Kafrelsheikh University	Semester: 1st Semester
Mechanical Engineering	Final Examination
Dept. Mechanical Engineering	Date: Dec 31th, 2018
Year: 2nd Year	Time allowed: 3 hour
Instructor: Assoc. Prof. Maher	Full Mark: 100

Subject: Thermodynamics II (MEP2014)

Questions and Answers Booklet

(a) This exam measures ILOs no.: a13.1, a13.2, a13.3, a13.4, a14.1, a14.2, a14.4, b2.1& b2.2.
(b) **No. of questions: 6 - No. of pages: 13** (three of them are blank, i.e. pages 7/13, 9/13, and 13/13).
(c) This is a close book exam. Only Thermodynamics tables and Charts (with students) are allowed.
(d) Clear, systematic answers and solutions are required. In general, marks will not be assigned for answers and solutions that require unreasonable (in the opinion of the instructor) effort to decipher.
(e) Ask for clarification if any question statement is not clear to you.
(f) **Answer only one question from questions# 4 and 5. If you answered both questions, the lowest marks will be considered only.**
(g) The weight of each problem is indicated.
(h) The exam will be marked out of 100. There are 44 extra marks.

Question 1 (43 Marks) **Note that:** $\eta_{\text{th, Otto}} = 1 - 1/r^{k-1}$, $\eta_{\text{th, Diesel}} = 1 - \frac{1}{r^{k-1}}\left[\frac{r_c^k - 1}{k(r_c - 1)}\right]$, $\eta_{\text{th, Brayton}} = 1 - \frac{1}{r_p^{(k-1)/k}}$

(A) Select the correct answer. Justify (prove) your answer by calculations or sketch or both when it is possible (38 Marks)

1) A unit mass of an ideal gas at temperature T undergoes a reversible isothermal process from pressure P_1 to pressure P_2 while **gaining** heat from the surroundings at temperature T in the amount of q. If the gas constant of the gas is R, the entropy change of the gas Δs during this process is **(2 Marks)**
   - (a) $s_{gen} = R\ln(p_2/p_1)$
   - (b) $s_{gen} = R\ln(p_2/p_1) - q/T$
   - (c) $s_{gen} = R\ln(p_1/p_2)$
   - (d) $s_{gen} = R\ln(p_1/p_2) - q/T$
   - (e) $s_{gen} = 0$
   - (f) None of the above

2) A unit mass of an ideal gas at temperature T undergoes a reversible isothermal process from pressure p_1 to pressure p_2 while **losing** heat to the surroundings at temperature T in the amount of q. If the gas constant of the gas is R, the entropy generation of the gas s_{gen} during this process **(2 Mark)**
   - (g) $s_{gen} = R\ln(p_2/p_1)$
   - (h) $s_{gen} = R\ln(p_2/p_1) - q/T$
   - (i) $s_{gen} = R\ln(p_1/p_2)$
   - (j) $s_{gen} = R\ln(p_1/p_2) + q/T$
   - (k) $s_{gen} = 0$

3. Air at 15°C is compressed steadily and isothermally from 100 kPa to 700 kPa at a rate of 0.12 kg/s. The minimum power input to the compressor is **(4 Marks)**
   (*a*) 1.0 kW
   (*b*) 11.2 kW
   (*c*) 25.8 kW
   (*d*) 19.3 kW
   (*e*) 161 kW
4. For a reversible adiabatic process, the change in entropy is **(½ Mark)**
   (a) zero
   (b) minimum
   (c) maximum
   (d) infinite
   (e) unity.

5. The property of a working substance which increases or decreases as the heat is supplied or removed in a reversible manner is known as **(1 Marks)**
   (a) enthalpy
   (b) internal energy
   (c) entropy
   (d) external energy.

6. The change of entropy of a gas process due to environment, when heat is gained by the gas is **(½ Mark)**
   (a) positive
   (b) negative
   (c) positive or negative.

7. Entropy generation for any irreversible process is always **(½ Mark)**
   (a) positive
   (b) negative
   (c) zero
   (d) zero or negative

8. Thermal efficiency of closed cycle gas turbine plant increases by **(1 Mark)**
   (a) reheating
   (b) intercooling
   (c) regenerator
   (d) all of the above.

