APPLIED THERMODYNAMICS
(MECH 2101)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

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

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) For a heat engine operating on Carnot cycle, the work output is $1/4^{th}$ of the heat rejected. The efficiency of the engine is
(a) 25% (b) 20% (c) 10% (d) 40%.

(ii) Work of compression in a reciprocating air compressor is least when the compression process is
(a) adiabatic (b) polytropic
(c) isothermal (d) none of these.

(iii) Which of the following statement is correct in reference to entropy generation in a closed system
(a) an isentropic process need not to be adiabatic or internally reversible
(b) if isentropic process is adiabatic, then it must be internally reversible
(c) if process is adiabatic and internally reversible, it must be isentropic
(d) all of these.

(iv) For the same compression ratio in a diesel cycle, specific work output increases if cut off ratio increases; and
(a) the thermal efficiency decreases
(b) the thermal efficiency increases
(c) heat input increases but heat rejection decreases
(d) none of these.

(v) The value of dryness fraction of steam increases from 0 to 1 indicates the moisture content in liquid-vapour mixture
(a) increases (b) decreases
(c) constant (d) first decreases and then increases.

(vi) At the critical state, the difference of density of saturated liquid and that of saturated vapour is equal to
(a) unity (b) zero (c) maximum (d) minimum.

(vii) In a vertical Spark Ignition engine when both inlet and outlet valves are closed and the piston is at the bottom dead centre, the stroke that follows would be
(a) suction (b) compression (c) expansion (d) exhaust.

(viii) The cooling of air during compression process brings out the following effect
(a) increase in work required (b) increase in specific volume of gas
(c) increase in pipe friction loss (d) decrease in specific volume of gas.

(ix) The refrigerant $CHClF_2$ may be denoted as
(a) R-12 (b) R-10 (c) R-22 (d) R-50.

(x) For sublimation to occur, a pure substance must be brought
(a) at a pressure between critical point and triple point
(b) at a temperature between critical point and triple point
(c) at a temperature and pressure between critical point and triple point
(d) below triple point pressure.

Group – B

2. (a) Two pipes carry steam, one at 0.8 MPa, 250°C, flowing @ 1 kg/s and the other at 0.8 MPa, 0.95 dry. Both the streams mix adiabatically and finally flow @ 2.3 kg/s. Determine the condition of steam after mixing.

(b) Steam initially at 0.3 MPa, 250°C is cooled at constant volume. (i) At what temperature will the steam become saturated vapour? (ii) What is the quality at 80°C? (iii) What is the heat transferred per kg of steam in this constant volume cooling process from 250°C to 80°C ?

6 + 6 = 12

3. (a) (i) Draw the phase equilibrium diagram for a pure substance on pressure-temperature (p-T) coordinates.
(ii) Why does the fusion line for water have negative slope?

(b) Calculate the amount of heat which enters or leaves 1 kg of steam initially at 5 bar and 250°C, when it undergoes the following processes:
(i) It is confined by a piston in a cylinder and is compressed to 10 bar and 300°C as the piston does 200 kJ of work on the steam.
(ii) It passes in steady flow through a device and leaves at 10 bar and 300°C, while per kg of steam flowing through it, a shaft puts in 200 kJ of work. Changes in kinetic energy and potential energy are negligible.
(iii) It flows into an evacuated rigid container from a large source which is maintained at the initial condition of the steam. Then 200 kJ of shaft work is transferred to the steam, so that its final condition is 10 bar and 300°C. Changes in kinetic energy and potential energy are negligible.

(2 + 1) + (3 + 3 + 3) = 12

Group – C

4. (a) One kg of water at 0^0C is brought in contact with a constant temperature thermal reservoir at 90^0C. When water reaches 90^0C, find (i) entropy change of water (ii) entropy change of the reservoir (ii) entropy change of the universe. (ii) If water was heated in two stages first from 0^0C to 40^0C with a 40^0C temperature reservoir and then to 90^0C with the 90^0C reservoir, what would have been the change of entropy of the universe?

   (b) 300 W of heat is supplied at a constant temperature of 290^0C to three heat engines each. The heat rejection takes place at a constant temperature of 85^0C. The following results were reported to have been obtained:
(i) 215 W heat is rejected. (ii) 150 W heat is rejected. (iii) 75 W heat is rejected.
Classify results as reversible/irreversible/impossible cycles in each case.

