ENGINEERING THERMODYNAMICS
(MECH 2203)

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.

Students should carry their own Steam Table

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) For free expansion process, work done is
(a) positive (b) negative
(c) zero (d) maximum.

(ii) Addition of heat to a gas at constant pressure results in
(a) rise in temperature only
(b) rise in pressure only
(c) rise in volume only
(d) rise in temperature, volume and doing some external work

(iii) Heat transferred to a closed stationary system at constant volume is equal to
(a) work transfer (b) increase in internal energy
(c) increase in enthalpy (d) increase in entropy.

(iv) A Carnot heat engine efficiency increases from initial value 0.2 to final value 0.3, when the sink temperature reduces by 30K. The initial sink temperature is
(a) 200K (b) 240K (c) 300K (d) 360K.

(v) Solids and liquids have
(a) one value of specific heat (b) two values of specific heat
(c) three values of specific heat (d) no specific value of specific heat.

(vi) In an isothermal process, the internal energy of a perfect gas
(a) increases
(b) decreases
(c) remains constant
(d) may increase or decrease depending on the properties of the gas

(vii) Kelvin Planck's law deals with
(a) conservation of work (b) conservation of heat
(c) conversion of work into heat (d) conversion of heat into work.

(viii) Air standard efficiency of Otto Cycle depends on
(a) ratio of specific heats (b) cut-off ratio
(c) compression ratio (d) both (a) and (c)

(ix) In Rankine cycle the work output from the turbine is given by
(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

(x) Entropy change of the universe for a reversible process is
(a) zero (b) positive
(c) negative (d) cannot be stated definitely.

Fill in the blanks with the correct word

(xi) Idea of temperature scale is obtained from _________ law of thermodynamics.

(xii) During throttling process, the property _________ does not change.

(xiii) Compression ratio of an Otto cycle is typically _________.

(xiv) The working fluid used in air standard diesel cycle is _________.

(xv) For an irreversible cycle, the value of $\oint \frac{\delta Q}{T}$ is _________.

Group - B

2. (a) Define thermodynamic property of a system. Make a comparison of heat and work. If an adiabatic process in a control mass, increases energy from E_1 to E_2 i.e. $E_2 - E_1 > 0$, what is the sign of W_{1-2}? *[(CO1)(Understand/LOCQ)]*

(b) A mass of gas is compressed in a quasi-static process from 80 kPa, 0.1 m^3 to 0.4 MPa, 0.03 m^3. Assuming that the pressure and volume are related by $PV^n = C$, where C is the constant, find the work done by the gas system. *[(CO2)(Apply/IOCQ)]*

6 + 6 = 12

3. (a) A gas undergoes a thermodynamic cycle consisting of the following processes: (i) Process 1-2: constant pressure p = 1.4 bar, V_1 = 0.028 m^3, W_{1-2} = 10.5 kJ (ii) Process 2-3: compression with pV = constant. $U_3 = U_2$ (iii) Process 3-1: constant volume, $U_1 - U_3$ = -26.4 kJ. There are no significant changes in KE and PE.
(i) Sketch the cycle on a p –V diagram. (ii) Calculate the net work for the cycle in kJ. (iii) Calculate the heat transfer for process 1-2. *[(CO2)(Analyse/IOCQ)]*

(b) A cylinder contains 1.25 m^3 of an ideal gas at 80 kPa, 375K. The gas is compressed following a quasistatic, polytropic process and the volume of gas reduced to one-fourth of its initial volume. The final pressure of the gas is 480 kPa. Calculate the mass of the gas, the total work done and the total heat transfer during the compression process. Take R = 287J/kgK, γ = 1.4 for the gas. *[(CO2)(Evaluate/HOCQ)]*

6 + 6 = 12

Group - C

4. (a) 10 kg superheated steam at 16 MPa pressure and 480°C is contained in a rigid vessel. The steam is then cooled till it reaches the saturated vapour state. Determine the amount of heat rejected to the surroundings during the cooling process. Show the process on $T - V$ diagram. *[(CO4)(Evaluate/HOCQ)]*

   (b) Determine the state of water and estimate the corresponding enthalpy for the given parameters:
   (i) $P = 2.50$ MPa and $u = 3026.2$ kJ/kg, (ii) $P = 200\,kPa$ and $x = 0.76$. *[(CO4)(Apply/IOCQ)]*

