

Code No: R21032

R10**SET - 1****II B. Tech I Semester, Regular Examinations, Nov – 2012****THERMODYNAMICS**

(Com. to ME, AE, AME, MM)

Time: 3 hours

Max. Marks: 75

Answer any **FIVE** Questions
All Questions carry **Equal** Marks

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1. a) What are different thermodynamic systems? Give example for each type with justification.  
b) A mass of 1 kg of air contained in a closed vessel at 1 bar, 300 K is stirred with a constant torque of 1 N-m at a speed of 1000 RPM till the volume doubles at constant pressure. The initial and final temperatures were found to be the same. If 10 kJ of heat is absorbed during the experiment, calculate its duration.
2. a) Define Internal Energy and show that internal energy is a property of the system.  
b) Air flows steadily at the rate of 0.4 kg/s through an air compressor, entering at 6 m/s with a pressure of 1 bar and a specific volume of  $0.85 \text{ m}^3/\text{kg}$ , and leaving at 4.5 m/s with a pressure of 6.9 bar and specific volume of  $0.16 \text{ m}^3/\text{kg}$ . The internal energy of air leaving is 88 kJ/kg greater than that of air entering. Cooling water in a jacket surrounding the cylinder absorbs heat from the air at the rate of 59 W. Calculate the power required to drive the compressor and cross sectional areas of inlet and outlet.
3. a) What is Clausius Inequality? Explain the Principle of Increase of Entropy for an adiabatic system.  
b) 1 kg of steam at 5 bar and  $200^\circ\text{C}$  in a closed system is first mixed adiabatically with 1 kg of saturated water at 5 bar. The mixture is then cooled at constant volume by heat loss to atmosphere at 300 K till its final state is 1 bar, 0.55 dry. Calculate the irreversibility.
4. a) A large insulated vessel is divided into two chambers, one containing 5 kg of dry saturated steam at 0.2 MPa and the other 10 kg of steam, 0.8 quality at 0.5 MPa. If the partition between chambers is removed and the steam is mixed thoroughly and allowed to settle, find the final pressure, steam quality and the entropy change in the process.  
b) Using TdS equations and Maxwell's relations, obtain the expression for Clausius – Clapeyron Equation.

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5. a) Explain how the real gas behavior is captured using Vander Waal's Equation of State. What are modifications done to Ideal Gas Equation of State?
- b) 0.5 kg of Helium and 0.5 kg of Nitrogen are mixed at  $20^{\circ}\text{C}$  and at a total pressure of 100 kPa. Find the
- Volume of the mixture,
  - The partial pressures of the constituent gases,
  - The mole fractions of the components,
  - The specific heats of the mixture and
  - Gas constant of the mixture.
6. a) With the help of a schematic diagram, explain how the adiabatic saturation temperature is obtained.
- b) Air at  $40^{\circ}\text{C}$  DBT and  $27^{\circ}\text{C}$  WBT is to be cooled and dehumidified by passing it over a cooling coil to a give a final condition of  $15^{\circ}\text{C}$  and 90% RH. Find the amount of heat moisture removed per kg of dry air.
7. a) For the air standard Brayton cycle, show that the thermal efficiency if a function of pressure ratio.
- b) In an air standard Otto cycle, the compression ratio is 7 and the compression begins at  $35^{\circ}\text{C}$ , 0.1 MPa. The maximum temperature in the cycle is  $1100^{\circ}\text{C}$ . Find i) Cycle efficiency and ii) Mean Effective Pressure of the cycle.
8. Write short notes on the following:
- Thermodynamic analysis of Throttling Process (Make necessary assumptions)
  - Vapour Compression Refrigeration Cycle
  - Absolute temperature scale

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1.
 - a) Establish the First Law of Thermodynamics from the Joule's Experiment.
 - b) Briefly explain the macroscopic and microscopic view points.
 - c) The energy in Joule (J) of a closed system can be expressed as $E=100+50T+0.04 T^2$. The heat absorbed is given by Q (in Joule) = $5000 + 20 T$. Temperature is in K. Calculate the work done during a process when the temperature rises from 500 K to 1000 K.

2.
 - a) State and prove Carnot's theorem.
 - b) A house is to be maintained at a temperature of 20°C by means of a heat pump pumping heat from the atmosphere. Heat losses through the walls of the house are estimated at 0.65 kW per unit of temperature difference between the inside of house and atmosphere.
 - i) If the atmospheric temperature is -10°C , what is the minimum power required to drive the pump?
 - ii) It is proposed to use the same heat pump to cool the house in the summer. For the same room temperature, the same heat loss rate, and the same power input to the pump, what is the maximum permissible atmospheric temperature?

