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Tutorial - 4 {Q-6 to 10}
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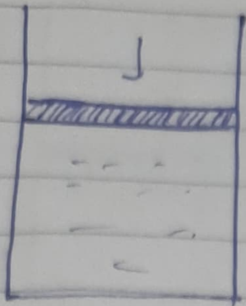

$P = const = 200 kPa = 2 bar$

$T_{sat} = T_{initial} = 120.23^\circ C$

Finally $P = 2 bar, T = 200^\circ C$

$\Rightarrow$ Superheated vapour.

$h_{ini} = h_f + x h_{fg}$
$= 504.7 + 0.7 (2201.7)$
$= 2045.89 \ kJ/kg$

$u_{initial} = u_f + x u_{fg}$
$= 504.49 + 0.7 (2024.92)$
$= 1921.934 \ kJ/kg$

At 2 bar, $200^\circ C$, superheated vapour, $h = 2870.46 \ kJ/kg$

$u = 2654.39 \ kJ/kg$

$\Delta h = 2870.46 - 2045.89 = 824.57 kJ$
$\Delta u = 2654.39 - 1921.934 = 732.456 \ kJ/kg$

Mass Calc.

Initially $x = 0.7 \Rightarrow v = v_f + x v_{fg}$
$= 0.001061 + 0.7 \times 0.883908$
$= 0.6197966 \ m^3/kg$

$\Rightarrow m = \frac{V}{v} = \frac{0.1}{0.6197966} = 0.016134 \ kg$

$\Rightarrow \boxed{m = 0.16134 \ kg}$

$\Rightarrow \Delta H = m \Delta h = 0.16134 \times 824.57 = 133.0388 \ kJ$

$\Delta U = m \Delta u = 118.174457 \ kJ$

$\boxed{Q = \Delta H = 133.0388 \ kJ}$ $\boxed{W = Q - \Delta U = 14.864 \ kJ}$
{as $P = const$}

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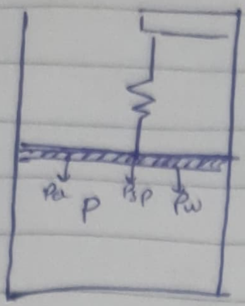
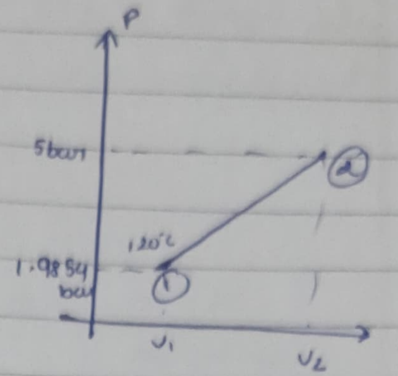


$K = 15\ N/m$



$$P = P_a + P_{sp} + P_w$$

$$= (P_a + P_w) + \frac{Kx}{A} = (P_a + P_w) + \frac{KV}{A^2}$$

$$\Delta P = \frac{K\,\Delta V}{A^2}$$

Initially saturated vapour at 120°C

$\Rightarrow P = 1.9854$ bar $(= P_{sat})$

$v = v_g = 0.8915\ m^3/kg$

$$V_1 = m v_g = 0.5 \times 0.8915 = 0.44575\ m^3$$

$$\Delta V = \frac{A^2}{K}\Delta P = \frac{(0.05)^2\,(5 - 1.9854) \times 10^5}{15 \times 10^3}$$

$$= 0.05024\ m^3$$

$$\Rightarrow V_{final} = V_1 + \Delta V = 0.49599\ m^3 = V_2$$

$$v_{final} = \frac{0.49599}{0.5} = 0.99198$$

$\because P_{final} = 5$ bar, $v_{final} = 0.99198 > v_g$

$v_g = 0.36812\ m^3/kg$

$\therefore$ superheated vapour

At 5 bar, $T = 800^\circ C \Rightarrow v = 0.98959\ m^3/kg$
$T = 900^\circ C \Rightarrow v = 1.08217\ m^3/kg$

$v = 0.99198\ m^3/kg$

By Interpolation
$$\frac{v - 0.98959}{1.08217 - 0.98959} = \frac{T - 800}{900 - 100}$$

$$\frac{T - T_1}{T_2 - T_1} = \frac{v - v_1}{v_2 - v_1} \Rightarrow \frac{0.99198 - 0.98959}{1.08217 - 0.98959} = \frac{T - 800}{100}$$

$$\Rightarrow \boxed{T = 802.5887^\circ C}$$

At 5 bar,
At $800^\circ \Rightarrow u = 3662.17\ kJ/kg$
$900^\circ C \rightarrow u = 3853.63\ kJ/kg$

$$\therefore \frac{u - u_1}{u_2 - u_1} = \frac{T - T_1}{T_2 - T_1} \Rightarrow \frac{u - 3662.17}{3853.63 - 3662.17} = \frac{802.5887 - 800}{900 - 800}$$

$$\Rightarrow \boxed{u = 3667.126\ kJ/kg}$$

$u_{initial} = u_g$ at $120^\circ C = 2529.0\ kJ/kg$

$\Rightarrow \Delta U = m \Delta u = 0.5(3667.126 - 2529.0) = 569.063\ kJ$

$W = \text{Area} = \frac{1}{2}(P_1 + P_2)(V_2 - V_1) = \frac{1}{2}(5 + 1.9854) \times 10^2 (0.49599 - 0.44575)$

