Thermo

Recitation #6

(03/14/23)

→ Session 1 : key concepts & Exam 2 pointers

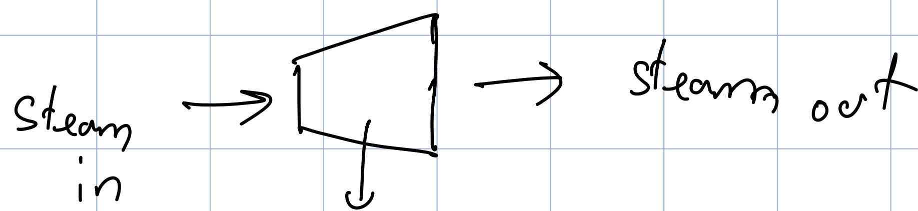
Session 2 : Problems : 1 entropy prob. , 1 turbine Prob.

Session 1

Key concepts

(1) reversibility

H.W #4.3



$w_s = 0.35\, w_s$

(a) Adiabatic & reversible $\equiv$ $\Delta S = 0$

isentropic

i.e $\eta = 100\%$

Path variables → Q & W

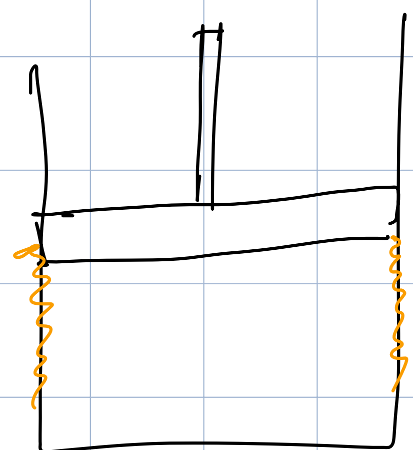
$$\Delta S = \frac{Q_{rev}}{T} \quad \Bigg| \quad \frac{dS}{dt} = \frac{\dot{Q}_{rev}}{T}$$

if irreversible.

$$\Delta S = \frac{Q_{irrev}}{T} + \underbrace{\dot{S}_{gen}}$$

Physical interpretation

irreversibility



friction on wall makes the process irrev.

