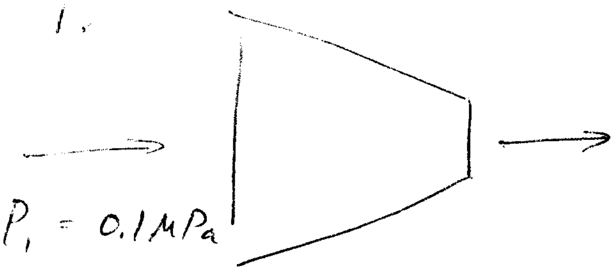
Air

1.



$P_1 = 0.1\,MPa$

$T_1 = 290\,K$

$V_1 = 6\,m/s$

$A_1 = 0.10\,m^2$

$P_2 = 0.7\,MPa$

$T_2 = 550\,K$

$V_2 = 2\,m/s$

Adiabatic

a) $\dot{m} = \frac{V_1 A_1}{v_1}$

Ideal gas? Yes $Pv = RT$

25 $v_1 = \frac{RT_1}{P_1} = \frac{0.287 \frac{kJ}{kg\,K} \cdot 290\,K}{100\,kPa} = 0.832 \frac{m^3}{kg}$

$\dot{m} = \frac{6\,m/s \cdot 0.10\,m^2}{0.832} = 0.72 \frac{kg}{s}$

b) $q + w_{other} + h_1 + \frac{V_1^2}{2} - \left(h_2 - \frac{V_2^2}{2}\right) = 0$

$w_{other} = h_2 - h_1 + \frac{V_2^2 - V_1^2}{2}$

$w_{other} = (555.74 - 290.16)\frac{kJ}{kg} + \frac{(2\,m/s)^2 - (6\,m/s)^2}{2} \frac{\frac{kJ}{kg}}{1000 \frac{m^2}{s^2}}$

$\dot{W}_{other} = w_{other}\,\dot{m} = 191.4\,kW$

c) Negligible kinetic energy change

2. $\eta_{th} = 1 - \frac{T_L}{T_H}$ maximum

15 $\eta_{max} = 1 - \frac{300}{500} = \frac{2}{5} = 0.4$

$\eta_{claim} = \frac{410}{1000} = 0.41$ Not possible

3. $\eta_{compressor} = \frac{h_{2s} - h_1}{h_{2a} - h_1}$

If the compressor is isentropic, then $s_2 = s_1$

20 and $s_2^\circ = s_1^\circ + R \ln\left(\frac{P_2}{P_1}\right)$

$s_2^\circ = 1.66802 \frac{kJ}{kg\,K} + 0.287 \frac{kJ}{kg\,K} \ln\left(\frac{0.7}{0.1}\right)$

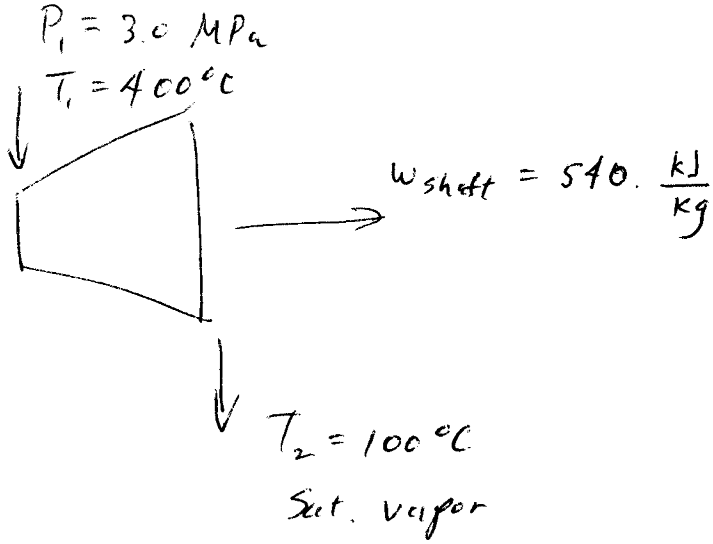
$= 2.2265 \frac{kJ}{kg\,K}$

$T_{2s} = 503.4\ K$

$h_{2s} = 506.54 \frac{kJ}{kg}$

$\eta_{compressor} = \frac{506.54 - 290.16}{555.74 - 290.16} = 81.5\%$

4.



a) $q + w_{other} = h_2 - h_1 = 2675.6 \frac{kJ}{kg} - 3231.7 \frac{kJ}{kg}$

where $w_{other} = -540 \frac{kJ}{kg}$

10

$q = -16.1 \frac{kJ}{kg}$ transferred from turbine to surroundings

b) $s_2 - s_1 = s_{gen} + \sum\left(\frac{\delta q}{T}\right)_{boundary}$

$s_2 = 7.3542 \frac{kJ}{kg\,K}$

10 $s_1 = 6.9235 \frac{kJ}{kg\,K}$

$(7.3542 - 6.9235) \frac{kJ}{kg\,K} = s_{gen} - \frac{16.1 \frac{kJ}{kg}}{500\,K}$

$s_{gen} = 0.4629 \frac{kJ}{kg\,K}$

c) For an isentropic turbine, $s_2 = s_1 = 6.9235 \frac{kJ}{kg\,K}$

In that case, the exit would be two-phase.

$$x = \frac{6.9235 - 1.3072}{6.047} = 0.9288$$

20 $h_{2s} = 419.17 \frac{kJ}{kg} + x \cdot 2256.4 \frac{kJ}{kg} = 2514.86 \frac{kJ}{kg}$

$$W_{\substack{other \\ isentropic}} = h_{2s} - h_1 = (2514.86 - 3231.7)\frac{kJ}{kg} = -716.8 \frac{kJ}{kg}$$

$W_{\substack{shaft \\ isentropic}} = 716.8 \frac{kJ}{kg}$ greater than actual