9. An Otto cycle with air as the working fluid has a compression ratio of 6.2. Under cold air standard conditions, the thermal efficiency of this cycle is **(1 Mark)**
   (a) 12%
   (b) 43%
   (c) 52%
   (d) 57%
   (e) 75%

10. Air in an ideal Diesel cycle is compressed from 2.8 L to 0.2 L, and then it expands during the constant pressure heat addition process to 0.30 L. Under cold air standard conditions, the thermal efficiency of this cycle is nearest to **(3 Marks)**
   (a) 32%
   (b) 43%
   (c) 62%
   (d) 65%
   (e) 73%

11. In an ideal Otto cycle, air of 1.2 kg/m^3 is compressed from 2 L to 0.25 L, and the net work output of the cycle is 600 kJ/kg. The mean effective pressure (MEP) for this cycle is **(2 Marks)**
    (a) 667 kPa
    (b) 738 kPa
    (c) 823 kPa
    (d) 850 kPa

12. An ideal Brayton cycle has a net work output of 250 kJ/kg and a backwork ratio of 0.62. If both the turbine and the compressor had an isentropic efficiency of 90%, the net work output of the cycle would be **(3 Marks)**
    (a) 79 kJ/kg
    (b) 139 kJ/kg
    (c) 182 kJ/kg
    (d) 293 kJ/kg
    (e) 379 kJ/kg

13. In an ideal Brayton cycle with regeneration, air is compressed from 100 kPa and 15°C to 600 kPa and 220°C, is heated to 500 °C in the regenerator, and then further heated to 1200 °C before entering the turbine. Under cold air standard conditions, the effectiveness of the regenerator is **(2 Marks)**
    (a) 26%
    (b) 42%
    (c) 65%
    (d) 57%
    (e) 72%

14. Consider a simple ideal Rankine cycle with fixed boiler and condenser pressures and turbine inlet temperature. If the cycle is modified with ideal regeneration that involves one closed feed water heater, (select the correct statement per unit mass of steam flowing through the boiler) **(1 Mark)**
    (a) the turbine work output will increase.
    (b) the amount of heat rejected will increase.
    (c) the cycle thermal efficiency will decrease.
    (d) the quality of steam at turbine exit will decrease.
    (e) the amount of heat input will decrease.

15. Consider a simple ideal Rankine cycle with fixed boiler and condenser pressures and turbine inlet temperature. If the cycle is modified with ideal reheating, (select the correct statement)
    (a) the turbine work output will decrease. **(1 Mark)**
    (b) the amount of heat rejected will increase.
    (c) the pump work input will decrease.
    (d) the moisture content at turbine exit will increase.
    (e) the amount of heat input will decrease.

16. Consider a simple ideal Rankine cycle with a fixed condenser pressure. If the boiler pressure is raised while the turbine inlet temperature is held constant, (select the correct statement) **(1 Mark)**
    (a) the turbine work output will decrease.
    (b) the amount of heat rejected will increase.
    (c) the cycle efficiency will decrease.
    (d) the moisture content at turbine exit will increase.
    (e) the pump work input will decrease.

17. Consider a simple ideal Rankine cycle. If the condenser pressure is raised while keeping turbine inlet state the same, (select the correct statement) **(1 Mark)**
   (a) the turbine work output will increase.
   (b) the amount of heat rejected will decrease.
   (c) the cycle efficiency will decrease.
   (d) the moisture content at turbine exit will increase.
   (e) the pump work input will increase.

18. Consider a simple ideal Rankine cycle with fixed boiler and condenser pressures. If the steam is superheated to a higher temperature, (select the correct statement) **(1 Mark)**
   (a) the turbine work output will decrease.
   (b) the amount of heat rejected will decrease.
   (c) the cycle efficiency will decrease.
   (d) the moisture content at turbine exit will increase.
   (e) the amount of heat input will increase.

19. Consider a simple ideal Rankine cycle with fixed turbine inlet temperature and condenser pressure. What is the effect of increasing the boiler pressure on **(3 Mark)**

Pump work input:	(*a*) increases, (*b*) decreases, (*c*) remains the same
Turbine work output:	(*a*) increases, (*b*) decreases, (*c*) remains the same
Heat supplied:	(*a*) increases, (*b*) decreases, (*c*) remains the same
Heat rejected:	(*a*) increases, (*b*) decreases, (*c*) remains the same
Cycle efficiency:	(*a*) increases, (*b*) decreases, (*c*) remains the same
Moisture content at turbine exit:	(*a*) increases, (*b*) decreases, (*c*) remains the same

