IBM VT

Carleton
UNIVERSITY

EXAMINATION

DURATION: 3 **HOURS**

No. of Students: 261

Department Name & Course Name: Mechanical and Aerospace Eng. / MAAE 2400 A & D + E

Course Instructor(s) Professor Beausoleil-Morrison / Professor Matida / Dr. Tang

AUTHORIZED MEMORANDA
Open book, standard calculator

Students **MUST** count the number of pages in this examination question paper **before** beginning to write, and report any discrepancy immediately to a proctor. This question paper has 5 pages.

This examination question paper **MAY** be taken from the examination room.

In addition to this question paper, students require:

	an examination booklet	yes X
	a Scantron sheet	no X

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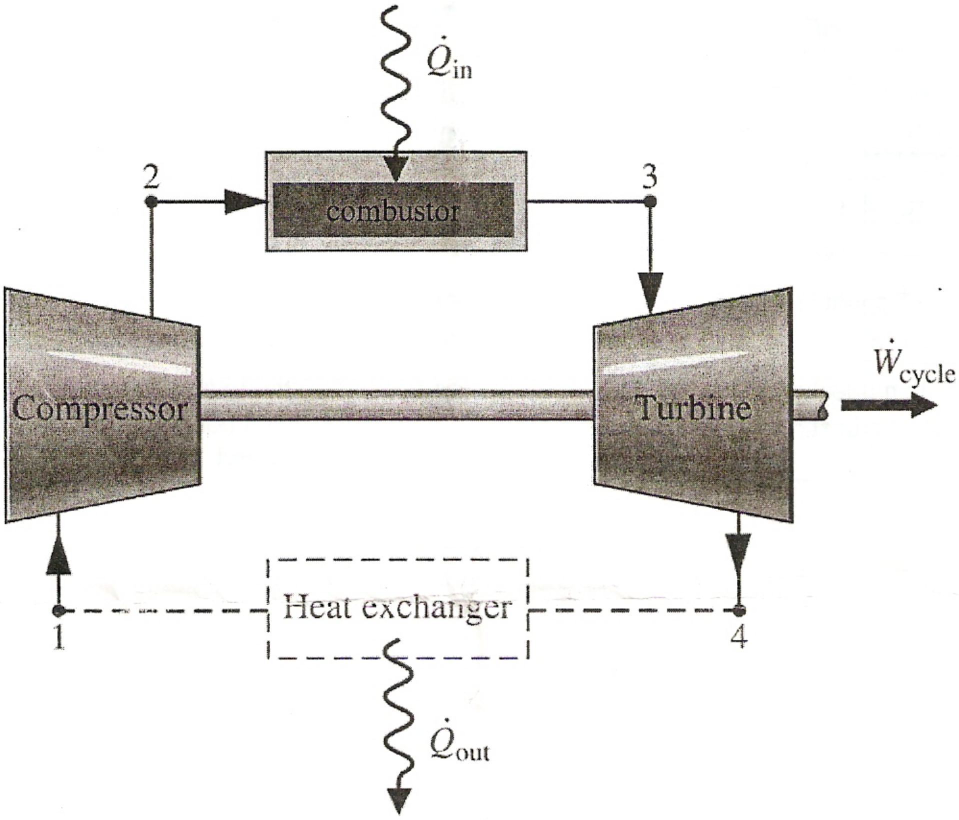
Question 1 (30 marks)

Air enters the compressor of a simple Brayton cycle at 300 K and 100 kPa and is compressed to 1.1 MPa by a compressor with an isentropic efficiency of 88%. The mass flow rate of air through the cycle is 100 kg/s. 75 MW of heat is added to the air stream at the combustor. The air is then expanded to 100 kPa by a turbine before before rejected to the ambient. The turbine's isentropic efficiency is 92%. Analyze the cycle using the air standard analysis.



Clearly list all assumptions taken in your analysis and perform the following:

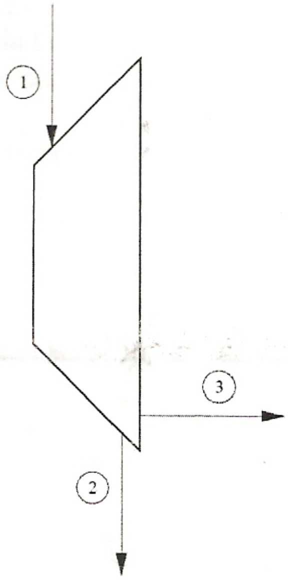
a) Indicate the state points of the cycle on a T-s diagram. (Note: follow the state point numbering scheme utilized in the above figure.)
b) Calculate the power input to the compressor in MW. 33.6MW
c) Calculate the cycle's net power output in MW. 30MW
d) Calculate the thermal efficiency of the cycle. 37.3%
e) Calculate the back work ratio. 44.8%

Question 2 (30 marks)

Steam flows steadily through the turbine illustrated below. The mass flow rate of the steam entering the turbine is 20 kg/s and the velocity at the inlet is 9 m/s (state 1). The inlet conditions of the steam are 11 MPa and 440°C.

Twenty percent of the mass flow rate of the working fluid exits the turbine at 1.5 MPa and 280°C, and a velocity of 22 m/s (state 2). The remainder of the working fluid exits the turbine at 8 kPa and 28 m/s (state 3).

The turbine is contained within an evacuated chamber (0 Pa absolute pressure). The temperature of the exterior surface of the turbine is 300°C and the turbine loses heat to the surroundings at the rate of 990 kW. The turbine produces work at the rate of 20 MW. Potential energy effects can be neglected.