$= \frac{1}{2} \times 6.9854 \times 10^2 \times 0.05024 = 17.547\ kJ$

$Q =$
$\therefore Q = \Delta U + W = 569.063 + 17.547 = \boxed{586.610\ kJ}$

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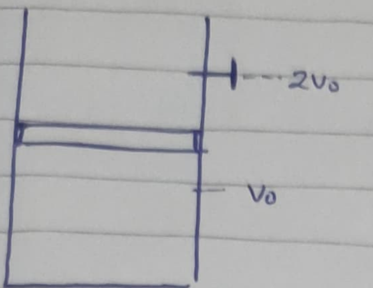

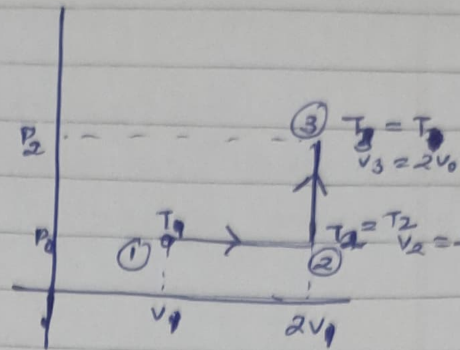

In final process $V = \text{const}$
as locked with pin

$P_1 = 200\,kPa = 2\,bar$
$T_1 = 600\,K$

$T_2 = T_2$	$T_3 = T_1$
$V_2 = 2V_1$	$V_3 = 2V_1$
$P_2 = P_1$	

$\boxed{P_2 = P_1 = 200\,kPa}$

By ideal gas law
{assuming nearly ideal behaviour} , $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$

$$\Rightarrow T_2 = \frac{V_2}{V_1} \cdot T_1$$

$$= \frac{2V_1}{V_1} \cdot T_1 = 2T_1$$

$\therefore \boxed{T_2 = 600 \times 2 = 1200\,K}$

~~As constant pressure process,~~
$\cancel{Q = m c_p \Delta T}$ $\cancel{\frac{Q}{m}} = \cancel{\Delta h} = c_p \Delta T$
=

From Ideal Gas Properties of air table, Cengel,

h for air at $1200\,K$ = $1277.79\,kJ/kg$

{Table A-17, Cengel}

{As absolute enthalpy can't be found directly
another method would be to use $c_p = c_0 + a\theta$
and integrate }

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$\therefore \boxed{P_2 = 200\,kPa, \quad T_2 = 1200\,K, \quad h_2 = 1277.79\ kJ/kg}$

$h_1 = h$ at $T = 600K = 607.02\ kJ/kg$

{from table A-17, Cengel}
Ideal gas properties of air

As process 1 is isobaric

$\Rightarrow \quad q_{12} = \Delta h = h_2 - h_1 = 1277.79 - 607.02$

$= 670.77\ kJ/kg$

State 3 $\Rightarrow$ temp $= T_3 = T_1 = 600K$

At 600K, $\boxed{h_3 = 607.02\ kJ/kg}$

from table A-17
ideal gas prop. of air

At state 3, $V_3 = 2V_1$, $T_3 = T_1$

Ideal gas law $\Rightarrow \dfrac{P_1 V_1}{T_1} = \dfrac{P_3 V_3}{T_3} = \dfrac{P_3 \cdot 2V_1}{T_1}$

$\Rightarrow P_3 = \dfrac{P_1}{2} = \dfrac{200\,kPa}{2} = 100\,kPa$

$\therefore \boxed{P_3 = 100\,kPa, \quad T_3 = 600K, \quad h_3 = 607.02\ kJ/kg}$

As, process 2-3 is isochoric $\Rightarrow \boxed{w_{23} = 0}$
{as pinned}

$q_{23} = \Delta U_{23} + \underset{0}{\underset{\parallel}{w_{23}}} = \Delta u_3 - \Delta u_2 = \cancel{933.33}\ 434.78 - 933.33$
kJ/kg kJ/kg
{from table}

$\boxed{q_{23} = -498.35\ kJ/kg}$

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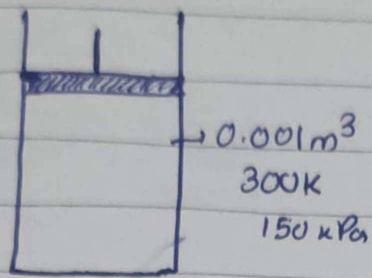