when adiabatic : $\dot{Q} = 0$

& for reversible process $\Delta S = \frac{\dot{Q}_{rev}}{T} = 0$

$\therefore$ $\Delta S = 0$ of adiabatic & reversible process

(b) $\eta = 35\%$

$$\Delta U = \cancel{Q}^{0} + \cancel{W_{ec}}^{0}$$

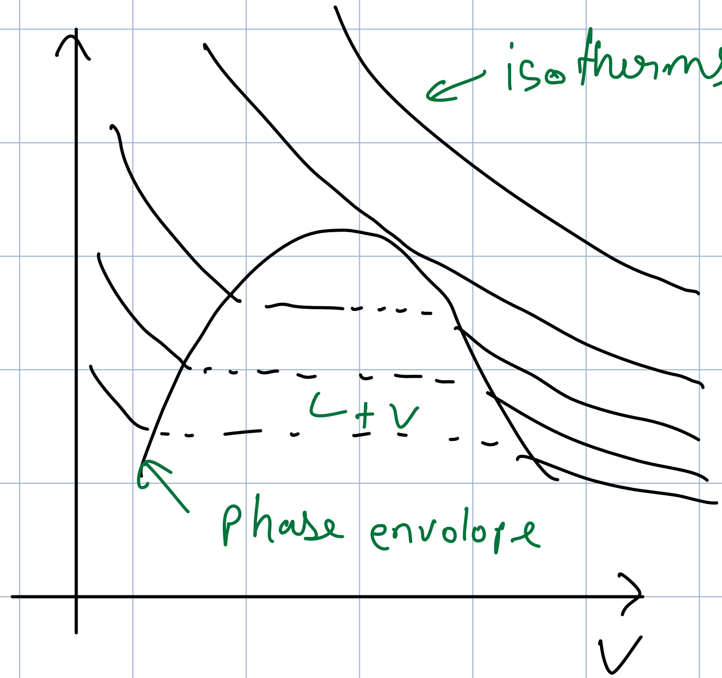
$$\Delta U = 0$$

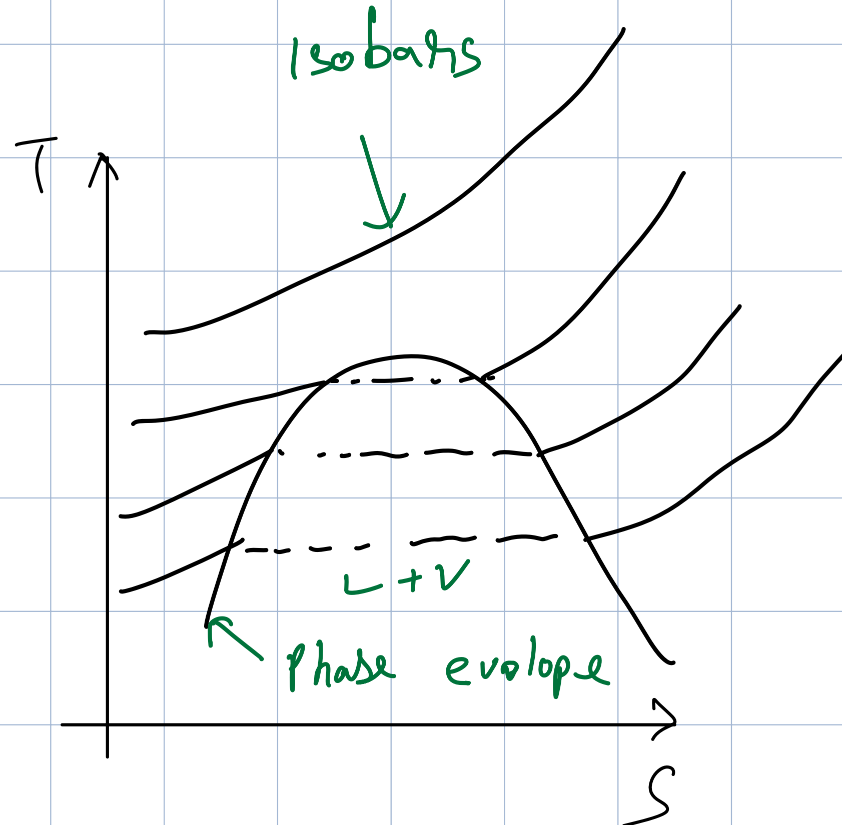
$$\therefore \quad \Delta H' = \cancel{\Delta U}^{0} + W_s'$$

$$\therefore \quad \Delta H' = W_s'$$

$$\Delta H \cdot \eta = W_s \cdot \eta$$

② T-S diagram





$V \propto \frac{1}{P}$ (Boyle's law)

$S \propto \frac{1}{T}$

$\Rightarrow \quad P_1 V_1 = P_2 V_2 \quad \Leftarrow$ governing eqns $\Rightarrow \quad \Rightarrow \quad S = \frac{\dot{Q}_{rev.}}{T}$

③ Reversible vs. irreversible outlet.