6 + 6 = 12

5. (a) Steam flows through a turbine at a rate of 3 kg/s. The inlet and exit enthalpy of steam are 2925 kJ/kg and 1740 kJ/kg respectively. Velocity of steam at inlet and outlet are 30 m/s and 240 m/s. There is heat loss to the surroundings at 40 kW. Calculate the power output from the turbine. *[(CO4)(Apply/IOCQ)]*

   (b) Explain briefly a throttling process. Why does the cooking time decrease upon using the pressure cookers? *[(CO3)(Remember/LOCQ)]*

6 + 6 = 12

Group - D

6. (a) Name any two thermal reservoirs. Explain with justification why these can be called thermal reservoirs.
   Two heat engines operating between the same thermal reservoirs receive equal amounts of heat. One heat engine is reversible and the other is irreversible. Explain which out of the two will reject more heat? *[(CO3)(Remember/LOCQ)]*

   (b) Two reversible heat engines are connected to a thermal reservoir at 850 K. Both receives a total of 2200 kJ heat from this reservoir and jointly produces a work output of 300 kJ. If the first heat engine rejects heat to a heat sink at 750 K and the second rejects to another heat sink at 650 K, determine the amount of heat received by each of the two sinks. *[(CO3)(Apply/IOCQ)]*

6 + 6 = 12

7. (a) Define the COP of a refrigerator. What is the difference between a refrigerator and a heat pump? What is entropy principle? *[(CO3)(Understand/LOCQ)]*

   (b) 2 kg of water at 353 K are mixed adiabatically with 3 kg of water at 303 K in an isobaric process of 1 atmosphere. Find the increase in the entropy of the total mass of water due to the mixing process. Take c_p of water to be 4.187 kJ/kg-K *[(CO3)(Evaluate/HOCQ)]*

6 + 6 = 12

Group - E

8. (a) Air volume of $580\,m^3$ enters an ideal Otto cycle at 100 kPa and 30°C. The temperature of air at the exit of the isentropic expansion is 520°C. The compression ratio of the cycle is 10. Consider, $\gamma = 1.4$. Determine (i) the highest pressure and temperature in the cycle, and (ii) the thermal efficiency. *[(CO5)(Remember/LOCQ)]*

(b) A power plant operates on a regenerative vapour power cycle with one open feedwater heater. Steam enters the first turbine stage at 12 MPa, 560°C and expands to 1 MPa, where some of the steam is extracted and diverted to the open feedwater heater operating at 1 MPa. The remaining steam expands through the second turbine stage to the condenser pressure of 6 kPa, from where saturated liquid goes to the pump. Saturated liquid exits the open feedwater heater at 1 MPa. Assuming ideal condition and neglecting pump work, calculate the mass of steam bled per kg of steam fed to the turbine.

[(CO5)(Analyse/IOCQ)]

5 + 7 = 12

9. (a) A single stage, single acting reciprocating air compressor delivers 15 m^3/minute of free air from 1 bar to 9 bar. The speed of the compressor is 350 rpm. Assuming the compression and the expansion processes, follow the law $Pv^{1.3}$ = constant and the clearance is (1/16) th of the swept volume, find the bore and the stroke of the compressor. Take bore/stroke ratio as 0.75. *[(CO6)(Apply/IOCQ)]*

(b) Steam at 20 bar, 360^0C is expanded in a steam turbine to 0.08 bar. It then enters a condenser, where it is condensed to saturated liquid state. The pump feeds back the water into the boiler. Assuming ideal processes, find per kg of steam, the net work and the cycle efficiency. *[(CO6)(Apply/IOCQ)]*

6 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	36.46	44.79	18.75

Course Outcome (CO):

After the completion of the course students will be able to
1. Define and describe thermodynamic systems as well as thermodynamic processes
2. Interpret different processes to examine work transfer in various quasi-static processes
3. Differentiate between heat transfer and work transfer
4. Interpret property values from steam table to weigh heat transfer and work transfer
5. Examine the working of air standard cycles, reciprocating compressor and basics of thermal power generation
6. Judge the efficiencies of Rankine cycles and air standard cycles as well as compression work of a compressor

**LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question.*