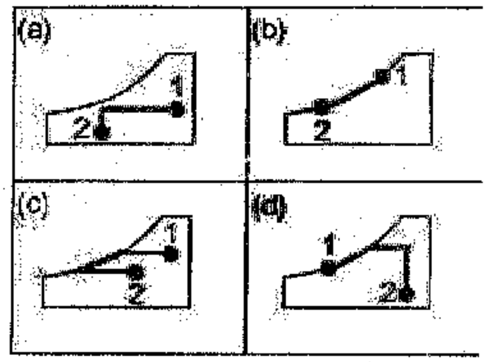
20. An ideal gas mixture consists of 1 kmol of N_2 and 4 kmol of CO_2. The gas constant of the mixture is **(2 Marks)**
   (a) 0.121 kJ/kg.K
   (b) 0.204 kJ/kg.K
   (c) 0.244 kJ/kg.K
   (d) 0.475 kJ/kg.K
   (e) 1.120 kJ/kg.K

21. An ideal gas mixture consists of 3 kmol of CO_2 and 7 kmol of N_2. The mass fraction of CO_2 in the mixture is **(2 Marks)**
   (a) 0.214
   (b) 0.402
   (c) 0.500
   (d) 0.652
   (e) 0.786

22. A rigid tank is divided into two compartments by a partition. One compartment contains 4 kmol of N_2 at 500 kPa pressure and the other compartment contains 6 kmol of CO_2 at 200 kPa. Now the partition is removed, and the two gases form a homogeneous mixture at 300 kPa. The partial pressure of N_2 in the mixture is **(2 Marks)**
   (a) 41 kPa
   (b) 60 kPa
   (c) 120 kPa
   (d) 150 kPa
   (e) 225 kPa

23. Humid air is cooled, dehumidified, and heated in an isobaric process. Which one of the psychometric charts below correctly depicts these processes? **(1½ Mark)**

(a) a
(b) b
(c) c
(d) d



(B)Show by sketch that multi-stages (i.e. two stages) compressi n with intercooling needs power less than a single stage compression. **(5 Marks)**

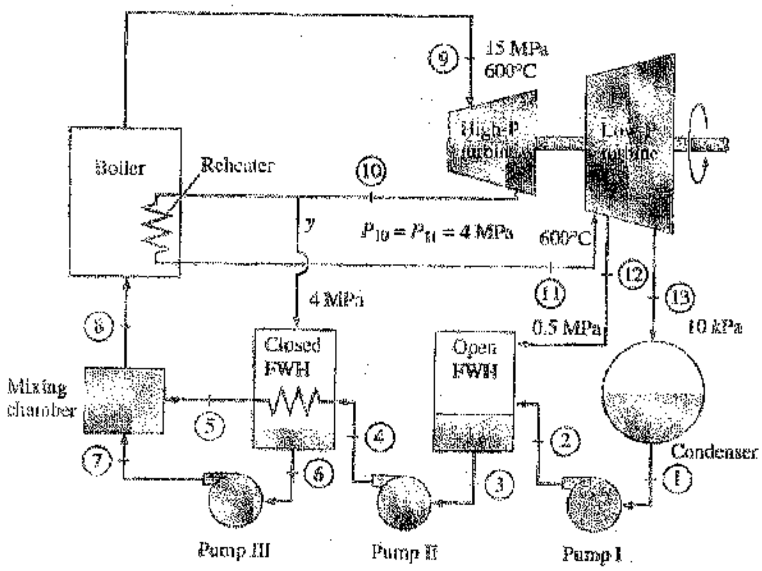
Question #2 (39 Marks)

Consider a 50 MW steam power plant that operates on an ideal reheat–regenerative Rankine cycle with one open feedwater heater, one closed feedwater heater, and one reheater. Steam enters the turbine at 15 MPa and 600°C and is condensed in the condenser at a pressure of 10 kPa. Some steam is extracted from the turbine at 4 MPa for the closed feedwater heater, and the remaining steam is reheated at the same pressure to 600°C. The extracted steam is completely condensed in the heater and is pumped to 15 MPa before it mixes with the feedwater at the same pressure. Steam for the open feedwater heater is extracted from the low-pressure turbine at a pressure of
0.5 MPa. Determine the fractions of steam extracted from the turbine as well as the thermal efficiency of the cycle.