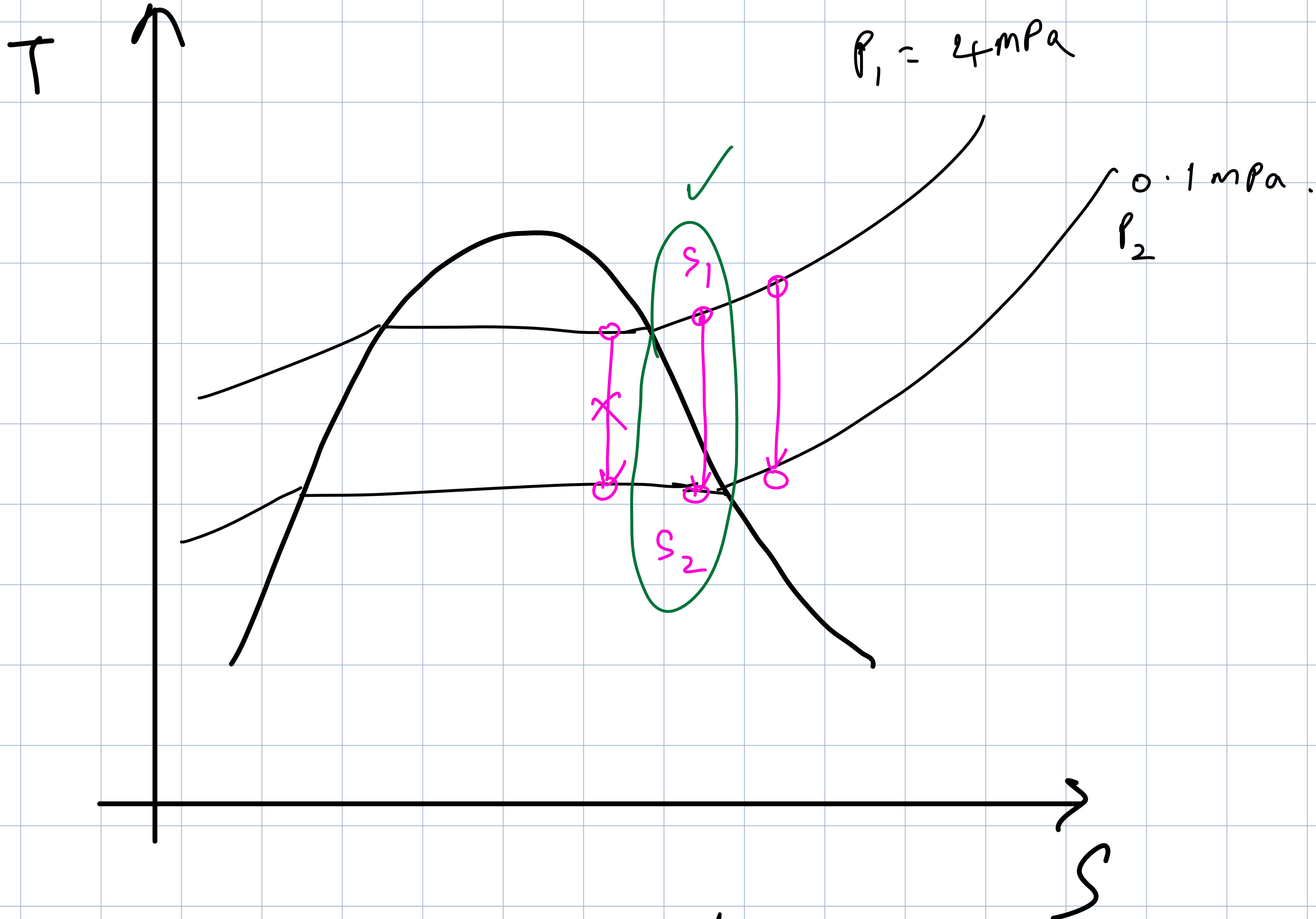
owing cases:

Reversible Outlet	Actual Outlet
superheated	superheated
wet steam	superheated
wet steam	wet steam

using quality, q, for calculating superheated states

when we talk about turbines: Adiabatic

if also reversible $\Rightarrow$ $\Delta s = 0$



$T_1 = 500$ if adiabatic & rev.

find steam quality.

$s_1 = 7.09 \ kJ/kgK$

$\because \Delta s = 0, \quad s_2 = s_1 = 7.09$

@ P_1: $\quad T^{sat} = 99.6\ ^\circ C$

$\quad \quad \& \quad s_v = 7.3589$

look at sat pressure table

$s_L = 1.3028$

$s_v = 7.3589$

we see,

$s_L < s_1 = s_2 < s_v$

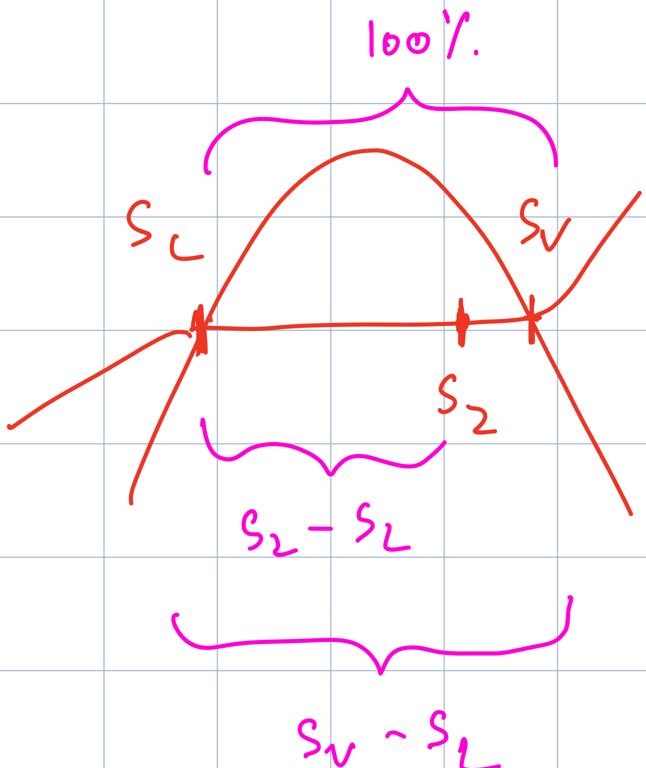
∴ wet steam.

