(vi) During throttling process:
(a) Internal energy does not change
(b) Pressure does not change
(c) Entropy does not change
(d) Enthalpy does not change.

(vii) The characteristic gas constant (R) is equal to the:
(a) Sum of two specific heats (b) Difference of two specific heats
(c) Product of two specific heats (d) Ratio of two specific heats.

(viii) The processes of a Carnot cycle are:
(a) Two adiabatic and two constant volume processes
(b) One constant volume, one constant pressure and two reversible adiabatic processes
(c) Two reversible adiabatics and two reversible isothermals
(d) Two constant volumes and two isothermal processes.

(ix) Specific enthalpy of an ideal gas depends only on
(a) pressure (b) specific volume
(c) temperature (d) mass.

(x) Latent heat of vapourisation of a pure substance becomes zero at
(a) triple point (b) critical point
(c) can never become zero (d) none of these.

Group - B

2. (a) In a system executing a non-flow process, the work and heat transfer per degree change of temperature are given by:

$$\frac{dW}{dT} = 200\ J/°C \ \ and \ \frac{dQ}{dT} = 160\ J/°C$$

Calculate the change of internal energy of the system when its temeprature changes from $T_1 = 55°C$ to $T_1 = 95°C$.

(b) Referring to the following data for saturated steam; determine the specific volume and specific enthalpy of saturated steam at 100°C having quality 0.6. Also find the saturation pressure at 102°C.

Temp. T (°C)	Saturation Pressure P (kPa)	Specific Volume (m^3/kg)		Specific Enthalpy (kJ/kg)	
		v_f	v_g	h_f	h_g
100	101.3	0.001044	1.67290	419.02	2676.05
105	120.8	0.001047	1.41936	440.13	2683.83

(c) Write the steady flow energy equation for a single stream entering and a single stream leaving a control volume and explain the various terms in it.

4 + 5 + 3 = 12

3. (a) State the first law of thermodynamics for a closed system undergoing a change of state. Show that energy is a system property.

(b) In a gas turbine unit, the mass flow rate of gases through the turbine is 15 kg/s and the power developed by the turbine is 12000 kW. The enthalpies of gases at the inlet and the outlet are 1260 kJ/kg and 400 kJ/kg respectively. The velocity of gases at the inlet and the outlet are 50 m/s and 110 m/s respectively. Calculate:
(i) The rate at which heat is rejected by the turbine;
(ii) The area of the inlet pipe, given that the specific volume of the gases at the inlet is 0.45 m^3/kg.

(2 + 4) + 6 = 12

Group - C

4. (a) 2 kg of water at 80^0 C is mixed adiabatically with 3 kg of water at 30^0C in a constant pressure process of 1 atmosphere. Find the increase in the entropy of the total mass of water due to the mixing process. (c_p of water = 4.187 kJ/kg-K). What is the entropy change of the universe?

(b) An inventor claims that his engine has the following specifications:
Temperature limits: 750°C and 25°C
Power developed: 75 kW
Fuel burned per hour: 3.9 kg
Heating value of the fuel: 74500 kJ/kg
State with justification whether the inventor's claim is valid or not.

(c) Give the Kelvin-Planck statement and the Clausius statement of the second law.

(4 + 1) + 4 + 3 = 12

5. (a) A heat engine operating between two reservoirs 1000 K and 300 K is used to drive a heat pump which extracts heat from the reservoir at 300 K at a rate twice that at which the engine rejects heat to it. If the efficiency of the engine is 40% of the maximum possible and the COP of the heat pump is 50% of the maximum possible, what is the temperature of the reservoir to which the heat pump rejects heat? What is the rate of heat rejection from the heat pump if the rate of heat supply to the engine is 100 kW?

(b) Show that the minimum theoretical work input required by a refrigeration cycle to bring two finite bodies (each of mass m, and specific heat c) from the same initial temperature to the final temperatures of T_1 and T_2 ($T_2 < T_1$) is given by: $W_{min} = mc\left[\sqrt{T_2} - \sqrt{T_1}\right]^2$.

6 + 6 = 12

Group - D

6. (a) The minimum pressure and temperature in an air standard Otto cycle are 100 kPa and 27°C. The amount of heat added to the air per cycle is 1500 kJ/kg.
   (i) Determine the pressures and temperatures at all points of the Otto cycle.
   (ii) Also calculate the specific work and thermal efficiency of the cycle for a compression ratio of 8: 1.
   Take for air: $c_v = 0.72\ kJ/kgK$, $\gamma = 1.4$.

   (b) Derive an expression for the indicated work input of an ideal reciprocating air compressor with isentropic compression.

7 + 5 = 12

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

   (b) 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.

4 + 8 = 12

Group - E

8. (a) Show a vapour compression refrigeration cycle on a P-h diagram. Obtain an expression for the COP and the quality of the refrigerant at the inlet to the evaporator.

   (b) A steam power station uses the following cycle: Steam at boiler outlet – 150 bar, 550⁰ C; Reheat at 40 bar to 550⁰ C; Condenser pressure at 0.1bar. Find (a) quality at L P turbine exit (b) pump work (c) turbine work.

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

9. (a) In a single heater regenerative cycle the steam enters the turbine at 30 bar, 400⁰ C and the exhaust pressure is 0.10 bar. The feed water heater is a direct contact type which operates at 4 bar. Neglecting pump work, find (a) the turbine work and (b) efficiency of the cycle.

   (b) With the help of T-s diagram explain what is meant by mean temperature of heat addition in a Rankine cycle and its significance. What are the considerations that fix the maximum temperature of steam?

(6 + 2) + 4 = 12

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.

N.B.: Students should be allowed to carry Steam Table / Mollier Chart.

Group – A
(Multiple Choice Type Questions)

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

   (i) Which of the following is an intensive property of a thermodynamic system?
   (a) Volume (b) Temperature
   (c) Mass (d) Energy.

   (ii) The relation *du = Tds –pdv* is true for
   (a) reversible processes only
   (b) reversible adiabatic processes only
   (c) all processes
   (d) reversible isothermal processes only.

   (iii) Sublimation is a phenomenon which is observed at a pressure
   (a) above the triple point pressure
   (b) below triple point pressure
   (c) between critical and triple point pressure
   (d) none of these.

   (iv) With the increase in pressure:
   (a) Boiling point of water increases and enthalpy of evaporation increases
   (b) Boiling point of water increases and enthalpy of evaporation decreases
   (c) Boiling point of water decreases and enthalpy of evaporation increases
   (d) None of these.

   (v) A thermodynamic cycle is impossible if
   (a) $\oint \frac{\partial Q}{T} < 0$ (b) $\oint ds = 0$ (c) $\oint \frac{\partial Q}{T} = 0$ (d) $\oint \frac{\partial Q}{T} > 0$.