Assignment - 2

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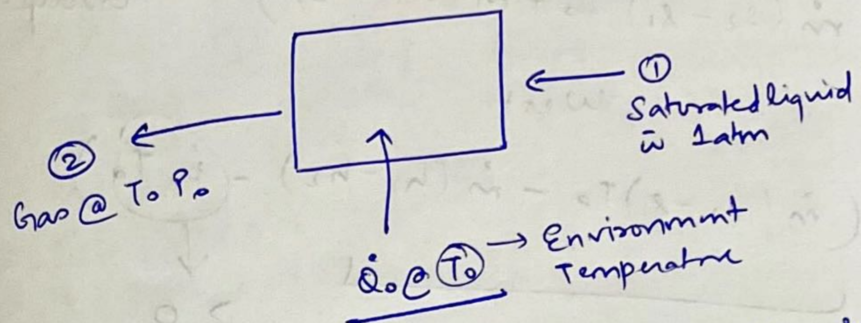
①.



Using entropy balance equation → $ds = s_{in} - s_{out} + P_s$

↓ differentiate wrt time

$\frac{ds}{dt} = \dot{S}_{in} - \dot{S}_{out} + \dot{P}_s$

0 → as in steady state

$0 = \dot{S}_{in} - \dot{S}_{out} + \dot{P}_s$

$\dot{S}_{out} = \dot{S}_{in} + \dot{P}_s$

$(\dot{Q}_0/T_0)$

$\dot{m}s_2 + \frac{\dot{Q}_{out}}{T_{out}} = \dot{m}s_1 + \cancel{\frac{\dot{Q}_{in}}{T_{in}}}^{0} + \dot{P}_s$

$\dot{m}(s_2 - s_1) = \dot{P}_s - \frac{\dot{Q}_0}{T_0}$ — ①

Energy balance → $dE = Q - W$) Differentiate in time

$\frac{dE}{dt} = \dot{Q} - \dot{W}$) Since it is a control volume

$\underbrace{\frac{dE}{dt}}_{0 \text{ (steady state)}} = \dot{Q} - \dot{W}_{ext} + \dot{m}\left((h_1 - h_2) + \underbrace{\left(\frac{V_1^2}{2} - \frac{V_2^2}{2}\right)}_{0} + \underbrace{g(z_1 - z_2)}_{0}\right)$

[since K.E & P.E changes are to be neglected as they are small.]

↓

$0 = \dot{Q}_0 - \dot{W}_{ext} + \dot{m}(h_1 - h_2)$

$\dot{W}_{ext} = \dot{Q}_0 + \dot{m}(h_1 - h_2)$ Substituting value of $\dot{Q}_0$ from ① into this

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~~$\dot{W}_{ext}$~~

$$0 = \left(\dot{P}_s T_0 - \dot{m}(s_2 - s_1) T_0 + \dot{m}(h_1 - h_2)\right) - \dot{W}_{ext}$$

$$\left(-\dot{W}_{ext}\right) = \left(\underline{\dot{m}(s_2 - s_1) T_0 - \dot{m}(h_1 - h_2)} - \left(\dot{P}_s T_0\right)\right)$$

as work required by shaft from external

$\dot{P}_s T_0 \geq 0$ as $\dot{P}_s \geq 0$

for max

$\dot{P}_s = 0$ → entropy production rate is constant

$$\boxed{\left(-\dot{W}_{ext}\right)_{max} = \dot{m}(s_2 - s_1) + \dot{m}(h_2 - h_1)}$$

Ans

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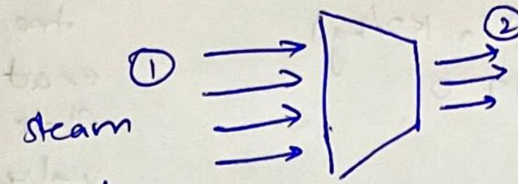
(2).