we know,

$$q = \frac{S_2 - S_L}{S_v - S_2} = \frac{7.09 - 1.3028}{7.3589 - 1.3028}$$

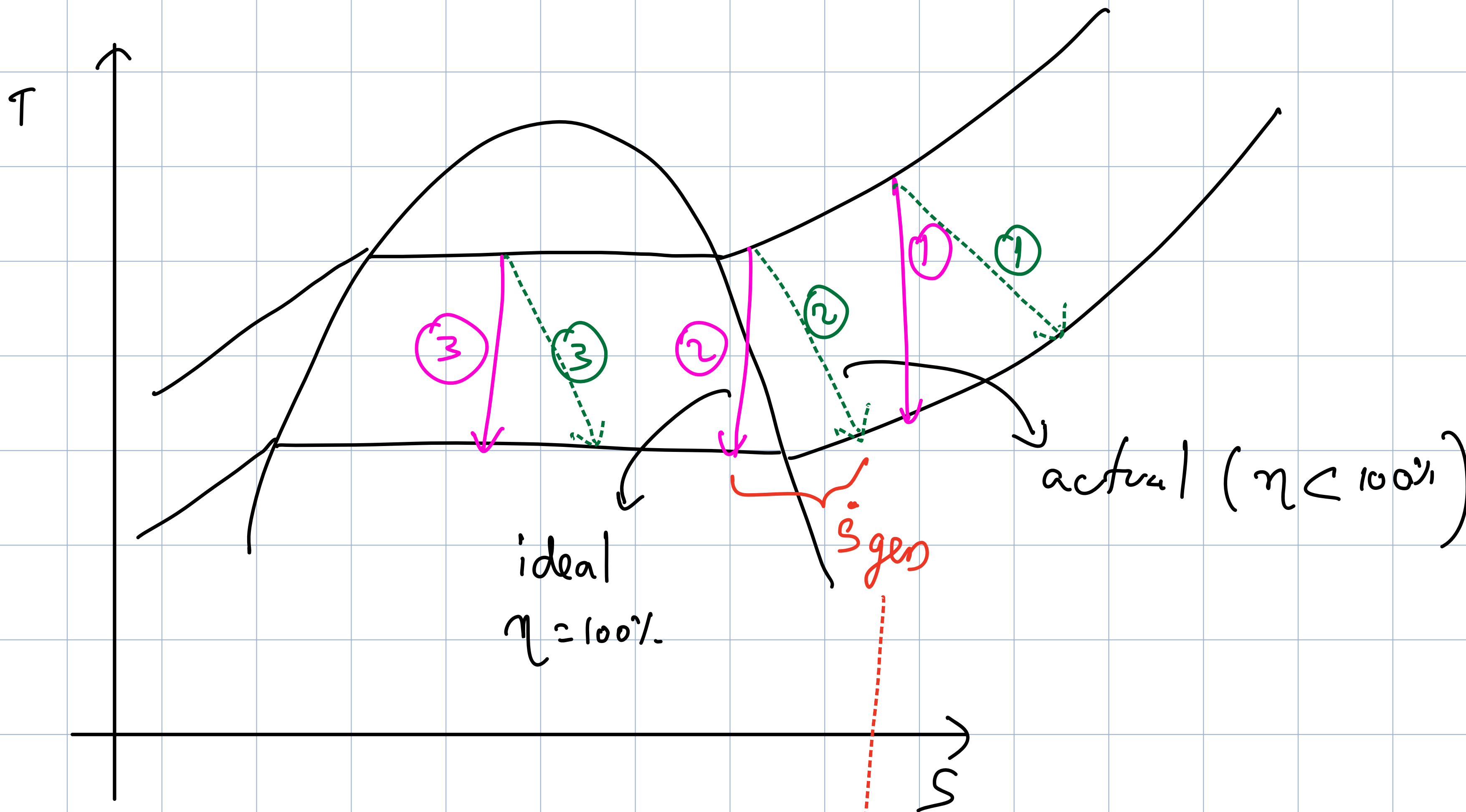
just ratio of lengths.

