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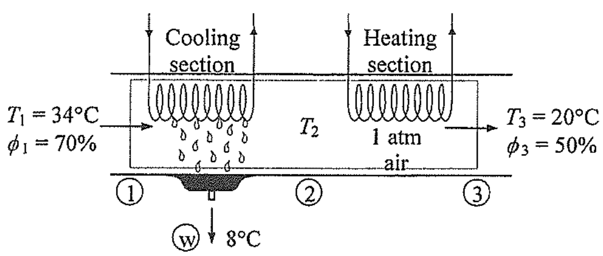
**Question 6 (17) Marks**

An air-conditioning system is to take in air at 1 atm, 34°C, and 70 percent relative humidity and deliver it at 20°C and 50 percent relative humidity. The air flows first over the cooling coils, where it is cooled and dehumidified, and then over the resistance heating wires, where it is heated to the desired temperature. Assuming that the condensate is removed from the cooling section at 8°C, determine:

1. (ii) The temperature of air before it enters the heating section. **(7 Marks)**
2. (iii) The amount of heat removed in the cooling section. **(4 Marks)**
3. (iv) The amount of heat transferred in the heating section, both in kJ/kg dry air. **(2 Marks)**
4. Exergy at inlet and exit of the air conditioning system **(4 Marks)**




**Solution:**

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**Question 5 (15) Marks**

A mixture of ideal gases consists of 4 kg of nitrogen and 6 kg of carbon dioxide at a pressure of 4 bar and a temperature of 20°C. Find :

(a) The mole fraction of each constituent, **(2 Marks)**
(b) The equivalent molecular weight of the mixture, **(1 Mark)**
(c) The equivalent gas constant of the mixture, **(1 Mark)**
(d) The partial pressures and partial volumes, **(2 Marks)**
(e) The volume and density of the mixture, and **(2 Marks)**
(f) The $c_p$ and $c_v$ of the mixture. **(2 Marks)**

If the mixture is heated at constant volume to 50°C, find the changes in internal energy, enthalpy, and entropy of the mixture if the heating is done at constant pressure.

Take $k$ : for $CO_2$ = 1.286 and for $N_2$ = 1.4. **(5 Marks)**

**Solution**

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## Question 4 (30) Marks

A 5400 kW gas turbine generating set operates with two compressor stages, the overall pressure ratio is 9 : 1. A high pressure turbine is used to drive the compressors and a low-pressure turbine drives the generator. The temperature of the gases at entry to the high pressure turbine is 625°C and the gases are reheated to 625°C after expansion in the first turbine. The exhaust gases leaving the low-pressure turbine are passed through a heat exchanger to heat the air leaving the high pressure stage compressor (Regenerator). The compressors have equal pressure ratios and intercooling is complete between the stages. The air inlet temperature to the unit is 20°C. The isentropic efficiency of each compressor stage is 0.8, and the isentropic efficiency of each turbine stage is 0.85, the heat exchanger (regenerator) effectiveness is 0.8.

Neglecting all pressure losses and changes in kinetic energy calculate:

i. Sketch flow diagram and T-s diagram **(10 Marks)**
ii. The thermal efficiency **(12 Marks)**
iii. Back Work Ratio (BWR) of the plant **(2 Marks)**
iv. The mass flow in kg/s. **(1 Mark)**
v. Exergy destruction through the regenerator **(5 Marks)**

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## Solution


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## Question 2 (38 Marks)

Consider a 100 MW regenerative vapor power cycle with two feedwater heaters (i.e. a closed one and an open one) and a reheat. Steam enters the first turbine stage at 12 MPa. 480°C, and expands to 2 MPa. Some steam is extracted at 2 MPa and fed to the closed feedwater heater. The remainder is reheated at 2 MPa to 440°C and then expands through the second-stage turbine to 0.3 MPa, where an additional amount is extracted and fed into the open feedwater heater operating at 0.3 MPa. The steam expanding through the third-stage turbine exits at the condenser pressure of 10 kPa. Feedwater leave the closed heater at 210°C, 12 MPa, and condensate existing as saturated liquid at 2 MPa is trapped into the open feedwater heater. Saturated liquid at 0.3 MPa leaves the open feedwater heater. Assume all pumps and turbine stages operate isentropically.

