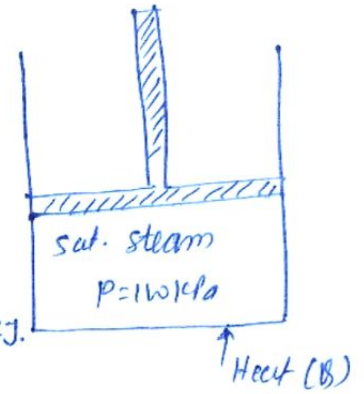
Q.1.) <u>Given</u> $P_1 = 100\,kPa$



steam quality $(x_1) = 1$ [$\because$ the steam is saturated)

from saturated steam table, at $P_1 = 100\,kPa$

$T_1 = 99.606^\circ c$

Specific Internal energy $(u_1) = 2505.5\ KJ/kg \Rightarrow U_1 = 2505.5\,KJ.$

" volume for gas $(v_g) = 1.6939\ m^3/kg$

total sp. volume $(v_1) = v_g = 1.6939\ m^3/kg. \Rightarrow V_1 = 1.6939\,m^3$

& $v_2 = 2\times 1.6939 = 3.3878\ m^3 = V_2$

As heat is added to the steam, it will become superheated therefore, from superheated steam table at $P_1 = 100\,kPa$

$$\left\{\begin{matrix} T & v \\ 470 \rightarrow & 3.4267 \\ 460 \rightarrow & 3.3805 \end{matrix}\right\} \qquad \frac{3.4267 - 3.3805}{470 - 460} = \frac{3.3878 - 3.3805}{T - 460}$$ [Interpolation]

$$\boxed{T = 461.58^\circ c}$$

superheated steam table, at $P = 100\,kPa$

$$\left\{\begin{matrix} T & u\ (KJ/kg) \\ 460 \longrightarrow & 3065.8 \\ 470 \longrightarrow & 3082.3 \end{matrix}\right\} \qquad \frac{3082.3 - 3065.8}{470 - 460} = \frac{u_2 - 3065.8}{461.58 - 460}$$

$u_2 = 3068.41\ KJ/kg$

$U_2 = 3068.41\ KJ.$

From 1st law

$\cancel{\delta Q = \Delta U}$. $\delta Q = \Delta U + P\Delta V$

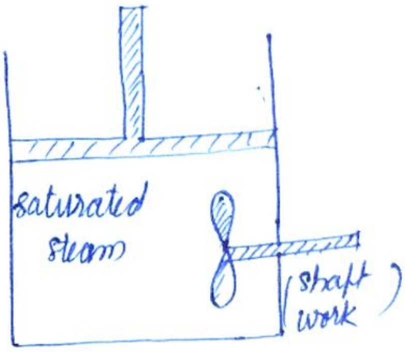
$\delta Q = (U_2 - U_1) + P(V_2 - V_1)$

$\delta Q = (3068.41 - 2505.5) + 100(3.3878 - 1.6939)$

$$\boxed{\delta Q = 732.3\ KJ}$$

Q.2.) Given $P_1 = 100\,kPa$, quality $(x_1) = 0.8$

paddle ~~ub~~ wheel work = 300 KJ



From saturated steam table at $P_1 = 100\,kPa$

$T_1 = 99.606°C$,

v_f (specific volume of fluid) $= 0.00104315\ m^3/kg$

v_g (" " gas) $= 1.6939\ m^3/kg$

$$v_1 = v_g x + v_f(1-x)$$

$$v_1 = 1.6939 \times 0.8 + 0.00104315\,(1-0.8)$$

$$v_1 = 1.35533\ m^3/kg.$$

The system is adiabatic $\Rightarrow \delta Q = 0 \Rightarrow dU = -\delta W_{sys} = -\delta W_{shaft} = -W_{paddle\ wheel}$

$$= -(-300\,KJ)$$

$$(U_2 - U_1) = 300\,KJ$$

$$(u_2 - u_1) = 300\ KJ/kg \quad \text{--- (1)}$$

from saturated steam table, at $P = 100\,kPa$ & $T = 99.606°C$

specific internal energy of fluid in mixture $(u_f) = 417.4\ KJ/kg$.

" " gas " $(u_g) = 2505.5\ KJ/kg$.

**NOTE:- If 'u' values are not given in steam table, we can calculate using 'h' & 'v' data

$$u_1 = u_g x + u_f(1-x)$$

$$u_1 = 2505.5 \times 0.8 + 417.4\,(1-0.8)$$

$$u_1 = 2087.88\ KJ/kg.$$

$\therefore u_2 = 300 + u_1 = 300 + 2087.88$ [from eqn (1)]

$$u_2 = 2387.88$$

At 99.606°C & 100 kPa , from saturated steam table,

$u_g = 2505.5\ KJ/kg$ & $u_2 = 2387.88$ (calculated above)

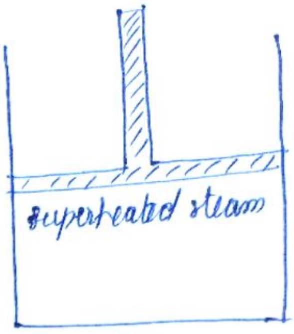
Since, $u_2 < u_g$, that means steam is not fully converted into vapor

therefor, $u_2 = u_g x + u_f(1-x)$

$\Rightarrow 2387.88 = 2505.5\,x + 417.4\,(1-x) \Rightarrow \boxed{x = 0.943}$

Q.3) Given $P_1 = 30\,bar = 30\times10^5\,Pa$

$P_2 = 10\,KPa$, $T_1 = 350°C$



From superheated steam table at $3\times10^6\,Pa$ & $350°C$

$u_1 = 2844.4\ KJ/kg$

$s_1 = 6.7449\ \frac{KJ}{kg\,K}$

Since the process is adiabatic, $\delta Q = 0 \Rightarrow s_1 = s_2 = 6.7449\ \frac{KJ}{kg\,K}$

