Masdar Institute of Science & Technology

UCC501 – Sustainable Energy

Fall 2014

Homework # 1

Release Date: September 15th 2014 Submission Date: September 29th 2014

Topics: Thermodynamics

Type: Individual

Remember to state clearly all the assumptions you make in addition to the ones specified in the assignment.

Question 1 (30 points)

A modern jet engine has a temperature after combustion of about 1500 K at 3200 kPa and h=1635.8 kJ/kg as it enters the turbine section (see state 3, Fig. 1). The compressor inlet is at 80 kPa, 260 K, h=260.32 kJ/kg (state 1) and the outlet (state 2) is at 3300 kPa, 780 K; h=800.28 kJ/kg the turbine outlet (state 4) into the nozzle is at 400 kPa, 900 K, h=933.15 kJ/kg and the nozzle exit (state 5) is at 80 kPa, 640 K, 649.53 kJ/kg. Neglect any heat transfer and neglect kinetic energy except out of the nozzle. Find the compressor and turbine specific work terms and the nozzle exit velocity. If the turbine specific work is completely used to drive the compressor, what is the turbine outlet enthalpy? And what is the jet engine efficiency?

Hint: the jet engine is driven by the thrust force due to the nozzle exit velocity.

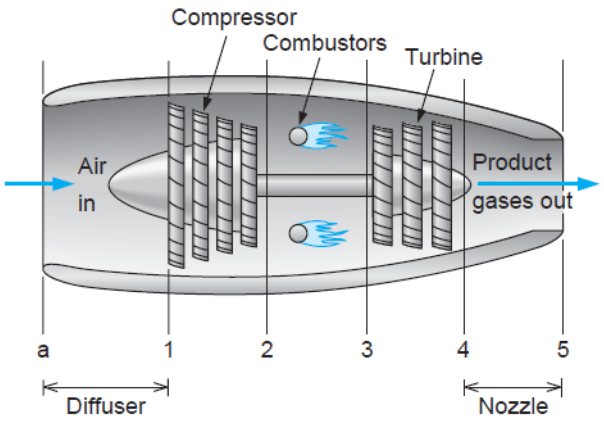

Figure 1

Question 2 (20 points)

An R-410a heat pump cycle shown in Fig. 2 has an R-410a flow rate of 0.05 kg/s with 5 kW into the compressor. The following data are given:

State	1	2	3	4	5	6
P, kPa	3100	3050	3000	420	400	390
T, °C	120	110	45		−10	−5
h, kJ/kg	377	367	134	—	280	284

Calculate the heat transfer from the compressor, the heat transfer from the R-410a in the condenser, and the heat transfer to the R-410a in the evaporator. What is the COP of the heat pump?

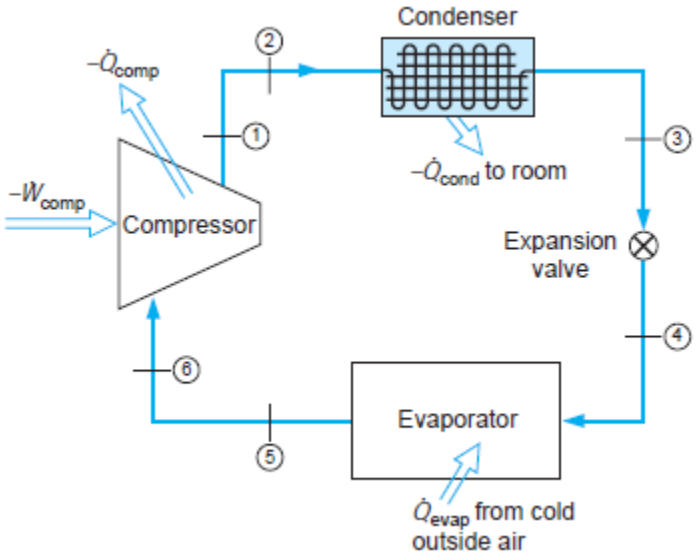

Figure 2

Question 3 (30 points)

A steam engine based on a turbine is shown in Fig. 3. The boiler tank has a volume of 100 L and initially contains saturated liquid with a very small amount of vapor at 100 kPa (v = 0.001043, u = 417.36 kJ/kg). Heat is now added by the burner. The pressure regulator, which keeps the pressure constant, does not open before the boiler pressure reaches 700 kPa. The saturated vapor enters the turbine at 700 kPa (v_g = 0.2729, u_g = 2572.5 kJ/kg, h_g = 2763.5 kJ/kg) and is discharged to the atmosphere as saturated vapor at 100 kPa (h_g = 2675.5 kJ/kg). The burner is turned off when no more liquid is present in the boiler. Find the total turbine work and the total heat transfer to the boiler for this process.

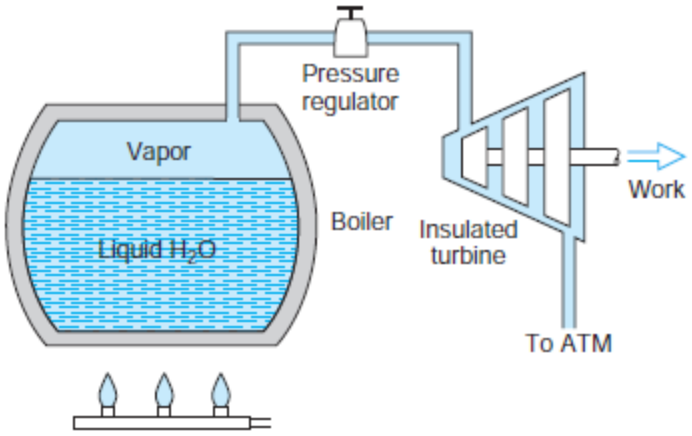

Figure 3

Question 4 (10 points)

A cyclic machine, shown in Fig. 4, receives 325 kJ from a 1000 K energy reservoir. It rejects 125 kJ to a 400 K energy reservoir, and the cycle produces 200 kJ of work as output. Is this cycle reversible, irreversible, or impossible?

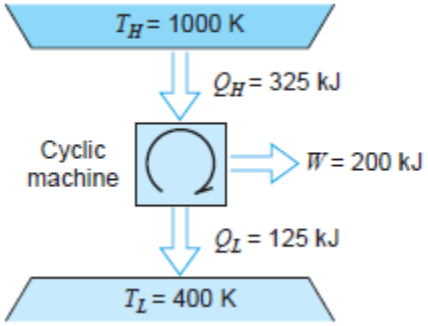

Figure 4

Question 5 (10 points)

A computer CPU chip consists of 50 g silicon, 20 g copper, and 50 g polyvinyl chloride (plastic). It now heats up from 15◦C to 70◦C as the computer is turned on. How much did the entropy increase?

Hint: use the entropy change for solids, three solids are involved, find the specific heat for each one.