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C#0361022

Mech 262

Assignment #7

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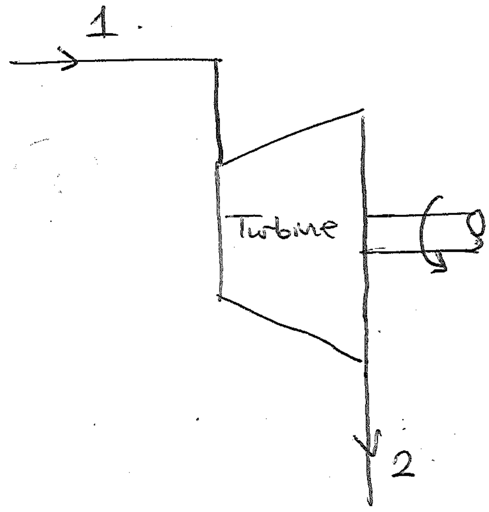
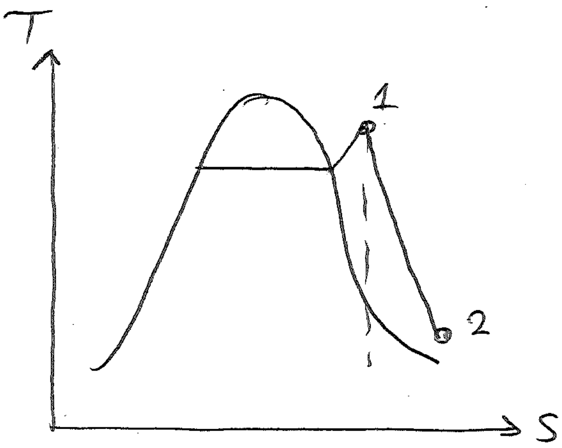
1-) Given: Steady State Operation
$V_1 = 70\ m/s$; Steam at 3 MPa and 500°C enters an insulated turbine.
Steam exists from the turbine with $V_2 = 140\ m/s$ at 0.3 MPa. $W_T = 667\ \frac{kJ}{kg}$.





1st Law of Thermodynamics:

$$\Delta E = Q - W + \underbrace{m_1\left(h_1 + \frac{V_1^2}{2} + gz_1\right)}_{\text{Inlet}} - \underbrace{m_2\left(h_2 + \frac{V_2^2}{2} + gz_2\right)}_{\text{Outlet}}$$

Steady State
$\boxed{\Delta E = 0}$

Insulated
$\boxed{Q = 0}$

State	T(°C)	P(MPa)	V(m/s)	h($\frac{kJ}{kg}$)	s($\frac{kJ}{kgK}$)
1	500°C	3	70	3456.5	7.2338
2		0.3	140	2782.2	7.12565

No altitude ∴ Pottential Energy has no contribution (negligible).
Mass is conserved $\Rightarrow \dot{m} = \dot{m}_1 = \dot{m}_2$

$$\dot{m}\left(h_1 + \frac{V_1^2}{2}\right) = \dot{m}\left(h_2 + \frac{V_2^2}{2}\right) + W_T$$

$$h_1 + \frac{V_1^2}{2} = h_2 + \frac{V_2^2}{2} + \frac{W_T}{\dot{m}}$$

$$h_2 = h_1 + \left(\frac{V_1^2 - V_2^2}{2}\right) - \frac{W_T}{\dot{m}}$$

At $P_1 = 3\ MPa$ and $T_1 = 500° \Rightarrow \boxed{h_1 = 3456.5\ kJ/kg}$
and $\boxed{S_1 = 7.2338\ \frac{kJ}{kgK}}$

$$h_2 = 3456.5\ \frac{kJ}{kg} + \frac{(140 m/s)^2 - (70 m/s)^2}{2} - 667\ \frac{kJ}{kg}$$

$$\boxed{h_2 = 2782.2\ kJ/kg}$$

At $P_2 = 0.3\ MPa$ and $h_2 = 2782.2\ \frac{kJ}{kg} \Rightarrow \boxed{S_2 = 7.12565\ \frac{kJ}{kgK}}$

by interpolation.