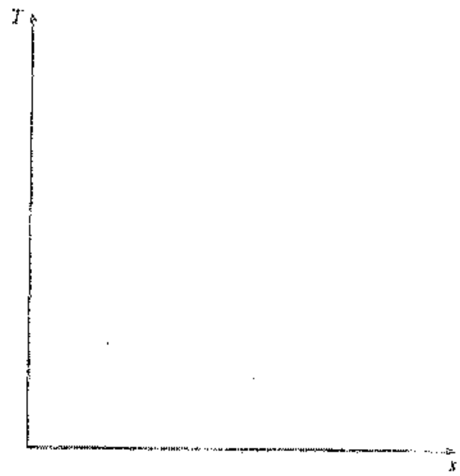
(a) Sketch T-s diagram for this cycle showing on it mass balance through the cycle. **(4Marks)**
(b) Enthalpy at each state on the schematic/T-s diagram **(12 Marks)**
(c) Determine the following:
  1) fractions of steam extracted from the turbine, **(4 Marks)**

2) heat supplied in the boiler and reheater in kJ/kg (4 Marks)
3) work of each turbine and each pump (5 Marks)
4) cycle efficiency, and (2 Marks)
5) mass flow rate of steam in boiler (kg/s) (2Marks)
6) rate of entropy generation during this cycle if the heat addition in the boiler and reheater is from a furnace of 1500 K ad heat removed from the condenser to a river of 15°C (5Marks)

Solution



Schematic diagram of question #2



T-s diagram of question #2

Question 3 (27) Marks

Air enters a gas turbine with two stages of compression and two stages of expansion at 100 kPa and 17°C. The first stage turbine is used only to derive the compressors. This system uses a regenerator as well as reheating and intercooling. The pressure ratio across each compressor is 4. A 400 kJ/kg of heat are added to the air in each combustion chamber; and the regenerator is increasing the temperature of air by 10°C.
Assume isentropic operations for all compressor and the turbine stages and use constant specific heats at room temperature.

(a) Sketch the schematic and T-s diagram of this cycle **(8 Marks)**
(b) Where the maximum temperature occurs and its value? **(8 Marks)**
(c) What is the back work ratio? **(3 Marks)**
(d) What is the effectiveness of the regenerator **(2 Marks)**
(e) What is the cycle thermal efficiency? **(2 Marks)**
(f) prove if the cycle is possible from view of 1st and 2nd laws of thermodynamics if the heat added to the engine at 2800K and rejected at 300K **(4 Marks)**

Solution

Schematic diagram of question #3

T-s diagram of question #3

Question 4 (15 Marks)

An insulated rigid tank is divided into two compartments by a partition, One compartment contains 8 kg of oxygen gas at 40°C and 100 kPa, and the other compartment contains 5 kg of nitrogen gas at 20°C and 150 kPa. Now the partition is removed, and the two gases are allowed to mix. Determine:

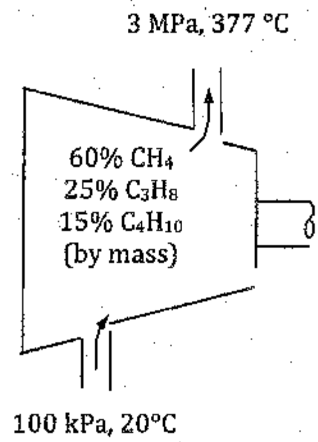
(a) the mixture temperature **(4 Marks)**

(b) the mixture pressure after equilibrium has been established **(11 Marks)**

Solution

Question 5 (15 Marks)

A mixture of hydrocarbon gases is composed of 60 percent methane, 25 percent propane, and 15 percent butane by mass. The mixture is compressed from 100 kPa and 20 °C to 3 MPa and 377 °C by an adiabatic compressor. Assuming constant specific heats at room temperature for all hydrocarbons gases, determine:



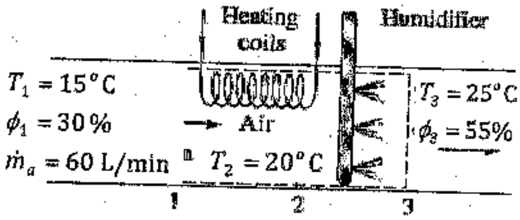
(a) the specific work required for the compressor. **(5 Marks)**

(b) the compressor isentropic efficiency **(5 Marks)**

(c) entropy generation. **(5 Marks)**

Question 6 (20 Marks)

An air-conditioning system is to take in outdoor air at 10°C and 30 percent relative humidity at a steady rate of moist air 60 L/min and to condition it to 25°C and 55 percent relative humidity. The outdoor air is first heated to 20°C in the heating section and then humidified by the injection of hot steam in the humidifying section. Assuming the entire process takes place at a pressure of 100 kPa.



(a) Sketch these processes on the psychrometric chart. **(4 Marks)**

(b) (ii) Determine the rate of heat supply in the heating section **(7 Marks)**

(c) (iii) Determine the mass flow rate of the steam required in the humidifying section. **(3 Marks)**

(d) (iv) Dew point at each state of the air **(6 Marks)**

Solution: