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Department of Mechanical Engineering
Fall Semester 2008

Examination I
In Exam Hall One

Thermodynamics 211 A
MWF 11 to 12, room E107

Closed Book and Notes

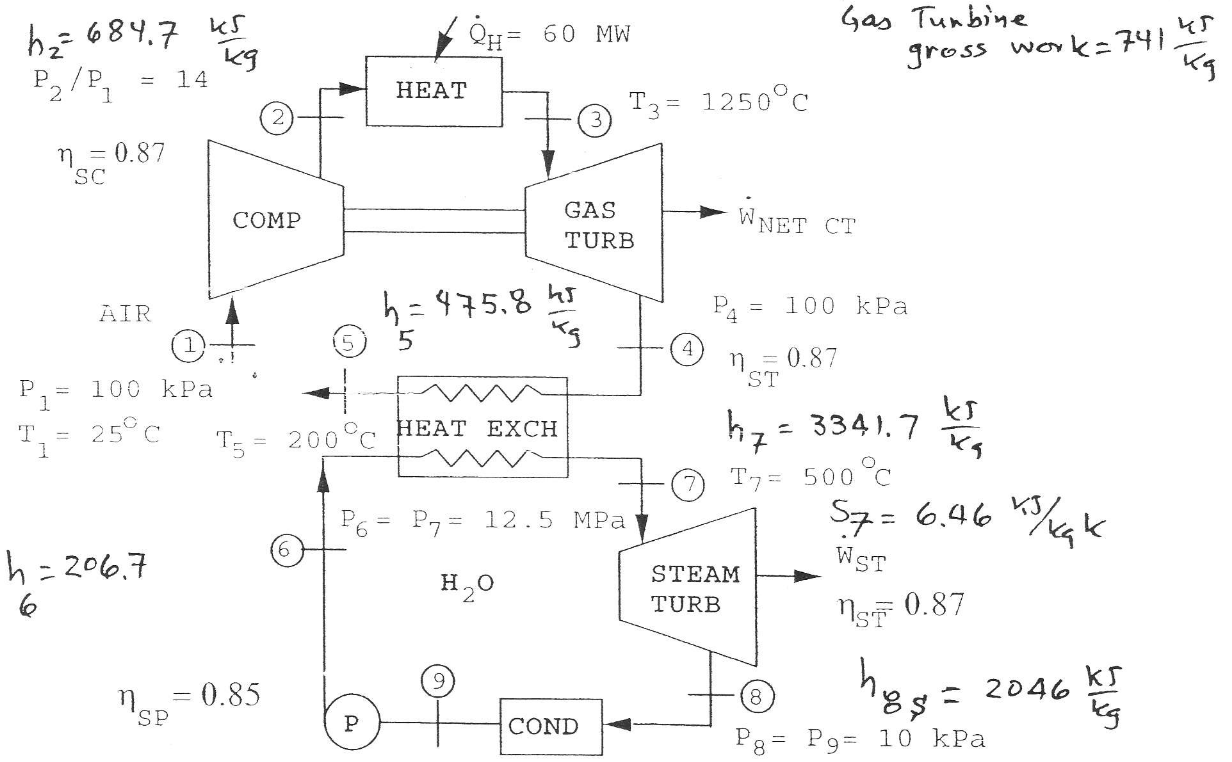
Answer on the attached sheets.
Write your name and ID number
Stop writing when the exam papers are called for
Please keep your eyes on your own paper

October 29, 2008
W. AssAF

Problem ONE

The power plant shown in Fig. 11.40 combines a gas-turbine cycle and a steam-turbine cycle. The following data are known for the gas-turbine cycle. Air enters the compressor at 100 kPa, 25°C, the compressor pressure ratio is 14, and the isentropic compressor efficiency is 87%; the heater input rate is 60 MW; the turbine inlet temperature is 1250°C, the exhaust pressure is 100 kPa, and the isentropic turbine efficiency is 87%; the cycle exhaust temperature from the heat exchanger is 200°C. The following data are known for the steam-turbine cycle. The pump inlet state is saturated liquid at 10 kPa, the pump exit pressure is 12.5 MPa, and the isentropic pump efficiency is 85%; turbine inlet temperature is 500°C and the isentropic turbine efficiency is 87%. Determine

a. The mass flow rate of air in the gas-turbine cycle.
b. The mass flow rate of water in the steam cycle.
c. The overall thermal efficiency of the combined cycle.



control volume: compressor.

~~ṁa~~ the first Law gives.

$\dot{m}_a h_{a_1} = \dot{m}_a h_{a_2} + \dot{W}_{comp}$.

