ENGINEERING THERMODYNAMICS
(MEC2103)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) For a thermodynamic cycle, the difference of values of any property between final and initial states should be
(a) positive (b) negative
(c) zero (d) non-zero.

(ii) The value of $\oint (\delta Q - \delta W)$ for a cyclic process is
(a) always positive (b) always negative
(c) always zero (d) any non-zero value.

(iii) Triple point of steam does not have a fixed value of
(a) temperature (b) pressure
(c) specific volume (d) none of these.

(iv) Within the control volume in a steady flow process, the value of any property remains constant with respect to
(a) time
(b) space co-ordinates
(c) both time and space co-ordinates
(d) neither time nor space co-ordinates.

(v) A reversible refrigerator has a COP of 1.5 working between two temperature limits. The COP of the same device when used as a heat pump with the same temperatures limits is
(a) 1.5 (b) 2.0 (c) 2.5 (d) 3.0

(vi) Following is an example of a reversible process
(a) Expansion in a piston-cylinder with friction present
(b) Heat transfer trough a finite temperature difference
(c) Unrestrained/free expansion
(d) An isothermal expansion of an ideal gas in a frictionless piston cylinder infinitesimally slowly.

(vii) According to Kelvin Planck statement
(a) PMM1 is impossible (b) Converse of PMM1 is impossible
(c) PMM2 is impossible (d) Both PMM1 and PMM2 are impossible.

(viii) The expression $ds = \frac{\delta Q}{T}$ is true only when
(a) heat transfer is reversible
(b) heat transfer is positive
(c) heat transfer is from the surrounding to the system
(d) heat transfer is from the system to the surrounding.

(ix) In a steam power plant, the enthalpy of steam at inlet and exit of the turbine are 4000 kJ/kg and 2500 kJ/kg, respectively. Neglecting pump work, the steam rate in **kg/kWh** is
(a) 2.4 (b) 1.5 (c) 3 (d) 4.5

(x) The ideal cycle on which a steam power plant works is
(a) Rankine cycle (b) Carnot cycle
(c) Otto cycle (d) Joule cycle

Fill in the blanks with the correct word

(xi) _____ is the property that does not change in a throttling process for a fluid.

(xii) The statement $\oint \frac{\delta Q}{T} < 0$ is known as _____ inequality.

(xiii) Ideal regenerative cycle has efficiency as that of a _____ cycle.

(xiv) When cut off ratio is equal to _____, a Diesel cycle approaches Otto cycle.

(xv) Between a constant volume line and a constant pressure line originating from the same point in a T-s plot of an ideal gas, the steepness of constant pressure line is _____.

Group - B

2. (a) Explain what is meant by thermodynamic equilibrium. State the zeroth law of thermodynamics. *[(CO2)(Understand/LOCQ)]*

(b) To a closed system 150 kJ of work is supplied. The initial volume is 0.6 m^3 and the pressure of the system changes as $p = (8 - 4V)$, where p is in bar and V is in m^3. Determine the final volume. *[(CO3)(Apply/IOCQ)]*

6 + 6 = 12

3. (a) Water is heated in a rigid tank through the bottom surface and a stirrer is used within the tank to keep the water at uniform temperature during the heating process. Water receives a heat of 40 kJ and a total heat loss of 11 kJ to the surroundings has taken place through the other surfaces of the tank. The stirrer does a work of 1 kJ. Calculate the final internal energy of the water if its initial internal energy is 20 kJ. *[(CO3)(Apply/IOCQ)]*

(b) Air at 20 bar and 300°C is contained in a piston cylinder device. The mass of the air is 0.12 kg and it is expanded isothermally to a pressure of 5 bar. It is then compressed adiabatically to the initial pressure and further compressed in an

isobaric manner to reach the initial state. Show the cycle in $p - v$ diagram and determine the work done in each process and the net work of the cycle.

[(CO3)(Apply/IOCQ)]

4 + 8 = 12

Group - C

4. (a) Explain the function of a nozzle. At the inlet to a nozzle, a fluid has an enthalpy of 2850 kJ/kg with negligible velocity. At the exit, the enthalpy drops to 2650 kJ/kg. Neglecting any change in the potential energy, what is the exit velocity of the fluid? *[(CO3)(Apply/IOCQ)]*

   (b) Draw a $T - v$ equilibrium diagram for water as a pure substance and show a few isobars including the critical isobar. Define and indicate in the diagram: saturated liquid line, saturated vapour line and critical point. *[(CO2)(Understand/LOCQ)]*

6 + 6 = 12

5. (a) Explain the terms critical pressure, critical temperature and critical volume with a phase equilibrium diagram of water. What is 'dryness fraction'? What is its value for a superheated steam sample? *[(CO2)(Understand/LOCQ)]*

   (b) A rigid vessel contains 5 kg of steam initially at 0.3 MPa, 250°C. The vessel is cooled down until the steam is transformed to saturated vapour. What is the temperature at this stage? What is the quality when it is further cooled to 80°C? What is the volume of the vessel? *[(CO2)(Understand/LOCQ)]*

6 + 6 = 12

Group - D

6. (a) Explain the difference between a heat pump and a refrigerator. Establish the relationship of their COPs when the same device is used for both applications.

[(CO4)(Apply/IOCQ)]

   (b) Two reversible heat engines A and B are arranged in series, A rejecting heat directly to B. Engine A receives 200 kJ at a temperature of 427°C from a hot source, while engine B is in communication with a cold sink at a temperature of 7°C. If the work output of A is twice that of B, find (i) the intermediate temperature between A and B (ii) the efficiency of each engine (iii) work outputs (iv) the heat rejected to the cold sink. *[(CO4)(Apply/IOCQ)]*

5 + 7 = 12

7. (a) 80 kg of liquid water at 100°C is mixed with 50 kg of water at 60°C, while the temperature of the surrounding is 15°C. Determine the decrease in available energy. *[(CO6)(Evaluate/HOCQ)]*

   (b) Determine the maximum work obtainable from two finite bodies at temperature T_1 *and* T_2 $(T_1 > T_2)$, both having the same heat capacity C . *[(CO6)(Evaluate/HOCQ)]*

6 + 6 = 12

Group - E

8. (a) Draw the p-v diagram of an air standard Otto cycle and determine the thermal efficiency in standard parameters. *[(CO5)(Analyze/IOCQ)]*

   (b) An Otto cycle takes in air at 1 bar and 15°C. The compression ratio is 8. In each cycle, heat added to air is 2000 kJ/kg. What is the net work output? To what value the compression ratio must be raised for an increase in net work by 20%? *[(CO5)(Analyze/IOCQ)]*

6 + 6 = 12

9. a) Superheated steam at 18 MPa, 560°C enters the turbine of a vapor power plant. Saturated liquid leaves the condenser at 0.045 bar, 26°C. Pressure losses are negligible. The turbine and pump have isentropic efficiencies of 82% and 77%, respectively. For the cycle, determine (i) the net work per unit mass of steam flow, in kJ/kg. (ii) thermal efficiency. *[(CO5)(Analyze/IOCQ)]*

   (b) The pressure and temperature at the beginning of compression of an air-standard Diesel cycle are 95 kPa and 300 K, respectively. At the end of the heat addition, the pressure is 7.2 MPa and the temperature is 2150 K. Determine (i) the compression ratio. (ii) cut-off ratio. (iii) thermal efficiency of the cycle. *[(CO5)(Analyze/IOCQ)]*

6 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	25	62.5	12.5