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$$\Delta S_{cv} = \int_1^2 \left(\frac{dQ}{T}\right) + m_i s_i - m_e s_e + \sigma_{cv}$$

Steady State $\boxed{\Delta S_{cv} = 0}$

$\boxed{\frac{dQ}{T} = 0}$ → Insulated.

$\sigma_{cv} + m_i s_i - m_e s_e = 0$

$\sigma_{cv} = m_e s_e - m_i s_i$

$\sigma_{cv} = m_2 s_2 - m_1 s_1$ $\qquad m = m_1 = m_2$.

$\sigma_{cv} = m(s_2 - s_1)$

$\sigma_{cv} = 1\cancel{kg}(7.12500 - 7.2338)\frac{kJ}{\cancel{kg}K}$

$$\boxed{\sigma_{cv} = -0.109 \frac{kJ}{°K}}$$

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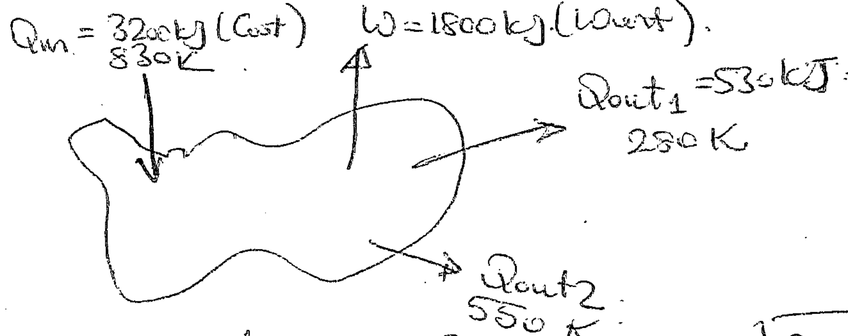
Since $\sigma_{cv} < 0$ it is impossible.
Entropy can never be destroyed.

2-)



a) $\eta = \frac{W_{out}}{Cost} = \frac{1800kJ}{3200kJ} \Rightarrow \boxed{\eta = 56.3\%}$

b) In = Out

$Q_{in} = Q_{out,1} + Q_{out,2} + W \Rightarrow 3200kJ = 530kJ + 1800kJ + Q_{out,2}$

$\Rightarrow \boxed{Q_{out} = 870 kJ.}$

$\Delta S_{cv} = \int_1^2 \left(\frac{dQ}{T}\right) + \cancel{m_i s_i} - \cancel{m_e s_e} + \sigma_{cv}$ $\qquad$ Steady State and $\boxed{m_i = m_e = m}$

$\Rightarrow \Delta S_{cv} = 0 \Rightarrow$

$\sigma_{cv} = -\int_1^2 \frac{dQ}{T} \Rightarrow \sigma_{cv} = -\left(\frac{3200 kJ}{830K} - \frac{530kJ}{280K} - \frac{870kJ}{550K}\right)$

$$\boxed{\sigma_{cv} = -0.381 \frac{kJ}{K}}$$

$\sigma_{cv} < 0$ it is impossible. Entropy cannot be destroyed c.) This happen when $P = 0$

$$\int_1^2 \left(\frac{dQ}{T}\right) = 0 = \frac{3200\,kJ}{830\,K} - \frac{530\,kJ}{280\,K} - \frac{Q_{out2}}{550\,K} = 0$$

$$\boxed{Q_{out_2} = 1079.4\,kJ}$$

✓

In = Out

$3200\,kJ = 530\,kJ + 1079.4\,kJ + W$

$$\Rightarrow \boxed{W = 1590.6\,kJ}$$

d.) The best system efficiency

$$\eta = \frac{Want}{Cost} = \frac{1590.6\,kJ}{3200\,kJ}$$

$$\boxed{\eta = 49.7\%}$$

✓

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