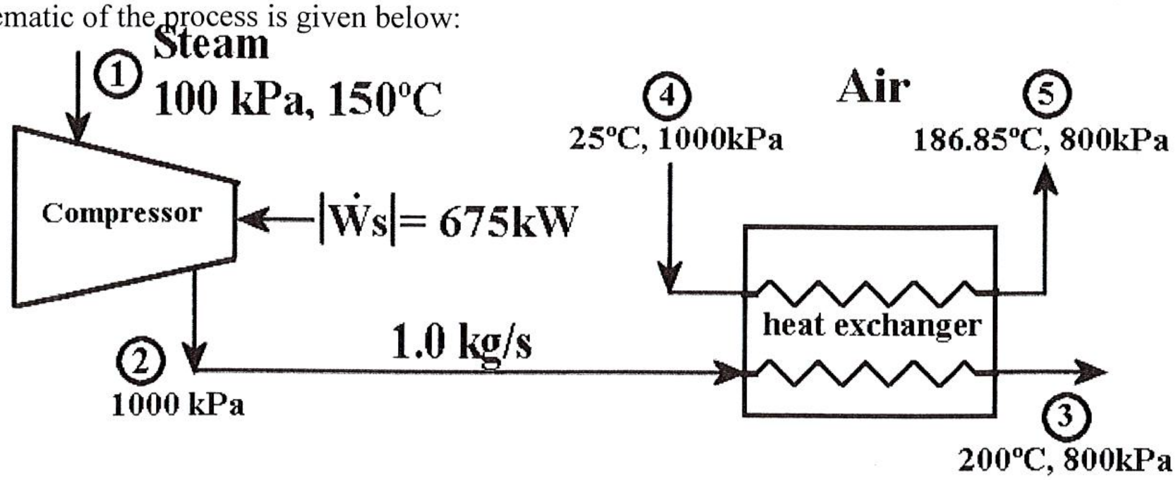
Example Exam

ES 3053 | **EXAM II** | **March 25, 2009**

Open Books and Notes

Solution

Steam flowing at 1.0 kg/s enters an adiabatic compressor at 150°C and 100kPa (point 1). It is compressed adiabatically to 1000kPa (point 2), requiring 675 kW of power to drive the compressor. The steam then flows to a heat exchanger where it is used to heat a stream of air from 25°C, 1000kPa (point 4) to 186.85°C (460K), 800kPa (point 5). The steam leaves the exchanger at 200 °C and 800kPa (point 3). A schematic of the process is given below:



I. 70 points

Fill in the following table:

	Point 1	Point 2' (isentropic base case)	Point 2 (actual case)	Point 3	Point 4	Point 5
P (kPa)	100	1000	1000	800	1000	800
T (°C)	150	449.9	487.4	200	25	186.85
h (kJ/kg)	2776.38	3370.98	3451.38	2839.25	298.62	462.34
s (kJ/kg-K)	7.6133	7.6133	7.7247	6.8158	6.2022	6.7046

II. 15 points

Find the thermal efficiency, η, of the compressor.

η= 0.881

III. 15 points

Find the flowrate of air assuming there is no heat loss from the heat exchanger.

m_{air} = 3.74 kg/s

Instructions:

1. Use the steam table, Table B.1, beginning on page 510 of your textbook for steam properties.
2. Use the ideal-gas properties of air given in Table A7.1 on page 496 of your text for air properties.
3. Turn in your calculations with this sheet filled in. Failure to turn in your calculations will result in no credit for the problem.

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Solution

I. $\boxed{\begin{array}{l} h_1\,(100\,kPa,\,150^\circ C) = 2776.38\ kJ/kg \\ s_1\,(100\,kPa,\,150^\circ C) = 7.6133\ kJ/kg\text{-}K \end{array}}$

isentropic base case:

T	s'	h'
400	7.4650	3263.88
?	7.6133	?
500	7.7621	3478.44

$\boxed{\begin{array}{l} T_2' = 449.9 \\ h_2' = 3370.98 \end{array}}$

$\Delta h' = 3370.98 - 2776.38 = 594\ kJ/kg$

$\Delta h(\text{actual}) = \dfrac{594.6}{0.881} = 675\ kJ/kg$

Point 2 actual case

$(h_2 - 2776.38)\ 1\ kg/sec = 675\ kJ/sec$

$\boxed{h_2 = 2776.38 + 675\ kJ/kg = 3451.38\ kJ/kg}$

T	h	s
400	3263.88	7.4650
?	3451.38	?
500	3478.44	7.7621

$\boxed{\begin{array}{l} s_2 = 7.7247 \\ T_2 = 487.4 \end{array}}$

Point 3

$\boxed{\begin{array}{l} s\,(800\,kPa,\,200^\circ C) = 6.8158 \\ h\,(800\,kPa,\,200^\circ C) = 2839.25 \end{array}}$

For air, point 4

$h\,(1000\,kPa,\,25^\circ C) = 298.62\ kJ/kg$

$s\,(1000\,kPa,\,25^\circ C) = 6.86305\ kJ/kg\text{-}K - 0.287\ \ln\dfrac{1000}{100} = 6.2022\ \dfrac{kJ}{kg\cdot K}$

For air, point 5

$h\,(800\,kPa,\,460K) = 462.34\ kJ/kg$

$s\,(800\,kPa,\,460K) = 7.30142\ kJ/kg\text{-}K - 0.287\ \ln\dfrac{800}{100} =$

$s\,(800\,kPa,\,460K) = 6.7046\ kJ/kg\text{-}K$

II. $\boxed{\eta = \dfrac{3370.98 - 2776.38}{675} = 0.881}$

III. $(1\,kg/sec)(675\,kJ/kg) = \dot m_{AIR}\,(462.34 - 298.62)\ kJ/kg$

$\dot m_{AIR} = 3.74\ kg/sec$