$\dot{m}_a (h_{a_1} - h_{a_2}) = \dot{W}_{comp}$.

about 50%

$\frac{P_2}{P_1} = 14 \Rightarrow P_2 = 1400$ Kpa.

control volume heatexchange

$\dot{Q}_H + \dot{m}_a h_2 = \dot{m}_a h_3$

$60000\ \$ = \dot{m}_a (h_3 - h_2) = \dot{m}_a (h_3 - 684.7)$

$T_3 = 1250°C = 1523.15\ K$

by interpolation

$$\begin{array}{ll|l} 1500 & 1635.8 & \frac{1500-1523.15}{1500-1550} = \frac{1635.8-h_3}{1635.8-1696.65} \\ 1523.15 & h_3 & \\ 1550 & 1696.65 & \end{array}$$

$h_3 = 1663.85$

$$\Rightarrow \dot{m}_a = \frac{60000}{(1663.85-684.7)} = \cancel{61} \boxed{61.27\ \frac{Kg}{s}}$$

ok.

For the heat ~~E~~XCH

$\dot{m}_a h_{4_{air}} + \dot{m}_{water} h_{6_{water}} = \dot{m}_a h_5 + \dot{m}_{water} h_{7_{water}}$

Gas turbine: $\eta = 0.87 = \frac{w_a}{w_s} \Rightarrow \cancel{w_a} = w_s = \frac{\cancel{887}\ 741}{0.87}$

$w_s = \cancel{644.67}\ KJ \cdot 851.724 \frac{KJ}{Kg}$

$\dot{m}_a \cancel{3} h_3 = \dot{m}_a h_4 + \dot{W}_{turbine}$

$h_3 = h_4 + w_{turbine}$

$\cancel{\Rightarrow}\ h_4 = h_3 - w_{turbine} = 1663.85 - 851.724$

$h_4 = 812.12\ KJ/Kg.$

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for the heat exchanger. good thinking

$\dot{m}_a (h_4 - h_5) + \dot{m}_{water} (h_6 - h_7) = 0.$

$$\dot{m}_{water} = \frac{-\dot{m}_a (h_4 - h_5)}{h_6 - h_7} = \frac{-61.27(812.12 - 475.8)}{206.7 - 334.17}$$

$\dot{m}_{water} = \cancel{161.65}\ Kg/s.$ NO

Problem Two

An indoor pool evaporates 1.512 kg/h of water, which is removed by a dehumidifier to maintain 21°C, $\phi = 70\%$ in the room. The dehumidifier, shown in Fig. P12.105, is a refrigeration cycle in which air flowing over the evaporator cools such that liquid water drops out, and the air continues flowing over the condenser. For an air flow rate of 0.1 kg/s the unit requires 1.4 kW input to a motor driving a fan and the compressor and it has a coefficient of performance, $\beta = Q_L/W_c = 2.0$. Find the state of the air as it returns to the room and the compressor work input.

$\dot{m}_a = 0{,}1 \text{ Kg/s}$ $\qquad \dot{W} = 1{,}4 \frac{KJ}{S}$

$\beta = \frac{Q_L}{W_c} = 2.0$

$T_3 = 21°C \qquad \phi_3 = \frac{P_v}{P_g} = 0{,}7$

$\phi_3 = \frac{P_{v_3}}{P_{g_3}} = 0{,}7 \qquad \dot{m}_p = 1{,}512 \text{ Kg/h} = 4.2\times10^{-4} \text{ Kg/s}$

~~$\dot{m}_{v_2} =$~~

~~first law applied to compressor~~ :

~~$\dot{m}_a \; h_{a_1} + \dot{m}_{v_1}$~~ first law applied to compressor.

$\cancel{\dot{m}_a h_{a_2}} + \dot{m}_{v_3} h_{v_2} = \dot{m}_{v_3} h_{v_3} + \dot{W}$

$\dot{m}_v (h_{v_2} - h_{v_3}) = 1{,}4$

but $T_3 = 21°C \Rightarrow h_{v_3} = 2538 \text{ KJ/Kg}$.

from chart $W_3 = 11 \frac{g\,H_2O}{Kg\,air} = \cancel{0{,}011} \frac{Kg\,H_2O}{Kg\,air}$ NO

~~for the condenser.~~

~~$\dot{m}_v h_i = \dot{m}_v h_e + \dot{Q}_L$~~

~~$h_i = h_e + q_L$~~

$W_3 = 0.622 \times \frac{P_{v_3}}{P_{a_3}} = \cancel{0{,}011}$ NO

$\Rightarrow P_{a_3} = \frac{0.622}{0.011} P_{v_3} = 56.54 P_{v_3}$

and P_{v_3} = 0.7 P_{g_3}

20	2.339
21	Pv
25	3.169.

$$\frac{20-21}{20-25} = \frac{2.339-P_v}{\cancel{3.169}\ 2.339-3.169}$$

~~0.2 =~~ P_{v_3} = 2.505 Kpa

=> P_{v_3} = 1.7535 Kpa.

P_{a_3} = 99.14289 Kpa.

~~ma~~ ~~mv~~

mp