16.050 Thermal Energy

Quiz #2 – Fall 2002
Date: 11/22/02

Do all three problems. All problems count the same.

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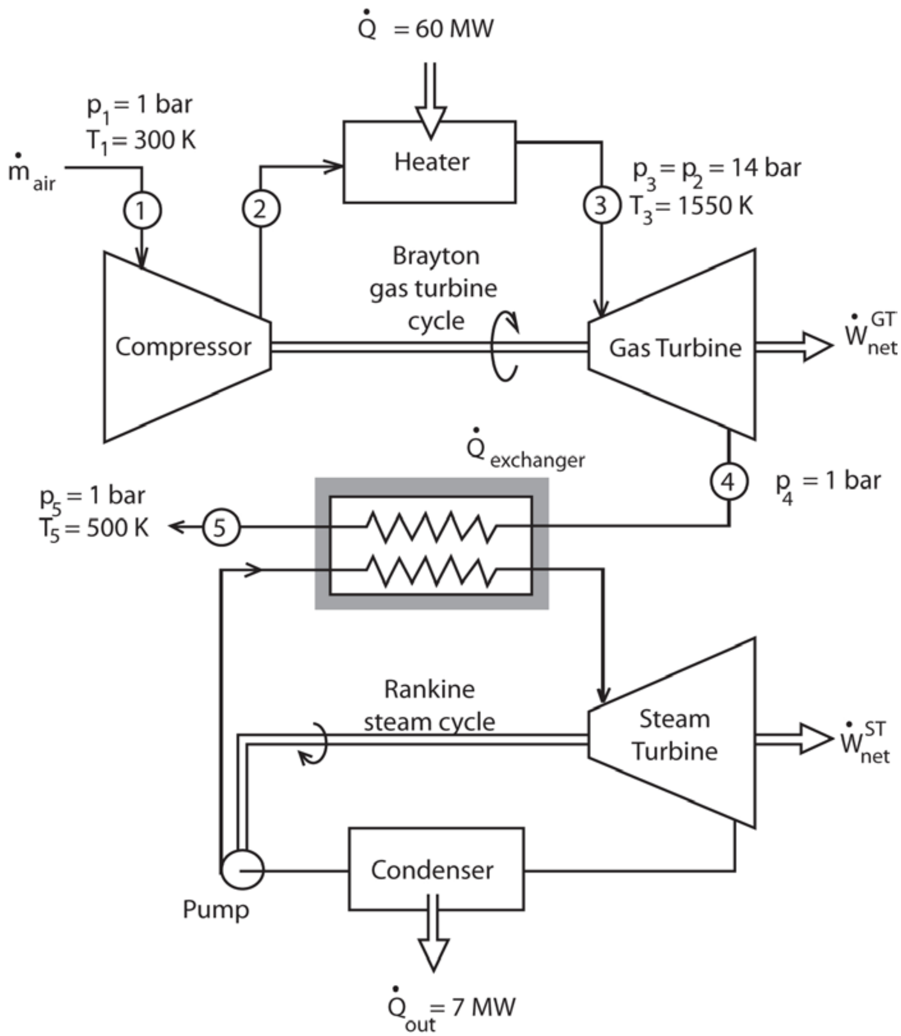
1. The power plant shown in the figure below combines a Brayton cycle and a Rankine cycle. All components are ideal, kinetic energy effects can be neglected and air can be assumed a perfect gas with cp=1 kJ/kgK.



a) Determine the compressor exit temperature T_2.

b) Find the air mass flow rate $\dot{m}_{air}$ of the ideal Brayton cycle.

c) Determine the turbine exit temperature T_4.

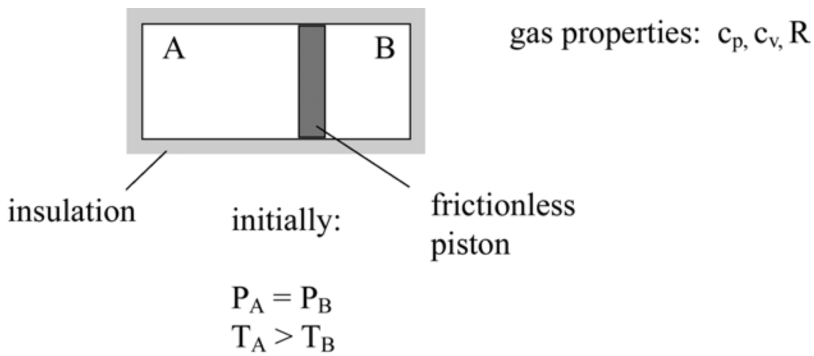
d) What is the ***net*** power output of the ideal Brayton cycle $\dot{W}_{net}^{GT}$?

e) How much heat $\dot{Q}_{exchanger}$ is transferred in the heat exchanger?

f) What is the ***net*** power output of the Rankine cycle $\dot{W}_{net}^{ST}$?

g) What is the overall thermal efficiency of the combined cycle?

