ME-301

APPLIED THERMODYNAMICS

Time Allotted: 3 Hours | Full Marks: 70

The questions are of equal value.
The figures in the margin indicate full marks.
Candidates are required to give their answers in their own words as far as practicable.

GROUP A
(Multiple Choice Type Questions)

1. Answer all questions. 10×1 = 10

(i) An open system is one in which
(A) heat and work cross the boundary of the system, but the mass of the working substance does not
(B) mass of working substance crosses the boundary of the system but the heat and work do not
(C) both the heat and work as well as mass of the working substances cross the boundary of the system
(D) neither the heat and work nor the mass of the working substances cross the boundary of the system

(ii) The specific volume of water when heated at 0 °C
(A) first increases and then decreases
(B) first decreases and then increases
(C) increases steadily
(D) decreases steadily

(iii) Kelvin-Planck's law deals with
(A) conservation of heat (B) conservation of mass
(C) conversion of heat into work (D) conversion of work into heat

(iv) The specific heat at constant pressure (C_p) is given
(A) $C_p = T(\delta s/\delta T)_p$ (B) $C_p = T(\delta T/\delta s)_p$ (C) $C_p = T(\delta v/\delta T)_p$ (D) $C_p = T(\delta u/\delta T)_p$

(v) Which one is the correct relationship between enthalpy and entropy
(A) dh = Tds – vdp (B) dh = Tds – pdv
(C) dh = Tds + pdv (D) dh = Tds + vdp

(vi) Zeroth law of thermodynamics tells us about
(A) internal energy (B) pressure (C) temperature (D) enthalpy

(vii) In the polytrophic process equation PV^n = const., if n = 0, the process is termed as
(A) isochoric (B) isobaric (C) isothermal (D) adiabatic

(viii) Absolute humidity is the mass of water vapour present in
(A) 1 kg of dry air (B) 1 m^3 of dry air (C) 1 kg of wet air (D) 1 m^3 of wet air

(ix) The reheat cycle power plant is mainly adopted to
(A) improve thermal efficiency
(B) keep the moisture content in low pressure stages to safe value
(C) decrease the capacity of condenser
(D) recover the waste heat of boiler

(x) As differential, heat and work would be described mathematically as
(A) inexact (B) exact (C) discontinuous (D) point function

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GROUP B
(Short Answer Type Questions)

Answer any *three* questions. 3×5 = 15

2. What is a pure substance? Draw the phase equilibrium diagram for a pure substance on P-V, T-S, and P-T plot with relevant constant property lines. 1+4

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3. 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 421 °C from the hot source, while engine B is in communication with a cold sink at a temperature of 5 °C. If the work OP of A is twice that of B, find 5
(i) Intermediate temperature between A and B.
(ii) The efficiency of each engine.
(iii) The heat rejected to the cold sink.

4. Define volumetric efficiency. Derive an expression in terms of clearance and pressure ratio. 2+3

5. Define mean temperature of heat addition (T_m). Show that the efficiency of the Rankine cycle is a function of T_m. Why reheat is needed in Rankine cycle? 1+2+2

6. A refrigeration used R – 134a as the working fluid and operates on an ideal vapour compression cycle between 0.14 MPa and 0.8 MPa. If the mass flow rate of the refrigeration is 0.06 kg/s. Determine 3+2
(a) the rate of heat removal from the refrigerated space, and
(b) the COP.

GROUP C
(Long Answer Type Questions)

Answer any *three* questions. 3×15 = 45

7. (a) Prove that the maximum work W_{max} is obtained by using one finite body at temperature T and a thermal energy reservoir at temperature T_0 ($T > T_0$) is given by 7

$$W_{max} = C_p\left[T - T_0 - T_0 \ln\frac{T}{T_0}\right].$$

(b) Calculate the decrease in available energy when 25 kg of water at 95 °C mixes with 35 kg of water at 35 °C, the pressure being taken as constant and the temperature of the surroundings being 15 °C (C_p of water = 4.2 kJ/kg K). 8

8. (a) Derive the energy balance equation for steady flow through a control volume with a single steam inlet and single steam outlet. 5
(b) Air at a temperature of 15 °C passes through a heat exchanger at a velocity of 30 m/s, where its temperature is raised to 700 °C. It then enters a turbine with the same velocity of 80 m/s and expands until the temperature falls to 650 °C on leaving the turbine. The air is taken at a velocity of 45 m/s to a nozzle where it expands until the temperature falls to 450 °C. If the air flow rate is 2 kg/s. Calculate 10
(i) the rate of heat transfer to the air in the heat exchanger,
(ii) the power output from the turbine assuming no heat loss, and
(iii) the velocity at exit from the nozzle, assuming no heat loss.
Take the enthalpy of air as in C_pt, where C_p is the specific heat equal to 1.005 kJ/kg K and t is the temperature.

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9. (a) Prove that a device that violates the Kelvin-Planck's statement of second law also violates the Clausius statement of the second law and vice versa. 5
(b) Derive Maxwell's equations. 5
(c) Air enters a compressor at ambient conditions of 96 kPa and 17 °C with a low velocity and exits at 1 MPa, 327 °C, and 120 m/s. The compressor is cooled by the ambient air at 17 °C at a rate of 1500 kJ/min. The power input to the compressor is 300 kW. Determine the mass flow rate of air and the rate of entropy generation. 5

10.(a) Explain the vapour compression cycle with the help of T-s and p-h diagrams. Can this Cycle is reversible? If not, why? 5
(b) A F-12 vapour compressor refrigeration system has a condensing temperature of 50 °C and evaporating temperature of 0 °C. The refrigeration capacity is 7 tonnes. The liquid leaving the condenser is a saturated liquid and compression is isentropic. Determine: 10
(i) the refrigerant flow rate;
(ii) the power required to run the compressor;
(iii) the heat rejected by the plant;
(iv) COP of the system.
The properties of F-12 are:

Temp.(°C)	Pressure (bar)	h_f (kJ/kg)	h_g (kJ/kg)	s_f (kJ/kgK)	s_g (kJ/kgK)
50	12.2	84.868	206.298	0.30	0.68
0	3.08	36.022	187.4	0.142	0.696

The enthalpy at the end of isentropic compression = 210 kJ/kg

11.(a) What do you understand by steam rate and heat rate? 2
(b) Draw a Reheat Regenerative Rankine Cycle on T-s coordinate for reducing both the above rates. 3
(c) Consider a regenerative cycle using steam as the working fluid. Steam leaves the boiler and enters the turbine at 4 MPa, 400 °C. After expansion to 400 kPa, some of the steam is extracted from the turbine for the purpose of heating the feed water in an open feed water heater. The pressure in the feed water heater is 400 kPa, and the water leaving it is saturated liquid at 400 kPa. The steam not extracted expands to 10 kPa. Determine the cycle efficiency. 10

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