3. Calculate the changes of entropy per kg of air in the following cases:
 - i) Air expands isothermally from 6 bar to 3 bar
 - ii) Air is compressed to half the volume at constant pressure and
 - iii) Heat is supplied to air at constant volume till the pressure becomes three foldWhat would be the change in entropy of the air undergoes the above three processes in sequence. Take $C_p = 1.005 \text{ kJ/kgK}$ and $C_v = 0.720 \text{ kJ/kgK}$.

4.
 - a) Using the Maxwell's relations, obtain the expression for the difference of specific heats at constant pressure and constant volume in terms of the derivatives of properties. Hence show that $C_p - C_v$ is always positive.
 - b) With the help of a schematic diagram, explain the measure of steam quality using the separating and throttling calorimeter.

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R10**SET - 2**

5. a) Explain the law of corresponding states. Hence briefly explain the significance of compressibility chart.
- b) Two vessels A and B, each of volume 3 m^3 may be connected together by a tube of negligible volume. Vessel A contains air at 7 bar, 95°C and vessel B contains air at 3.5 bar, 205°C . Find the change of entropy when A is connected to B. Assume the mixing to be complete and adiabatic.
6. a) Define the following properties: i) Humidity Ratio ii) Dew Point temperature and iii) Relative humidity
- b) Cooling water enters the cooling tower at a rate of 1000 kg/h and 70°C . Water is pumped from the base of the tower at 24°C and some makeup water is added afterwards. Air enters the tower at 15°C , 50% RH, 1.01325 bar and leaves the tower saturated at 34°C , 1 bar. Calculate the flow rate of dry air in kg/h and the makeup water required per hour.
7. a) An engine working on Otto cycle has an air standard efficiency of 56% and rejects 544 kJ/kg of air. The pressure and temperature of air at the beginning of compression are 0.1 MPa and 60°C respectively. Compute i) the compression ratio of the engine and b) maximum pressure in the cycle.
- b) Explain the simple Rankine cycle with the help of a schematic and T-S diagram.
8. Write short notes on the following
- a) Clausius Inequality
- b) Clausius – Clapeyron Equation
- c) Equivalence of Clausius and Kelvin-Planck statements of Second law of Thermodynamics

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1. a) What is Thermal Equilibrium and hence define Zeroth Law of Thermodynamics.  
b) Define Point and Path functions. Give one example for each.  
c) 3 kg of air in a rigid vessel at 5 bar and  $100^{\circ}\text{C}$  is stirred till the pressure reaches 15 bar. Meanwhile, the air absorbs 200 kJ of heat. Calculate the final temperature and stirrer work.
2. a) Show that the absolute temperature scale is independent of working fluid.  
b) Two streams of air, one at 1 bar,  $27^{\circ}\text{C}$  and velocity of 30 m/s and the other at 5 bar,  $227^{\circ}\text{C}$  and velocity of 50 m/s mix in equal proportion in a chamber from which heat at the rate of 100 kJ/kg is removed. The mixture is then passed through an adiabatic nozzle. Find the velocity of the stream issuing out of the nozzle. The temperature of the air leaving the nozzle is  $27^{\circ}\text{C}$  and its  $C_p = 1.005 \text{ kJ/kgK}$ .
3. a) Show that the thermal efficiency of reversible engine operating between two heat reservoirs is greater than that of an irreversible engine.  
b) 1 kg of ice at  $-10^{\circ}\text{C}$  is exposed to the atmosphere which is at  $25^{\circ}\text{C}$ . The ice melts and comes in contact with the atmosphere. i) Determine the entropy increase of the universe, ii) What is the minimum amount of work necessary to convert the water back into ice at  $-10^{\circ}\text{C}$ ?  $C_p$  of ice is 2.093 kJ/kgK and the latent heat of fusion of ice is 333 kJ/kg.
4. a) Explain the measurement of steam quality using the separating and throttling calorimeter by means of schematic diagram.  
b) Obtain the expression for Joule-Kelvin coefficient for an ideal gas undergoing Joule – Thomson expansion.

