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) When two bodies are separately in thermal equilibrium with a third body, they are also in thermal equilibrium with each other. This statement is called
(a) Zeroth law of thermodynamics (b) First law of thermodynamics
(c) Kelvin Planck's statement (d) Clausius statement.

(ii) In a reversible process, the entropy of the system
(a) can never decrease (b) can never increase
(c) may increase or decrease (d) will always remain constant.

(iii) Internal energy of an ideal gas depends on
(a) temperature, specific heats and pressure
(b) temperature, specific heats and enthalpy
(c) temperature, specific heats and entropy
(d) temperature only.

(iv) Volume of wet steam (per unit mass) with dryness fraction x is given by
(a) $x.v_f$ (b) $x.v_g$
(c) $v_f + x.v_g$ (d) $v_g + x.v_f$
(Symbols have their usual meaning.)

(v) Internal energy is defined by the
(a) zeroth law of thermodynamics (b) first law of thermodynamics
(c) second law of thermodynamics (d) law of entropy.

(vi) Choose the correct statement:
(a) Critical point involves equilibrium of solid and vapour phases
(b) Critical point involves equilibrium of solid and liquid phases
(c) Critical point involves equilibrium of solid, liquid and vapour phases
(d) Triple point involves equilibrium of solid, liquid and vapour phases.

(vii) For a reversible adiabatic process, the change in entropy of a system is
(a) always positive (b) always negative
(c) zero (d) unity.

(viii) If the temperature of the source is increased, the efficiency of the Carnot engine
(a) decreases (b) increases
(c) remains unchanged (d) depends on other factors.

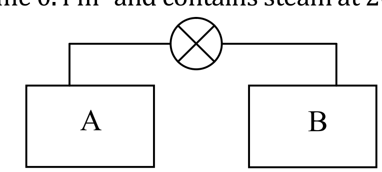
(ix) Regenerative Cycle efficiency is
(a) always greater than simple Rankine thermal efficiency
(b) greater than simple Rankine thermal efficiency only when steam is bled at particular pressure
(c) same as simple Rankine efficiency
(d) always less than simple Rankine efficiency but specific work output is more.

(x) The air-standard Otto cycle comprises
(a) two constant pressure processes and two constant volume processes
(b) two constant pressure and two reversible adiabatic processes
(c) two constant volume processes and two reversible adiabatic processes
(d) none of the above.

Group – B

2. (a) Steam enters a turbine at 120 bar, 400^0C. At the exit of the turbine, pressure is 1 bar and the entropy is 0.5 J/g-K greater than that at the inlet. The process is adiabatic and the changes in KE and PE may be neglected. Find the work done by the steam in kJ/kg. What is the mass flow rate required for a power output of 1000 kW?

(b) Tank A has a volume 0.4 m^3 and contains steam at 200^0C, 10% saturated



liquid, 90% saturated vapour, by volume. An evacuated tank B is connected to tank A via a valve. The valve is now opened slowly and the tanks eventually come to same pressure which is found to be 4 bar. During the process, heat is transferred such that the final temperature remains 200^0C. Find the volume of the tank B.

(4 + 2) + 6 = 12

3. (a) A 800 - L tank initially contains water at 100 kPa and a quality of 1 %. Heat is transferred to water, thereby raising its temperature and

pressure. At a pressure of 3MPa a safety valve opens and saturated vapour at that pressure flows out. The process continues, maintaining the pressure inside 3MPa until the quality in the tank is 90%, then stops. Determine (i) the total mass of water that has flown out (ii) the total heat transfer to the tank.

(b) A fluid system undergoes a non-flow frictionless process following the pressure-volume relation $p = \frac{5}{V} + 1.5$, where p is in bar and V is in m^3. During the process, the volume changes from 0.15 m^3 to 0.05 m^3, and the system rejects 45 kJ of heat. Determine (i) change in internal energy and (ii) change in enthalpy.

7 + (3 + 2) = 12

Group – C

4. (a) A house requires $2 \times 10^5\ kJ/h$ for heating in winter. A heat pump is used to absorb heat from cold air outside in winter and reject heat to the house. Work required to operate the heat pump is $3 \times 10^4\ kJ/h$. Determine (i) heat abstracted from outside (ii) co-efficient of performance.