1. Draw schematically the flow diagram and T-s diagram for this cycle. **(12 Mark)**
2. Determine for this cycle:
   - (a) The thermal efficiency **(14 Marks)**
   - (b) The mass flow rate of steam entering the first turbine, CFWH, and OFWH, in ton/hr. **(5 Marks)**
   - (c) The rate of heat transfer from the working fluid in the condenser to the cooling water per kg of steam entering the fist-stage turbine **(2 Marks)**
   - (d) Exergy distortion during this cycle if heat addition and rejection are done from/to heat source/sink at 1000K and 300 K, respectively. **(5 Marks)**

## Solution

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**27.** Air is cooled and dehumidified as it flows over the coils of a refrigeration system at 85 kPa from 30°C and a humidity ratio of 0.023 kg/kg dry air to 15°C and a humidity ratio of 0.015 kg/kg dry air. If the mass flow rate of dry air is 0.7 kg/s, the rate of heat removal from the air is **(2 Marks)**

(*a*) 5 kJ/s
(*b*) 10 kJ/s
(*c*) 15 kJ/s
(*d*) 20 kJ/s
(*e*) 25 kJ/s

**28.** Air at a total pressure of 90 kPa, 15°C, and 75 percent relative humidity is heated and humidified to 25°C and 75 percent relative humidity by introducing water vapor. If the mass flow rate of dry air is 4 kg/s, the rate at which steam is added to the air is **(3 Marks)**

(*a*) 0.032 kg/s
(*b*) 0.013 kg/s
(*c*) 0.019 kg/s
(*d*) 0.0079 kg/s
(*e*) 0 kg/s

**29.** An ideal-gas mixture whose apparent molar mass is 36 kg/kmol consists of $N_2$ and three other gases. If the mole fraction of nitrogen is 0.30, its mass fraction is **(1 Mark)**

(*a*) 0.15
(*b*) 0.23
(*c*) 0.30
(*d*) 0.39
(*e*) 0.70

**29.** An ideal-gas mixture consists of 2 kmol of N2 and 4 kmol of CO2. The apparent gas constant of the mixture is **(2 Marks)**

(*a*) 0.215 kJ/kg.K
(*b*) 0.225 kJ/kg.K
(*c*) 0.243 kJ/kg.K
(*d*) 0.875 kJ/kg.K
(*e*) 1.24 kJ/kg.K

**b. State the reason(s) (4 Marks)**

1. Intercooling in multistage compression decreases the compression work

2. Rehaeting in multistage expansion increases the expansion work

3. Diesel cycle efficiency is higher that Otto cycle efficiency

4. Excessive moisture in steam is not desirable in steam turbines

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19. Mole fraction of a component of gas mixture is equal to **(1 Mark)**

(*a*) $1/f$ (*b*) $f^2$
(*c*) $f$ (*d*) $f/p$

where, $f$ = Volume fraction, and
$p$ = Pressure of the mixture.

21. In a gaseous mixture the specific volume of each component is given by **(1 Mark)**

(*a*) $V/m$ (*b*) $V_i/m_i$
(*c*) $V/m_i$ (*d*) none of the above.

where, $V$ = Volume of the mixture,
$V_i$ = Volume of the *i*th component,
$m$ = Mass of mixture, and
$m_i$ = Mass of the *i*th component.

22. In an ideal gas the partial pressure of a component is **(1 Mark)**

(*a*) inversely proportional to the square of the mole fraction
(*b*) directly proportional to the mole fraction
(*c*) inversely proportional to the mole fraction
(*d*) equal to the mole fraction.

