077		
$s, \text{kJ/kg}\cdot\text{K}$					5.100

(Answers are available on pages 102 & 103 of *Thermodynamics for Beginners* by R. Shanthini)

(10) Fill in the blank spaces of the following table with the help of a Steam Table:

Property	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6
$t, ^\circ\text{C}$	425	200				
$p, \text{bar}$	160	20	70	5		
$m, \text{kg}$	1	1	1	1	1	1
$v, \text{m}^3/\text{kg}$						0.1
$V, \text{m}^3$						
$x, \%$					65	
$h, \text{kJ/kg}$			2100			
$u, \text{kJ/kg}$					2008	2940
$s, \text{kJ/kg}\cdot\text{K}$				7.4		

(Answers are available on page 104 of *Thermodynamics for Beginners* by R. Shanthini)