$$= 0.956$$



$$\underline{\underline{q = 95.6\ \%}}$$

Now if irrev. process



$$\Delta \dot{S} = \frac{Q_{irrev}}{T} + \dot{S}_{gen}.$$

owing cases:

Reversible Outlet	Actual Outlet
1 superheated	1 superheated
2 wet steam	2 superheated
3 wet steam	3 wet steam

using quality, q, for calculating superheated states

from Exam 2 learning objective.

4 Exam 2 Pointers.

→ learning objective.

→ Exam pattern

Q1	60 pts	OR	60 pts	11 – 11:45
Q2	30 pts		20 pts	11:45 – 12
Q3	10 pts.		20 pts.	12 – 12:15

Focus on: entropy calc, irreversible / rev. processes, T-S diagram.

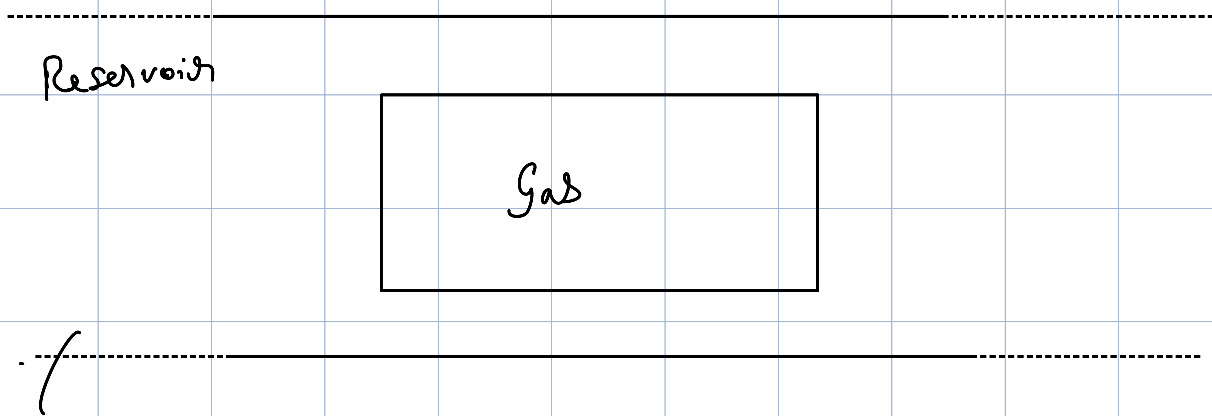
→ Focus on understanding problems in H.W's & Recitation.

→ Draw diagram & graph, Assumptions, governing equation ⇒ All these carry points.

→ Calculators, download material on your device. (you cannot use internet)

Session 2 : Problems

Q1



$T_{res} = 50°C = 323.15K$

for gas

(1) $T_1 = 15°C$ $\xrightarrow{\text{heated}}$ $T_2 = 30°C$

$P_1 = 0.1013\ MPa$ $\quad P_2 = P_1$

$\underline{V_1} = 60\ m^3$

Assume : Ideal gas

no. of moles = $n = \frac{PV}{RT} = \frac{0.1013 \times 10^6 \times 60}{8.314 \times 288.15}$

$$\underline{n = 2537.1 \text{ mol}}$$

$$(\Delta S_{univ})_p = (\Delta S_{gas})_p + (\Delta S_{surrounding})_p$$

$$(\Delta S_{gas})_p = \frac{Q}{T} = \frac{n c_p dT}{T} = n \int_{T_1}^{T_2} \frac{c_p}{T} dT = n c_p \ln\left(\frac{T_2}{T_1}\right)$$

$$= 2537.1 \times \frac{7R}{2} \ln\left(\frac{303.15}{288.15}\right)$$

$$(\Delta S_{gas})_p = 3746.4 \text{ J/K}$$

$$\left(\Delta S_{surr.}\right)_p = \frac{Q_{res}}{T_{res}} = \frac{-Q_{gas}}{T_{res}} = \frac{-n C_p \Delta T}{T_{res}}$$