The process is polytropic with $pv^{5/4} = \text{const}$

Given: $P_f = 600\,kPa$
& $pv^{5/4} = \text{const}$

$$\Rightarrow P_1 V_1^{5/4} = P_2 V_2^{5/4}$$

$$\Rightarrow (150)(10^{-3})^{5/4} = (600)(V_2)^{5/4}$$

$$V_2 = (10^{-3})\left(\frac{150}{600}\right)^{4/5}$$

$$V_2 = (0.32987 \times 10^{-3})\,m^3$$

For polytropic process, $pv^x = \text{const} = c$

$$W = \int_{V_1}^{V_2} dw = \int_{V_1}^{V_2} p\,dV = \int_{V_1}^{V_2} \frac{c}{V^x}\,dV \qquad x \neq 1$$

$$\Rightarrow \left[\frac{c\,V^{1-x}}{1-x}\right]_{V_1}^{V_2}$$

$$= \left[\frac{pV^x \cdot V^{1-x}}{1-x}\right]_{V_1}^{V_2} = \frac{P_2V_2 - P_1V_1}{1-x}$$

$$\boxed{W = \frac{P_1V_1 - P_2V_2}{x-1}} = \frac{150\times10^3 \times 10^{-3} - 600\times10^3 \times 0.32987\times10^{-3}}{1.25 - 1}$$

$$\boxed{W = -191.688\ J} = -0.191688\ kJ$$

$$\therefore \boxed{W = -0.191688\ kJ}$$

$T_1 = 300K$

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \Rightarrow T_2 = \left(\frac{P_2}{P_1}\right)\left(\frac{V_2}{V_1}\right) \cdot T_1 = 4 \times 0.32987 \times 300$

$= 395.844\ K$

$u_{300} = 214.07\ kJ/kg$

$u_{390} = 278.93\ kJ/kg$, Let $u_{395.844} = u$

$u_{400} = 286.16\ kJ/kg$

By interpolation ; $\frac{u - 278.93}{286.16 - 278.93} = \frac{395.844 - 390}{400 - 390}$

$\Rightarrow \boxed{u = 283.155\ kJ/kg}$

$\Delta u = 283.155 - 214.07 = 69.085\ kJ/kg$

For air $R = 0.2871\ kJ/kg\ K$

$Pv = RT \Rightarrow \frac{PV}{m} = RT \Rightarrow m = \frac{P_1V_1}{RT_1} = \frac{150 \times 10^{-3}}{0.2871 \times 300}$

$= 1.741 \times 10^{-3}\ kg$

$\therefore \boxed{\Delta U = m\Delta u = 0.1203}\ kJ$

$Q = \Delta U + W = 0.1203\ kJ + (-0.191688\ kJ)$

$\boxed{Q = -0.07137\ kJ}$

$\therefore \boxed{W = -0.191688\ kJ}$ $\boxed{Q = -0.07137\ kJ}$

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(10) $P_1 = 400 kPa$, $P_2 = 150 kPa$

$T_1 = 600 K$, $T_2 = 400 K$

In a polytropic process , $Pv^n = const$

$V = \frac{RT}{P}$ $\Rightarrow$ $P\left(\frac{T}{P}\right)^n = P^{1-n}T^n = const$

$\left(\frac{P_1}{P_2}\right)^{1-n} = \left(\frac{T_2}{T_1}\right)^n \Rightarrow \left(\frac{400}{150}\right)^{1-n} = \left(\frac{400}{600}\right)^n$

$\Rightarrow \left(\frac{8}{3}\right)^{1-n} = \left(\frac{2}{3}\right)^n = 2^{3(1-n)} \cdot 2^{-n} = (3^{1-n}) \cdot 3^{-n}$

$= 2^{3-4n} = 3^{1-2n}$

$\Rightarrow (3-4n)\log(2) = (1-2n)\log 3$

$\rightarrow n = \frac{3\log 2 - \log 3}{4\log 2 - 2\log 3} = 1.704713$

$\therefore \boxed{n = 1.70471}$

$Pv = RT$

$\Delta U = C_v \Delta T$, $w = \frac{P_1v_1 - P_2v_2}{n-1} = \frac{R(T_1 - T_2)}{n-1}$

$\Rightarrow \Delta U = 0.717(400-600)$

$\boxed{\Delta U = -143.4 kJ/kg}$

$= \frac{0.2971(600-400)}{1.70471-1}$

$\boxed{W = 81.4531 kJ/kg} = \boxed{\underset{\sim}{W}\ 81.4531\ kJ/kg}$

$\boxed{q = \Delta U + w = -61.9468 kJ/kg}$

$\therefore$

$\boxed{q = -61.94689 kJ/kg}$

$\boxed{w = 81.4531 kJ/kg}$

$\boxed{n = 1.70471}$