23. A room contains 50 kg of dry air and 0.6 kg of water vapor at 25°C and 95 kPa total `pressures. The relative humidity of air in the room is **(2 Marks)**

(*a*) 1.2%
(*b*) 18.4%
(*c*) 56.7%
(*d*) 65.2%
(*e*) 78.0%

24. A 40-m³ room contains air at 30°C and a total pressure of 90 kPa with a relative humidity of 75 percent. The mass of dry air in the room is **(2 Marks)**

(*a*) 24.7 kg
(*b*) 29.9 kg
(*c*) 39.9 kg
(*d*) 41.4 kg
(*e*) 52.3 kg

25. A room contains air at 30°C and a total pressure of 96.0 kPa with a relative humidity of 75 percent. The partial pressure of dry air is **(1 Mark)**

(*a*) 82.0 kPa
(*b*) 85.8 kPa
(*c*) 92.8 kPa
(*d*) 90.6 kPa

26. The air in a house is at 20°C and 50 percent relative humidity. Now the air is cooled at constant pressure. The temperature at which the moisture in the air will start condensing is **(2 Marks)**

(*a*) 8.7°C
(*b*) 11.3°C
(*c*) 13.8°C
(*d*) 9.3°C
(*e*) 10.0°C

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(*a*) 55 percent
(*b*) 62 percent
(*c*) 65 percent
(*d*) 72 percent

**14.** Helium gas (k=1.667) in an ideal Otto cycle is compressed from 20°C and 1.6 L to 0.2 L, and its temperature increases by an additional 600°C during the heat addition process. The temperature of helium before the expansion process is **(3 Marks)**
(*a*) 900°C
(*b*) 1200°C
(*c*) 1500°C
(*d*) 1700°C
(*e*) 820°C

**15.** In an ideal Otto cycle, air is compressed from 1.20 kg/m³ and 2.2 L to 0.26 L, and the network output of the cycle is 440 kJ/kg. The mean effective pressure (MEP) for this cycle is **(2 Marks)**
(*a*) 612 kPa
(*b*) 599 kPa
(*c*) 552 kPa
(*e*) 367 kPa

**16.** In an ideal Brayton cycle, air is compressed from 100 kPa and 25°C to 1000 kPa. Under cold-air-standard conditions, the thermal efficiency of this cycle is **(1 Mark)**
(*a*) 46 percent
(*b*) 47 percent
(*c*) 48 percent
(*d*) 39 percent
(*e*) 61 percent

**17.** Consider an ideal Brayton cycle executed between the pressure limits of 1300 and 100 kPa and temperature limits of 27 and 1000°C with argon (k=1.667, $c_p$=0.5203 kJ/kg.k) as the working fluid. The net work output of the cycle is **(4 Marks)**
(*a*) 68 kJ/kg
(*b*) 93 kJ/kg
(*c*) 146 kJ/kg
(*d*) 158 kJ/kg
(*e*) 186 kJ/kg

**18.** In a mixture of gases, the partial pressure $p_i$ of any component in the mixture can be found by **(1 Mark)**

(a) $p_i = n_i R_i T/V$ (b) $p_i = m_i R_i T/V_i$
(c) $p_i = n_i \bar{R} T/V$ (d) $p_i = n_i \bar{R} T/V_i$

where, $R_i$ = gas constant of ith constituent,
$\bar{R}$ = Universal gas constant,
V = Volume of the mixture,
$V_i$ = Volume of the ith constituent, and
T = Temperature of the mixture.

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6. In a Rankine cycle, the maximum pressure is 8 MPa. The optimum reheat pressure is **(1 Mark)**

(*a*) 1 MPa
(*b*) 2 MPa
(*c*) 3 MPa
(*d*) 4 MPa

7. For the same compression ratio, and inlet pressure and temperature, Otto cycle efficiency **(1 Mark)**

(*a*) decreases with increasing specific heat ratio
(*b*) increases with increasing specific heat ratio
(*c*) remains same unaffected by changing specific heat ratio
(*d*) none of the above.

8. For same compression ratio, and inlet pressure and temperature **(1 Mark)**

(*b*) thermal efficiency of Otto cycle is less than that of Diesel cycle
(*a*) thermal efficiency of Otto cycle is greater than that of Diesel cycle
(*c*) thermal efficiency of Otto cycle is same as that for Diesel cycle
(*d*) thermal efficiency of Otto cycle cannot be predicted.