$$= \frac{-2537.1 \times \frac{7R}{2}(15)}{323.15}$$

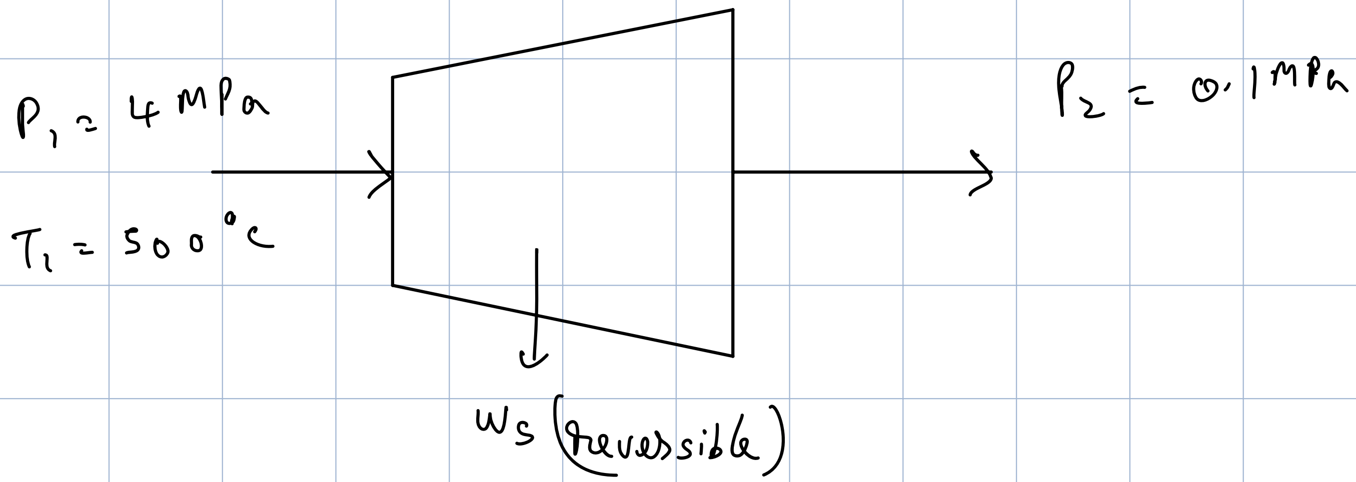
$$\left(\Delta S_{surr}\right)_p = -3426.9 \text{ J/k}$$

$$\therefore \left(\Delta S_{univ}\right)_p = 3746.4 + (-3426.9)$$

$$\left(\Delta S_{univ}\right)_p = 319.5 \text{ J/k}$$

* Irreversible due to T gradient.

Q2



<u>Assume</u> : Steady-state

Adiabatic

ideal turbine → $\underbrace{\dot{Q} = 0 \text{ \& Reversible}}_{\substack{\Delta S = 0 \\ \text{isentropic}}}$

(a) <u>Mass balance</u> : $\dot{m}_1 = -\dot{m}_2 = \dot{m}$

@ $P^{sat} = 0.1 MPa$

$$\left.\begin{aligned} S^L &= 1.3028 \\ S^V &= 7.3589 \end{aligned}\right\} kJ/kg\,K$$

$$\left.\begin{aligned} H^L &= 417.50 \\ H^V &= 2674.95 \end{aligned}\right\} kJ/kg$$

$\therefore$ $S^L < S_2' < S^V$

interpolation of H @ 2

	S	H	
L	x_1 1.3028	417.50	y_1
2	x 7.0922	2575.54	y
V	x_2 7.3589	2674.95	y_2

$$y = \frac{y_2 - y_1}{x_2 - x_1}(x - x_2) + y_2$$

$$= \frac{7.3589 - 1.3028}{2674.95 - 41.75}(7.0922 - 7.3589) + 2674.95$$

$$= 2575.54$$

$$q = \frac{S_2' - S^L}{S^V - S^L} = \frac{7.0922 - 1.3028}{7.3589 - 1.3028} = 0.956$$