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5. a) Show that for an ideal gas, the slope of constant volume line on T-S diagram is more than that of constant pressure line.  
b) A closed rigid and insulated vessel is divided by a diaphragm into two equal compartments, each of volume  $0.1 \text{ m}^3$ . Each compartment contains air at a temperature of  $20^\circ\text{C}$ . The pressure in one compartment is  $2.5 \text{ MPa}$  and in other compartment is  $1 \text{ MPa}$ . The diaphragm is ruptured so that the air in both the compartments mixes to reach a uniform pressure throughout the cylinder. Find the net change of entropy for the mixing process.
6. a) What is the significance of Psychrometric chart? Represent the following processes on the Psychrometric chart: i) Sensible heating, ii) Adiabatic dehumidification and iii) Latent heat removal.  
b) The moist air enters the heater-humidifier unit at  $5^\circ$ ,  $100 \text{ kPa}$ ,  $50\% \text{ RH}$ . The flow rate of dry air is  $0.1 \text{ kg/s}$ . Liquid water at  $10^\circ\text{C}$  is sprayed into the mixture at the rate of  $0.002 \text{ kg/s}$ . The mixture leaves the unit at  $30^\circ\text{C}$ ,  $10 \text{ kPa}$ . Calculate the relative humidity at the outlet and the rate of heat transfer.
7. a) With the help of P-V and T-S diagrams, compare the Otto, Diesel and Dual cycles for the same maximum pressure and the temperature.  
b) In a gas turbine plant with air at the inlet of the compressor is at  $0.1 \text{ MPa}$ ,  $30^\circ\text{C}$ . The pressure ratio is 6 and the maximum temperature in the cycle is  $900^\circ\text{C}$ . Find the cycle efficiency and net work. If the pressure ratio is increased to 10, for the same maximum temperature, calculate the cycle efficiency and the net work. Comment on the result.
8. Write short notes on the following:  
a) First law of Thermodynamics applied to a process in a closed system and to an open system  
b) Adiabatic saturation temperature

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1. a) What are different modes of Work? Explain any two of them with the help of relevant State – Space diagram.
b) Briefly explain the concept of Continuum.
c) 5 kg of steam at 5 bar, 0.5 dry, contained in a closed rigid system is adiabatically stirred till the steam becomes dry and saturated. If the stirrer delivers a torque of 1 N-m and its speed is 1000 RPM, calculate the time for which the stirrer should be on.
2. a) Explain the First Law of Thermodynamics applied to a process in a closed system. Make necessary assumptions
b) A heat engine drives a heat pump. The heat delivered by the heat engine as well as by the pump is used to heat the water circulating through the heat radiators of a building. The efficiency of the heat engine is 27% and the coefficient of performance of heat pump is 4. Calculate the ratio of heat transferred to the circulating water to the heat taken by the heat engine.
3. An aluminium block ($C_p = 400 \text{ J/kgK}$) with a mass of 5 kg is initially at 40°C in a room with air at 20°C . It is cooled reversibly by transferring heat to a completely reversible cyclic heat engine until the block reaches 20°C . The room serves as the constant temperature heat sink for the engine. Compute the change in entropy of the block, change in entropy of the room and work done by the engine. If the aluminium block is allowed to cool by natural convection to room air, compute the change in entropy of the block, change in entropy of the room and change in entropy of the universe.
4. a) Using the Maxwell's relations, Obtain the expression for the difference of specific heats at constant pressure and constant volume in terms of the derivatives of properties. Hence obtain its expression for an ideal gas.
b) A rigid closed tank of volume 3 m^3 contains 5 kg of wet steam at a pressure of 200 kPa. The tank is heated until the steam becomes dry saturated. Determine the final pressure and heat transfer to the tank.

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R10**SET - 4**

5. a) A gaseous mixture consists of 1 kg of oxygen and 2 kg of nitrogen at a pressure of 150 kPa and a temperature of 20°C . Determine the changes in internal energy, enthalpy and entropy when the mixture is heated to a temperature of 100°C , i) at constant volume and ii) at constant pressure.
- b) Relative merits of Ideal gas equation of state and the Vander Waal's equation of state.
6. a) Explain working of cooling tower and hence write the energy and mass balance equations for water and air undergoing heat and mass interactions.
- b) Two streams of air, one at 25°C , 50% RH and other at 25°C and 60% RH are mixed adiabatically to obtain 3 kg of dry air at 30°C . Calculate the air drawn from both the streams and the humidity ratio of the mixed air.
7. a) Show that for an Otto cycle, the thermal efficiency is a function of compression ratio and show the variation of efficiency with compression ratio.
- b) In an air standard Diesel cycle, the compression ratio is 15. The compression begins at 0.1 MPa, 40°C . The heat added is 1.675 MJ/kg. Find i) Maximum temperature in the cycle, ii) Cycle efficiency, iii) Cut-off ratio and d) MEP of the cycle
8. Write short notes on any two of the following:
- a) Thermodynamic Analysis of Rankine Cycle by using schematic and T-S diagram
- b) Carnot cycle and its efficiency when used as reversible engine