CBCS SCHEME

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21MR34

Third Semester B.E. Degree Examination, Jan./Feb. 2023
Thermodynamics

Time: 3 hrs. Max. Marks: 100

Note: *1. Answer any FIVE full questions, choosing ONE full question from each module.*
2. Use of thermodynamics Data Handbook is permitted.

Module-1

1 a. Derive an expression for displacement work for a polytropic process for which case this expression is invalid. Give the expression for that case. **(10 Marks)**

b. The temperature 't' an a linear Celsius scale is related to thermometric property 'P' by the relation t = a in P + b, where a and b are constants. The value of 'P' at ice point and steam point are 2.5 and 9.5 respectively on Celsius scale. Determine the temperature 't' corresponding to reading of 'P' at 4.5. **(10 Marks)**

OR

2 a. State the first law of thermodynamics for a cycle process. Show that energy is a property of the system. **(10 Marks)**

b. 12 kg of air per minute is delivered by a centrifugal air compressor. The inlet and outlet conditions of air are $\overline{V}_1 = 12 m/s$, P_1 = 1 bar, $V_1 = 0.5 m^3/kg$ and $\overline{V}_2 = 90 m/s$, P_2 = 8 bar, $V_2 = 0.14 m^3/kg$. The increase in enthalpy of air passing through the compressor is 150 kJ/kg, and heat loss to the surrounding is 700 kJ/min. Find :

i) Motor power required to drive the compressor

ii) Ratio of inlet to outlet pipe diameter

Assume that inlet and discharge lines are at the same level. **(10 Marks)**

Module-2

3 a. State the Kelvin – Planck and Clausius statements of the second law of thermodynamics and prove their equivalence. **(10 Marks)**

b. A reversible heat engine operates between two reservoirs at temperatures 700°C and 50°C. The engine drives a reversible refrigerator which operates between reservoir at temperatures of 50°C and –25°C. the heat transfer to the engine is 2500 kJ and the network output of the combined engine refrigerator plant is 400kJ.

i) Determine the heat transfer to the refrigerant and net heat transfer to the reservoir at 50°C

ii) Reconsider i) given that efficiency of the heat engine and COP of the refrigerator are each 45% of their maximum possible value. **(10 Marks)**

OR

4 a. State and prove Clausius inequality. **(06 Marks)**

b. Explain the concept of available and unavailable energy. **(04 Marks)**

c. $1.2 m^3$ of air is heated reversibly at constant pressure from 300K to 600K, and their cooled reversibly at constant volume back to initial temperature. If the initial pressure is 1 bar, calculate:

i) The net heat flow

ii) The overall change in entropy

Represent the processes on T-S plot. **(10 Marks)**

Module-3

5 a. Explain the following :
i) Compressibility factor
ii) Compressibility chart
iii) Low of corresponding state
iv) Reduced properties. **(10 Marks)**

b. 1 kg of carbon monoxide has a volume of $2m^3$ at 80°C. Determine its pressure using :
i) Ideal gas equation
ii) Vander Waal's equation
Constants for Vander Waal's equation :
$a = 147.90\ kN\text{-}m^4(kg\ mol)^2$
$b = 0.0393m^3(kg\ mol)$. **(10 Marks)**

OR

6 a. Derive Maxwell's equations. **(08 Marks)**

b. Define the following :
i) Enthalpy of combustion
ii) Adiabatic flame temperatures
iii) Air – fuel ratio
iv) Excess air. **(04 Marks)**

c. Analyze the data on products of the combustion of Methane (CH_4) with atmospheric air on a 'dry' basis [$CO_2 = 10\%$, $O_2 = 2.37\%$, $CO = 0.53\%$, $N_2 = 87.10\%$] to
i) Determine the air fuel ratio used in combustion (molar and mass)
ii) Determine percentage theoretical air needed for complete combustion. **(08 Marks)**

Module-4

7 a. Define the following :
i) Triple point
ii) Critical point
iii) Dryness fraction
iv) Sublimation. **(04 Marks)**

b. Explain the working of a separating and throttling calorimeter. **(08 Marks)**

c. A vessel having a capacity of $0.05m^3$ contains a mixture of saturated water and saturated steam at a temperature of 245°C. The mass of water present is 10kg. Find the pressure, mass, specific – volume, enthalpy, entropy and internal energy. **(08 Marks)**

OR

8 a. With the help of neat diagram explain the working of regenerative Rankine cycle and derive the efficiency of the cycle. **(10 Marks)**

b. In a single heater regenerative Rankine cycle. The steam enters the turbine at 30 bar, 400°C and. The exhaust pressure is 0.10 bar. The feed water heater is a direct contact type which operates at 5 bar. Find :
i) The efficiency and steam rate of the cycle
ii) Increase in steam rate and efficiency as compared to the Rankine cycle without regeneration Neglect pump work. **(10 Marks)**

Module-5

9 a. Derive an expression for air standard efficiency of Otto cycle with P-V and T-S diagram. **(10 Marks)**

b. An ideal diesel cycle running at 2000 rpm has a compression ratio of 20 and uses air as the working fluid. The state of air at the beginning of the compression process is 95KPa and 20°C. If the maximum temperature in the cycle is not to exceed 2200K, determine :

i) Cycle efficiency
ii) Mean effective pressure
iii) Net work output per kg of air,
iv) Take density of air as 1.225 kg/m^3. **(10 Marks)**

OR

10 a. Explain with block diagram and T-S diagram the following methods to improve the efficiency of a Brayton cycle :

i) Regeneration
ii) Inter-cooling
iii) Reheating. **(10 Marks)**

b. A simple gas turbine plant operating on the Brayton cycle has air inlet temperature 27°C, pressure ratio of 9, and maximum cycle temperature 727°C. What will be the improvement is cycle efficiency and output if the turbine expansion process is divided into two stages each of pressure ratio 3, with intermediate reheating to 727°C. **(10 Marks)**

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