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Q- NO-3 :-

Consider a piston-cylinder assembly containing 10.0 Kg of water. Initially, the gas has a pressure of 20.0 bar and occupies a volume of $1.0\ m^3$. The system undergoes a reversible process in which it is compressed to 100 bar. The pressure volume relationship during this process is given by

$$P V^{1.5} = const.$$

Calculate the work done and heat heat transferred during this process.

Solution:-

Mass of water $= m = 10\ Kg$

Initial pressure $= P_1 = 20\ bar$

$P_2 = 100\ bar$

$V_1 = 1.0\ m^3$

$P \hat{V}^{1.5} = const.$

Work done $= \hat{W} = ?$

Heat $= \hat{q} = ?$

convert pressure unit from bar to MP_a,

So,

$P_1 = 2\ MP_a$

$P_2 = 10\ MP_a$

WORK:-

$$\hat{W} = -\int P_E\, d\hat{V}$$

$$P_1 \hat{V}_1^{1.5} = P_2 \hat{V}_2^{1.5}$$

$$\hat{V}_2 = \left(\frac{P_1 \hat{V}_1^{1.5}}{P_2}\right)^{1/1.5}$$

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$$\hat{V}_2 = \left[\frac{2\,MPa}{} \left| \left(\frac{0.1\,m^3}{Kg} \right)^{1.5} \right| \frac{}{10\,MPa} \right]^{1/1.5}$$

$$\hat{V}_2 = \left(0.2 \times (0.1)^{1.5} \right)^{1/1.5} m^3/Kg$$

$$\hat{V}_2 = (0.2 \times 0.0516)^{0.667}$$

$$\hat{V}_2 = 0.0342 \; m^3/Kg$$

Now,

$$\hat{W} = -\int_{0.1}^{0.0342} P_E \, d\hat{V} = -\int_{0.1}^{0.0342} P \, d\hat{V} \rightarrow (i)$$

$$P\hat{V}^{1.5} = P_1 \hat{V}_1^{1.5}$$

$$P = \frac{P_1 \hat{V}_1^{1.5}}{\hat{V}^{1.5}}$$

$$P = \frac{2\,MPa}{} \left| \left(\frac{0.1\,m^3}{Kg} \right)^{1.5} \right| \left(\frac{Kg}{\hat{V}\,m^3} \right)^{1.5}$$

$$P = \frac{0.0632}{\hat{V}^{1.5}} MPa$$

Putting the value of P in eq (i)

$$\hat{W} = -\int_{0.1}^{0.0342} \frac{0.0632}{\hat{V}^{1.5}} d\hat{V}$$

$$\hat{W} = \frac{-0.0632}{-0.5} \left| \frac{1}{V^{0.5}} \right|_{0.1}^{0.0342}$$

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$$\hat{W} = \frac{0.0632}{0.5}\left[\frac{1}{(0.0342)^{0.5}} - \frac{1}{(0.1)^{0.5}}\right]$$

$$\hat{W} = (0.1264)(2.245)\ MPa\ \frac{m^3}{Kg}$$

$$\hat{W} = 0.2830\ MPa\ \frac{m^3}{Kg}$$

$$\hat{W} = \frac{0.2830\ \cancel{MPa}\ \cancel{m^3}}{Kg}\left|\frac{1000\cancel{KPa}}{1\ \cancel{MPa}}\right|\frac{KN}{\cancel{KPa}\ \cancel{m^2}} \qquad (\because Nm = J)$$

$$\hat{W} = 284\ \frac{KJ}{Kg}$$

Heat ✓ $\hat{q} = ?$

We know that

$$\Delta\hat{U} = \hat{q} + \hat{W}$$

$$\hat{q} = \Delta\hat{U} - \hat{W} \longrightarrow (ii)$$

$$\Delta\hat{U} = \hat{U}_2 - \hat{U}_1$$

At stat 1

$$P_1 = 2MPa$$

Temp at $T_1 = ?$ by linear interpolation

At 2MPa $\hat{V}_l = 0.0012\ m^3/Kg$, $\hat{V}_v = 0.0996\ m^3/Kg$

Temp (°C)	$\hat{V}$ (m^3/Kg)
212.4	0.0996
T	0.1
225	0.1038

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By linear interpolation

$T = 213.6°C$

Temp. diff.