at 10KPa (P_2) and 45.806°C, from saturated steam table

specific entropy of fluid (s_f) = 0.6492 KJ/kgK

" " gas (s_g) = 8.1488 KJ/kgK

and $s_1 = s_2 = 6.7449$

Since $s_f < s_2 < s_g$, hence the steam is in saturated cond^n after expansion

Now

$$s = s_g x + s_f(1-x)$$

$$6.7449 = 8.1488\,x + 0.6492\,(1-x)$$

$\boxed{x = 0.81}$ at 10 KPa

from saturated steam table at 10KPa

$u_f = 191.8\ KJ/kg$, & $u_g = 2437.2\ KJ/kg$.

$$u_2 = u_g x + u_f(1-x)$$

$$u_2 = 2437.2\times0.81 + 191.8\,(1-0.811)$$

$u_2 = 2010.574\ KJ/kg. \Rightarrow U_2 = 2010.574\ KJ$

$$\delta W = -\Delta U$$

$$\delta W = -(U_2 - U_1) = -(2010.574 - 2844.4)\ KJ$$

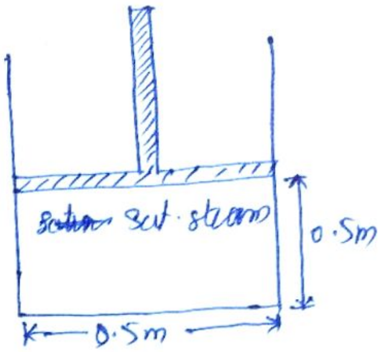
$\boxed{\delta W = 834.2\ KJ}$ Ans

8.4) PART-I

Given $P_1 = 500\,kPa$, $P_2 = 1\,MPa$

$x_1 = 1$

Volume is kept constant.



from saturated steam table at 500kPa

$T_1 = 151.831°C$

$v_1 = v_g = 0.37481\ m^3/kg$

$u_1 = u_g = 2560.7\ kJ/kg$

Now

Volume of cylinder (V) $= \frac{\pi}{4} \times 0.5^3 = 0.098125\,m^3$

mass of steam $= \frac{V}{v} = \frac{0.098125\,m^3}{0.37481\ m^3/kg} = 0.2618\ kg$

The heat added, will be fully utilized to convert saturated steam into superheated vapor. Because it does not produce any work.

At final condn; $P_2 = 1\,MPa$ (given)

$v_2 = 0.37481\ m^3/kg = v_1$ (since volume is constant)

from superheated steam table at $P = 1\,MPa$

$$\left\{\begin{matrix} T & v \\ 540 \rightarrow & 0.37295 \\ 560 \rightarrow & 0.38235 \end{matrix}\right\}$$

$$\cancel{\frac{0.38235 - 0.37295}{560 - 540} = \frac{T_2 - 540}{0.37481 - 0.37295}}$$

$$\frac{0.38235 - 0.37295}{560 - 540} = \frac{0.37481 - 0.37295}{T_2 - 540}$$

$$\boxed{T_2 = 544°C}$$

Since; $V = \text{constant}, \Rightarrow \delta W = 0 \Rightarrow \delta Q = \Delta U$ (from 1st law)

$\delta Q = (U_2 - U_1)$

superheated steam table at $P = 1\,MPa$ & 544°C

$$\left\{\begin{matrix} T & u\ (kJ/kg) \\ 540 \rightarrow & 3193.3 \\ 560 \rightarrow & 3227.8 \end{matrix}\right\}$$

$$\frac{3227.8 - 3193.3}{560 - 540} = \frac{u_2 - 3193.3}{544 - 540}$$

$u_2 = 3200.1\ kJ/kg$.

~~Therefore; $\delta Q = (U_2 - U_1)$~~ =

Therefore, $\delta Q = (U_2 - U_1) = (3200.1 - 2560.7)$ KJ/kg

$\delta Q = 639.4$ KJ/kg

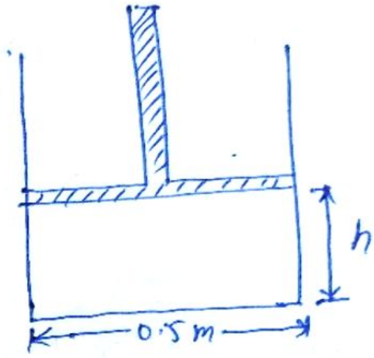
$\delta Q = (639.4 \times 0.2618)$ KJ

$\boxed{\delta Q = 167.39 \text{ KJ}}$

PART-II

Given $T_3 = 700°C$ (final temp)

and $P_2 = 1$ mPa



The steam is a superheated condition, therefore from stable at 1 mPa and 700°C at this condition

$v = 0.44783$ m³/kg (find specific volume)

$U_3 = 3476.3$ KJ/kg

{ h: final height of piston after piston is released

find volume = mv

$\pi \frac{0.5^2}{4} \cdot h = 0.2618 \times 0.44783$

$\therefore \boxed{h = 0.597 m}$

from 1st law

$\delta Q = \Delta U + P(\Delta V)$

$\delta Q = (U_2 - U_1) + P(v_3 - v_2)$

$\delta Q = (3476.3 - 3200.1) + 1000(0.44783 - 0.37481)$

$\delta Q = 349.22$ KJ/kg

$\delta Q = (349.22 \times 0.2618)$ KJ

$\boxed{\delta Q = 91.4 \text{ KJ}}$