$v_1 = 3\,m/s$

$P_1 = 35\,bar = 3.5\,MPa$

$T_1 = 800\,k = 537^\circ c$

$P_2 = 1\,bar = 0.1\,MPa$

$T_2 = 400\,k = 127^\circ c$

$\dot{m} = 4500\,kg/hr$

Since steady state flow

$\dot{m}_1 = \dot{m}_2 = m = 4500\,kg/hr$

Using energy balance differentiated w.r.t. time for control volume

$$\underbrace{\frac{dE}{dt}}_{0} = \underbrace{\cancel{\dot{Q}}}_{0} - \underbrace{\cancel{\dot{W}}_{ext}}_{0} + \dot{m}\left(h_1 - h_2 \right) + \left(\frac{v_1^2 - v_2^2}{2}\right) + \underbrace{g(\cancel{z_1 - z_2})}_{0}$$

(steady state)

negligable heat exchage in turbine nozzle

as nozzle

change in PE very small

$$0 = \dot{m}\left((h_1 - h_2) + \frac{v_1^2 - v_2^2}{2}\right)$$

$$\left(v_2^2 = 2(h_1 - h_2) + v_1^2\right)$$

we need h_1 value at $P_1 = 3.5\,MPa$, $T_1 = 537^\circ c$

h_2 value at $P_2 = 0.1\,MPa$, $T_2 = 127^\circ c$

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But in the steam table the following info is given → nearby value as at the exact state value h value not given → To get it we will make use of line

h (in KJ/kg)

P = 3.5 MPa → T = 520°C 3497.0

→ T = 540°C 3542.3

&

P = 0.1 MPa T = 125°C 2726.7

T = 130°C 2736.7

$y = mx + c$

$$3497.0 = \left(\frac{3542.3 - 3497.0}{20}\right)(520) + c$$

$$3497.0 = (2.265)(520) + c$$

$$c = 2319.2 \text{ KJ/kg}$$

Again applying for required value

$$\therefore h_1 = (2.265)(527) + 2319.2$$

$$\boxed{h_1 = 3512.855 \text{ KJ/kg}}$$

$$2726.7 = \left(\frac{10}{5}\right)(125) + c$$

$$2726.7 = 250 + c$$

$$c = 2476.7 \text{ KJ/kg}$$

$$\left(h_2 = (2)(127) + 2476.7 = (2730.7 \text{ KJ/kg})\right)$$

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$v_2^2 = 2(782.155)10^3 + v_1^2$

$v_2 = \sqrt{1564310 + 9} \approx \boxed{1250.727 \text{ m/s}}$

Now for entropy production

$\Delta s = S_{in} - S_{out} + P_s$ (entropy balance equation)

↓ diff w time

$\cancel{\frac{ds}{dt}} = \cancel{\dot{S}_{in}} - \cancel{\dot{S}_{out}} + \dot{P}_s$ (as $\dot{Q}_{in}$ and $\dot{Q}_{out}$ = 0 so no contribution in s_1 and s_2)

$\dot{S}_{in} = \dot{m}s_1$, $\dot{S}_{out} = \dot{m}s_2$

0 (steady state)

$\dot{m}(s_2 - s_1) = \dot{P}_s$

Again

		s (in kJ/kg-K)
P = 3.5 MPa	T = 520°C	7.2172
	T = 540°C	7.2737
P = 0.1 MPa	T = 125°C	7.4932
	T = 130°C	7.5183

Again using line equation

$y = mx + c$

$7.2172 = \left(\frac{7.2737 - 7.2172}{20}\right)(520) + c$

$c = 5.7482 \text{ kJ/kg-K}$

$s_1 = \left(\frac{0.0565}{20}\right)(527) + 5.7482 \approx 7.23698 \text{ kJ/kg-K}$

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$$7.4932 = \frac{(7.5183 - 7.4932)(125)}{5} + c$$

$$c = 6.8657 \text{ KJ/kg-K}$$

<u>Now</u>

$$s_2 = \frac{(7.5183 - 7.4932)(127)}{5} + 6.8657$$

$$s_2 = 7.50324 \text{ KJ/kg-K}$$

<u>Now</u> $\dot{P}_s = \dot{m}(s_2 - s_1)$

$$= \frac{4500}{3600} \text{ kg/s} (0.26626) 10^3 \text{ J/kg-K}$$

$$\boxed{\dot{P}_s = \cancel{332.825}\ (332.825) \text{ J/K-s}}$$

and $v_2 = 1250.727$ m/s