$225 - 212.4 = 12.6$

Specific velocity difference

$0.1038 - 0.0996 = 4.2 \times 10^{-3}$

Now at State 1, $P_1 = 2 MPa$

$T_1 = 213.6°C$

$\hat{u}_2 = ?$

u_1 (KJ/kg)	T°C
2600.3	212.4
u_1	213.6
2628.3	225

By linear interpolation

$\hat{u}_1 = 2602.97$ KJ/kg

At state 2, $P_2 = 10 MPa$, $\hat{V}_2 = 0.0342 \frac{m^3}{kg}$

$\hat{U}_2$ KJ/kg	$\hat{V}_2$ m^3/kg
3045.8	0.0328
$\hat{U}_2$	0.0342
3144.5	0.0356

By linear interpolation b/w $\hat{u}$ & $\hat{V}$ we get

$\hat{u}_2 = 3095.15$ KJ/kg

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$$\Delta \hat{u} = \hat{u}_2 - \hat{u}_1$$

$$= (3095.15 - 2602.97)\ \frac{KJ}{Kg}$$

$$\Delta \hat{u} = 429.18\ KJ/Kg$$

putting values of $\Delta \hat{u}$ & $\hat{w}$ in eq iii,

$$\hat{q} = \Delta \hat{u} - \hat{w}$$

$$\hat{q} = (492.18 - 283.80)\ KJ/Kg$$

$$\hat{q} = 208.38\ KJ/Kg$$

Q-No-2:-

i) System:-

A system is the set of substances and energy that is being studied. If, for example, reactions are occuring in a jar, everything inside the Jar is the system and everything outside the jar is the surroundings.

ii) Surroundings:-

Everything in the universe surrounding a thermodynamic system. The surrounding is everything else that is not the system defined.

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iii) Adiabatic:

In thermodynamics, an adiabatic process is a type of thermodynamics process which occurs without transferring heat or mass between the system and its surroundings.

iv) Isolated system:

An isolated system is either of the following; a physical system so far removed from other systems that it does not interact with them. A thermas flask is the best example of an isolated system.

v) Extensive property:

Extensive property depend on the size of the system as size change its properties change and denoted by capital letter like volume is 'V' in m^3.

Q#2: Compute $\hat{V}$, Specific internal energy of steam at 7 bar and specific enthalpy 2600 $\frac{KJ}{Kg}$?

Solution:

Pressure = $P = 7$ bar

Specific enthalpy = $\hat{H} = 2600\ KJ/Kg$

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Specific volume $= \hat{V} = ?$
Specific internal energy $\hat{u} = ?$

To find specific volume we have find First dryness fraction 'x'.

$x = ?$

From saturated Steam table @ 7bar and 2600 $\frac{KJ}{Kg}$ specific enthalpy, we have

Specific enthalpy At liquid $= \hat{h}_f = 697 \frac{KJ}{Kg}$

Specific enthalpy vaporization $= \hat{h}_{fg} = 2067 \frac{KJ}{Kg}$

$\hat{h} = 2600 \frac{KJ}{Kg}$

dryness fraction:

$$\hat{h} = h_f + x \hat{h}_{fg}$$

$$x = \frac{\hat{h} - \hat{h}_f}{h_{fg}}$$

$$x = \frac{2600\ KJ/Kg - 697 \frac{KJ}{Kg}}{2067 KJ/Kg}$$

$x = 0.921$

For Specific volume:

$$\hat{V} = x \hat{V}_g$$

From steam table @ 7 bar and 2600 $\frac{KJ}{Kg}$ of $\hat{h}$

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Specific volume, $\hat{V}_g = 0.2728 \frac{m^3}{Kg}$

$$\hat{V} = (0.921) \times \left(0.2728 \frac{m^3}{Kg}\right)$$

$$\hat{V} = 0.2515 \frac{m^3}{Kg}.$$

For specific Internal energy:

From steam table @ 7bar and 2600 $\frac{KJ}{Kg}$ of $\hat{h}$

$$\hat{u}_f = 696 \frac{KJ}{Kg}$$

$$\hat{U}_g = 2573 \text{ KJ/Kg}$$

$$\hat{u} = (1-x)\hat{u}_f + x\hat{U}_g$$

$$= (1-0.921)\, 696 \frac{KJ}{Kg} + (0.921)\left(2573 \frac{KJ}{Kg}\right)$$

$$= 55 \frac{KJ}{Kg} + 2365 \frac{KJ}{Kg}$$

$$\hat{u} = 2420 \text{ KJ/Kg}.$$