(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 reservoirs at temperatures of 50°C and −25°C. The heat transfer to the engine is 2500kJ and the net work output of the *combined* engine-refrigerator plant is 400kJ. Determine (i) the heat transfer to the refrigerant and (ii) the heat rejection to the reservoir at 50°C .

(c) Determine the entropy change of 4 kg of a perfect gas whose temperature varies from 127°C to 227°C during a constant volume process. The specific heat varies with the absolute temperature by the relation $c_v = (0.48 + 0.0096T)\ kJ/kgK$.

(2 + 1) + (3 + 2) + 4 = 12

5. (a) A cyclic heat engine operates between source temperature of 1000°C and sink temperature of 40°C. Find the least rate of heat rejection per kW net output of the engine.

(b) Two Carnot engines work in series between a thermal source at 550 K and a sink at 350 K. If both engines develop equal power, determine the intermediate temperature.

(c) An iron cube at a temperature of 400°C is dropped into an insulated bath containing 10 kg water at 25°C. The water finally reaches a

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temperature of 50°C at steady state. Given that the specific heat of water is equal to 4186 J/kgK. Find the entropy changes for the iron cube and the water. Is the process reversible?

3 + 4 + 5 = 12

Group – D

6. (a) A single stage single acting reciprocating air compressor delivers 15 m^3 of free air per minute from 1 bar to 9 bar. The speed of the compressor is 350 rpm. Assuming that the compression and expansion follows the law $pv^{1.3}$ = constant, and the clearance is 1/16th of the swept volume, find the bore and stroke of the compressor. Take Bore/Stroke ratio as 0.75.

(b) Obtain an expression for mean effective pressure of an Otto cycle in terms of initial pressure and other standard parameters.

7 + 5 = 12

7. (a) An air-standard Diesel engine has a compression ratio of 15 and the heat addition at constant pressure takes place at 6% of the stroke. Find the air-standard efficiency of the engine. Take $\gamma = 1.4$ for air. Draw the $p - V$ plot of the cycle.

(b) What is the advantage of staging a compression process? What is meant by perfect intercooling?

(c) Compare the thermal efficiencies of the Otto cycle, the Diesel cycle, and the Dual combustion cycle under the same compression ratio and heat rejection.

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

Group – E

8. (a) A steam power plant operates on a theoretical reheat cycle. Steam at boiler at 150 bar, 550°C expands through the high-pressure turbine. It is reheated at a constant pressure of 40 bar to the initial temperature of 550°C and expands through the low-pressure turbine to a condenser at 0.1 bar. Draw the $T - s$ diagram. Find (i) the quality of steam at turbine exhaust (ii) the cycle efficiency and (iii) steam rate in kg/kWh.

(b) Briefly discuss with the help of a p-h diagram the performance of a vapour compression refrigeration system for the following factors: (i) effect of decrease in suction pressure (ii) effect of increase in delivery pressure.

(1 + 3 + 3 + 1) + 4 = 12

9. (a) A refrigeration machine is required to produce ice at 0°C from water at 20°C. The machine has a condenser temperature of 298K while the evaporator temperature is 268K. 6 kg of Freon-12 refrigerant is circulated through the system per minute. The refrigerant enters the compressor with a dryness fraction of 0.6. Specific heat of water is 4.187 kJ/kg-K and the latent heat of fusion of ice is 335 kJ/kg. Find (i) the dryness fraction of the refrigerant at condenser inlet (ii) COP of the plant (iii) quantity in tonnes of ice produced in 24 hours. The table of properties of Freon-12 is given in the table below:

Temp (K)	h_f (kJ/kg)	h_{fg} (kJ/kg)	s_f (kJ/kg-K)
298	59.7	138	0.2232
268	31.4	154	0.1251

(b) In a steam power cycle, the steam is supplied to turbine at 15 bar in a dry saturated state. The condenser pressure is 0.4 bar. Calculate Rankine efficiency neglecting pump work and the mass flow rate for a power output of 100 MW. Compare this with Carnot efficiency between the same two temperatures.

(3 + 2 + 2) + 5 = 12