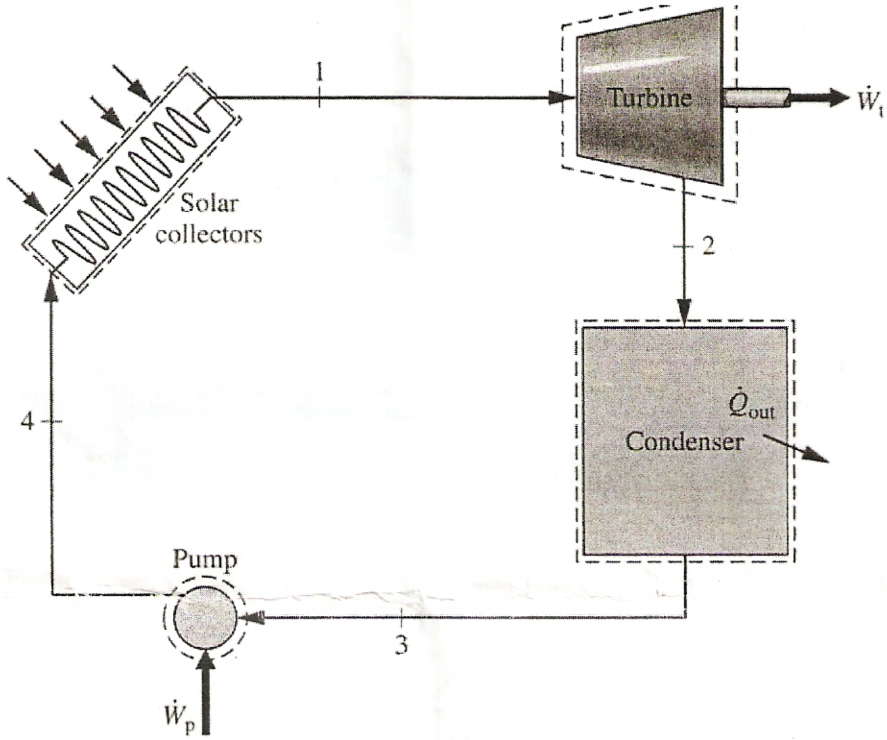


Clearly indicate all sources of data used in your analysis and clearly indicate all assumptions. Do the following:

a) Clearly indicate on a schematic the system boundary and the direction of energy transfer by work and the direction of heat transfer between the system and its surroundings.
b) Write a 1st law energy balance for the system that is consistent with the schematic drawn in Part (a). List all assumptions and cancel the unnecessary terms.
c) Determine the enthalpy at state 1 in kJ/kg. 3195.95
d) Determine the enthalpy at state 2 in kJ/kg. 2992.7
e) Determine the enthalpy at state 3 in kJ/kg. 1548.8
f) Determine the quality at state 3. 0.614
g) Determine the temperature at state 3. 41.51°C
h) Sketch the process on a T-v diagram. Clearly indicate states 1, 2, and 3 on the diagram.
i) Calculate the rate of entropy production (kW/K) within the turbine and prove that the process is possible. $-12.82 \frac{kW}{K}$
j) What is the mode of heat transfer from the turbine to the surroundings.

Question 3 (25 marks)

A solar-thermal power plant that operates on a Rankine cycle with Refrigerant 134a as its working fluid is illustrated below. The power plant generates a net power of 1 kW. The rate of energy input from the solar collectors to the working fluid is 600 W per m^2 of solar collector surface area. The steady-state operating data for the power plant is given in the table below the figure.



State	p (bar)	h (kJ/kg)	x
1	18	276.83	1
2	7	261.01	0.9952
3	7	86.78	0
4	18	87.93	—

Perform the following:

a) Indicate the state points of the cycle on a T-s diagram. Clearly indicate the 7 bar and 18 bar isobars (lines of constant pressure). You must follow the state point numbering scheme utilized in the above figure.

b) Determine the saturation temperatures of the working fluid at the solar-collector pressure and at the condenser pressure. Indicate these on the T-s diagram. $T_1 = 62.91°C$, $T_2 = 26.72°C$

c) Calculate the mass flow rate of Refrigerant 134a. 0.0682

d) Calculate the required surface area of the solar collector in m^2. 2.15 m^2

e) Calculate the power input to the pump in W. 0.0798 kW

f) Calculate the power output from the turbine in W. 1.08 kW

g) Calculate the back work ratio. 7.4%

h) Calculate the thermal efficiency of the cycle. 7.78%

Question 4 (15 marks)

You are asked to design the refrigeration cycle for a food freezer with the following constraints:

- The design is to be based upon a simple vapour compression cycle employing 1 compressor, 1 expansion valve, 1 evaporator, and 1 condenser.
- The compressor is isentropic.
- The working fluid is ammonia.
- The freezer must maintain the frozen food at a temperature of -18°C.
- The freezer's condenser rejects heat to a room that is 28°C.
- The maximum permissible temperature of the ammonia is 115°C.

Perform the following:

a) Sketch a schematic of the vapour compression cycle and label the state points.
b) What is the maximum possible evaporator pressure? (Limit your selection to the pressures listed in the ammonia tables.) 2.07[illegible] bar
c) What is the minimum possible condenser pressure? (Limit your selection to the pressures listed in the ammonia tables.) 10.993 bar
d) Indicate the location of the state points on a T-s diagram. Indicate the isobars corresponding to the evaporator and condenser pressures. Indicate the isotherms representing the food and room temperatures.