$$q = 95.6\%$$

$$H_2' = H^L + q\underbrace{\left(H^V - H^L\right)}_{\Delta H_{vap}}$$

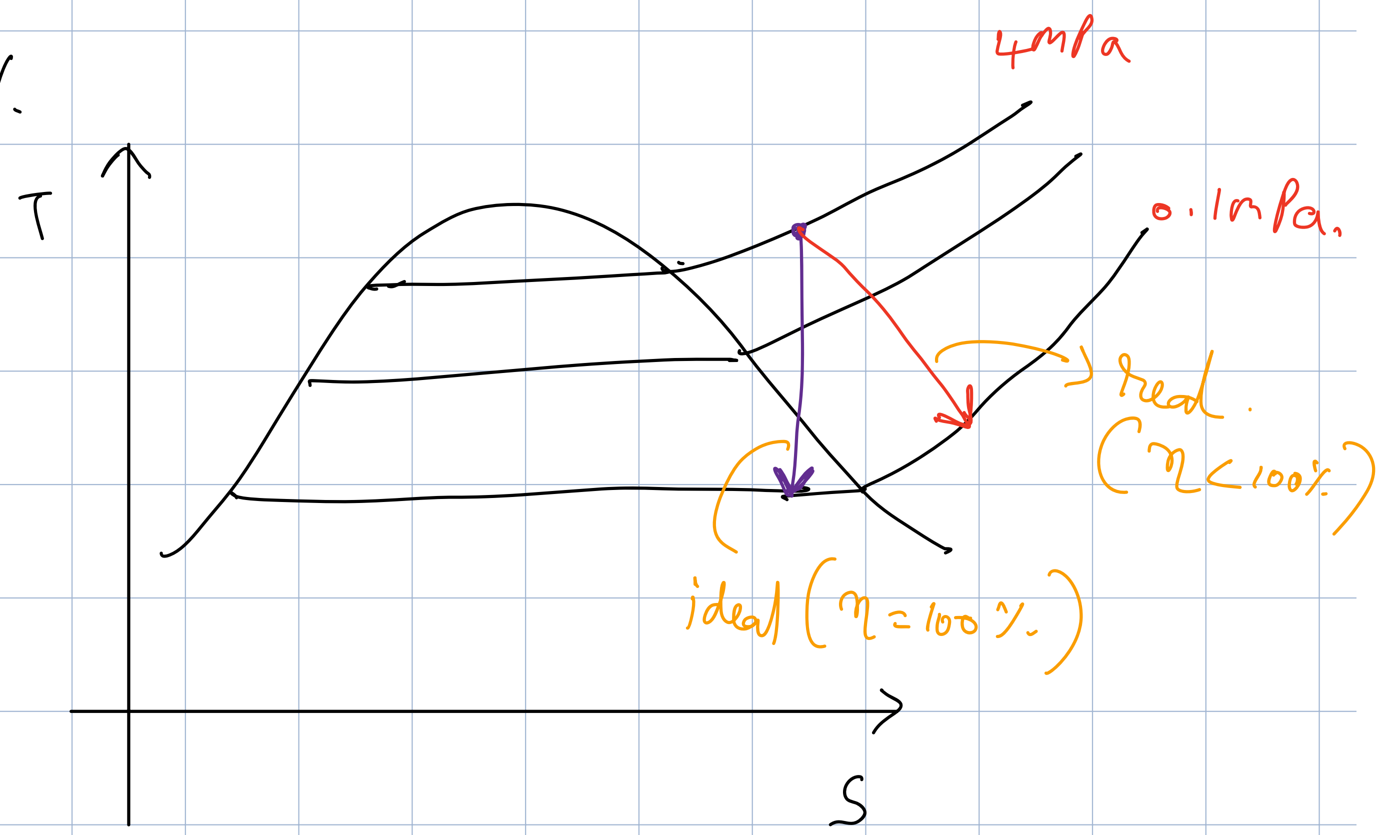
$$= 417.50 + 0.956\left(2674.95 - 417.50\right)$$

$$H_2' = 2575.54 \text{ kJ/kg}$$

$$\Delta H' = W_s' = H_2' - H_1 = 2575.54 - 3446.0$$

$$\Delta H' = -870.46 \text{ kJ/kg}$$

b) if $\eta = 80\%$



$$W_s = \Delta H' = \Delta H \cdot \eta = -870.46 \times 0.8$$

$$= \boxed{-696.37\ kJ/kg}$$