2. The sketch below shows a perfectly insulated container with two compartments separated by a non-adiabatic, frictionless piston. Both compartments are at the same pressure ($p_A = p_B$) and contain an equal amount of the same gas ($m_A = m_B$). Initially compartment A is at a higher temperature than compartment B ($T_A > T_B$).



a) Which way, if at all, does the piston move? Indicate by an arrow on a drawing in your exam book (A sentence or two is expected, perhaps bolstered by some equations).

b) Is the final internal energy U_{final} of the system (both compartments together) lower, equal or higher than the initial internal energy $U_{initial}$ of the system? Why? (A sentence or two is expected, perhaps bolstered by some equations.)

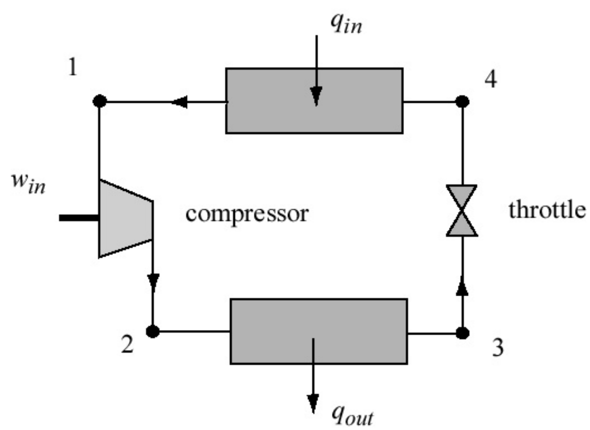
c) What is the final temperature of the system T_{final} expressed in terms of T_A and T_B?

d) What is the change in entropy of compartment A? What is the change in entropy of compartment B?

e) What is the change in entropy of the surroundings?

f) Is this process reversible or irreversible? How do you know? (***Note:*** *you do not have to prove your answer mathematically to get full credit. Explain in a sentence how you know whether the process is reversible or irreversible*)

3. A refrigerator using refrigerant R12 (see attached tables for properties) operates between pressures p_1 = 1.6 bar and p_2 = 6 bar. The refrigeration cycle consists of four processes as sketched in the figure below. The refrigerant is compressed ideally from a saturated vapor at station 1 to a superheated gas at station 2, cooled in a heat exchanger from superheated gas to a saturated liquid at station 3, and expanded through a throttle from saturated liquid to the lower pressure p1 at station 4. From 4 to 1 the liquid-vapor mixture absorbs heat from the surroundings through another heat exchanger. Kinetic energy effects can be neglected.



a) Explain how the states change across the throttle (do not give numbers, explain your reasoning in a sentence or two).

b) Sketch the refrigeration cycle in an h-s diagram and label the states.

c) What is the work input required to drive the compressor per kg of refrigerant?

d) How much heat is removed from the surroundings per kg of refrigerant?

e) What is the coefficient of performance for the refrigerator?

Properties of Saturated R12 (Liquid-Vapor)

		Specific Volume m^3/kg		Internal Energy kJ/kg		Enthalpy kJ/kg		Entropy kJ/kgK	
Press., bars	Temp., C	Sat. Liquid *vf**10^3	Sat. Vapor *vg*	Sat. Liquid *uf*	Sat. Vapor *ug*	Sat. Liquid *hf*	Sat. Vapor *hg*	Sat. Liquid *sf*	Sat. Vapor *sg*
1.2	-25	0.6786	0.13117	13.25	160.26	13.33	176.48	0.0552	0.7126
1.4	-22	0.6827	0.11717	15.92	161.48	16.02	177.83	0.0660	0.7103
1.6	-18	0.6883	0.10124	19.51	163.12	19.62	179.63	0.0802	0.7068
1.8	-15	0.6926	0.09102	22.20	164.35	22.33	180.97	0.0906	0.7051
2.2	-10	0.7000	0.07665	26.72	166.39	26.87	183.19	0.1080	0.7019
2.6	-5	0.7078	0.06496	31.27	168.42	31.45	185.37	0.1251	0.6991
3.0	0	0.7159	0.05539	35.83	170.44	36.05	187.53	0.1420	0.6965
3.5	4	0.7227	0.04895	39.51	172.04	39.76	189.23	0.1553	0.6946
4.0	8	0.7297	0.04340	43.21	173.63	43.50	190.91	0.1686	0.6929
4.5	12	0.7370	0.03860	46.93	175.20	47.26	192.56	0.1817	0.6913
5.0	16	0.7446	0.03442	50.67	176.78	51.05	194.19	0.1948	0.6898
5.5	20	0.7525	0.03078	54.44	178.32	54.87	195.78	0.2078	0.6884
6.0	24	0.7607	0.02759	58.25	179.85	58.73	197.34	0.2207	0.6871
6.5	26	0.7650	0.02614	60.17	180.61	60.68	198.11	0.2335	0.6859
7.0	28	0.7694	0.02478	62.09	181.36	62.63	198.87	0.2335	0.6859
7.5	30	0.7739	0.02351	64.01	182.11	64.59	199.62	0.2400	0.6853

Superheated Properties of R12

Refer to:
Moran & Shapiro, *Fundamentals of Engineering Thermodynamics*, 2nd Ed. John Wiley and Sons. pp.708, Table A-9.