9. The air standard Brayton cycle comprises **(1 Mark)**

(*a*) two constant volume processes and two constant entropy processes
(*b*) two constant pressure and two constant entropy processes
(*c*) two constant pressure processes and two constant volume processes
(d) none of the above.

10. In air standard Diesel cycle, at fixed compression ratio and fixed value of specific heat ratio (k) **(1 Mark)**

(*a*) thermal efficiency increases with increase in heat addition cut-off ratio
(*b*) thermal efficiency decreases with increase in heat addition cut-off ratio
(*c*) thermal efficiency remains same with increase in heat addition cut-off ratio
(*d*) none of the above.

11. An Otto cycle with air as the working fluid has a compression ratio of 8.2. Under cold-air-standard conditions, the thermal efficiency of this cycle is **(1 Mark)**

(*a*) 43 percent
(*b*) 56 percent
(*c*) 66 percent
(*d*) 75 percent

12. A Carnot cycle operates between the temperature limits of 300 and 2000 K, and produces 600 kW of net power. The rate of entropy change of the working fluid during the heat addition process is **(3 Mark)**

(*a*) 0
(*b*) 0.300 kW/K
(*c*) 0.353 kW/K
(*d*) 0.261 kW/K
(*e*) 2.0 kW/K

13. Air in an ideal Diesel cycle is compressed from 3 to 0.20 L, and then it expands during the constant pressure heat addition process to 0.35 L. Under cold air standard conditions, the thermal efficiency of this cycle is: **(3 Mark)**

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Kafrelsheikh University
Faculty of Engineering
Dept. Mech. Engineering
Year: 2nd Year Mechanical
Subject: Thermodynamics II (MPE2104)

Semester: 1st Semester
Final Examination
Date: Jan. 24th, 2017
Time allowed: 3 hours
Full Mark: 100

(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 (Pages 7/13, 8/15, 10/15, 13/13 are empty)
(c) This is a close book exam. Only ***Thermodynamics tables and Steam Chart*** are allowed.
(d) The weight of each problem is indicated.
(e) The exam will be marked out of 100. There are 51 marks bonus.

## Question 1 (51) 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 your answer whenever possible by sketch, calculations, or both. (23 Marks)**

**درجة أي سؤال لن تعطى الا اذا كان هناك تفسير لإختيارك سواء كان هذاالتفسير عباره عن رسم توضيحى أو حسابات أو الإثنين معاً**

1. Rankine cycle efficiency of a good steam power plant may be in the range of **(1 Mark)**
   (*a*) 15 to 20%
   (*b*) 35 to 45%
   (*c*) 70 to 80%
   (*d*) 90 to 95% .

2. Rankine cycle comprises of **(1 Mark)**
   (*a*) two isentropic processes and two constant volume processes
   (*b*) two isentropic processes and two constant pressure processes
   (*c*) two isothermal processes and two constant pressure processes
   (*d*) none of the above.

3. In Rankine cycle the work output from the turbine is given by **(1 Mark)**
   (*a*) change of internal energy between inlet and outlet
   (*b*) change of enthalpy between inlet and outlet
   (*c*) change of entropy between inlet and outlet
   (*d*) change of temperature between inlet and outlet.

4. Regenerative heating *i.e.,* bleeding steam to reheat feed water to boiler **(1 Mark)**
   (*a*) decreases thermal efficiency of the cycle
   (*b*) increases thermal efficiency of the cycle
   (*c*) does not affect thermal efficiency of the cycle
   (*d*) may increase or decrease thermal efficiency of the cycle depending upon the point of extraction of steam.

5. Rehaet cycle thermal efficiency **(1 Mark)**
   (*a*) is greater than simple Rankine cycle $\eta_{th}$ only when steam is reheated at particular P.
   (*b*) is always greater than simple Rankine thermal efficiency
   (*c*) is same as simple Rankine cycle thermal efficiency
   (*d*) is always less than simple Rankine cycle thermal efficiency.