6 + 6 = 12

5. (a) (i) What do you understand by entropy transfer? (ii) Why is entropy transfer associated with heat transfer and not with work transfer?

   (b) Steam at 7 bar, 355°C enters one open feed water heater operating at steady state. A separate steam of liquid water enters at 7 bar, 35°C. A single mixed stream exits at saturated liquid at 7 bar. Heat loss and kinetic energy and potential energy effects can be neglected. Determine (i) the ratio of mass flow rates of the incoming streams, (ii) the rate at which entropy is produced within the heater per kg steam at exit.

(1 + 2) + (4 + 5) = 12

Group – D

6. (a) A single acting reciprocating air compressor designed to deliver air at a gauge pressure of 7 bar has a stroke of 75 cm length with a clearance of 3% of stroke volume. The compressor was overhauled for the study of the effect of clearance and a distance piece 0.5 cm thick was fixed with cylinder head, thereby decreasing the clearance. The compressor was then commissioned with changed clearance. Make calculations for the percentage change in (i) volume of free air delivered (ii) power necessary to drive the compressor. Intake pressure is 1 bar.

   (b) In an air standard diesel cycle, the compression ratio is 15. The fluid properties at the beginning of compression are 300 K, 100 kPa. For a peak temperature of 1600 K, calculate (i) the percentage of stroke at which cut off occurs (ii) the cycle efficiency (iii) the specific work output.

6 + 6 = 12

7. (a) An air-standard dual cycle has a compression ratio 16 and compression begins at 1 bar, 50°C. The maximum pressure attained in the cycle is 70

bar. The heat transferred to air at constant pressure is equal to that at constant volume during heat addition. Draw the p-V diagrams for this cycle. Find the pressures and temperatures at the cardinal points & the cycle efficiency. Given that, $c_v = 0.718$ kJ/kg, $c_p = 1.005$kJ/kg K.

   (b) Show that the volumetric efficiency of a reciprocating compressor is given by $\eta_{vol} = 1 + C - C(p_2/p_1)^{1/n}$; symbols have their usual meaning.

7 + 5 = 12

Group – E

8. (a) With the help of a temperature-entropy (T-s) diagram, explain how the quality at turbine exhaust gets restricted?

   (b) A steam power plant operating on the ideal reheat Rankine cycle has steam condition at turbine inlet at 150 bar, 600°C and is condensed at pressure of 0.1 bar. If the moisture content at turbine is not to exceed 10.4%, determine (i) the pressure at which the steam should be reheated and (ii) the thermal efficiency of the cycle. Assume the steam is reheated to the inlet temperature of the turbine.

3 + (4 + 5) = 12

9. (a) What is an absorption refrigeration cycle? How does it differ from a vapour compression cycle?

   (b) A vapour compression refrigeration system using R-12 is employed to produce 8640 kg of ice per day. The condensing and evaporating temperatures of the refrigerant are 48°C and -20°C, respectively. Saturated liquid leaves the condenser and saturated vapour leaves the evaporator. Compression is isentropic. Water at 35°C is used to form ice and the temperature of ice should be -8°C. (i) Show the corresponding thermodynamic cycle in a temperature-entropy (T-s) diagram. Determine (ii) the refrigerating effect in kJ/s, (iii) the temperature of refrigerant at the end of compression, (iv) the flow rate of refrigerant, and (v) the power required to drive the compressor in kW. Take specific heat of ice = 2.26 kJ/kg-K, latent heat of fusion (water to ice transition) = 334.72 kJ/kg, and specific heat of water = 4.187 kJ/kg-K.
The following data for R-12 may be used:
Specific heat of vapour = 0.82 kJ/kg-K.

Temperature (°C)	Pressure (bar)	Specific Enthalpy (kJ/kg)		Specific Entropy (kJ/kg-K)	
		liquid	vapour	liquid	vapour
48	11.64	82.83	205.83	0.2973	0.6802
-20	1.51	17.82	178.74	0.0731	0.7087

(2 + 2) + (2 + 1 + 2 + 2 + 1) = 12