(b) Steam is supplied to a turbine at 30 bar and 350°C. The turbine exhaust pressure is 0.08 bar. The main condensate is heated regeneratively in two stages by steam bled from the turbine at 5 bar and 1 bar respectively. Calculate masses of steam bled off at each pressure per kg of steam entering the turbine and theoretical thermal efficiency of the cycle. 7 + 8

2013
APPLIED THERMODYNAMICS

Time Allotted : 3 Hours *Full Marks* : 70

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. Choose the correct alternatives for the following : 10 × 1 = 10

   i) A certain quantity of fluid in a cylinder bounded by a moving piston constitutes a/an

      a) closed system b) open system

      c) steady flow system d) isolated system.

   ii) Which of the following is the basic of temperature measurement ?

      a) Zeroth law of thermodynamics

      b) First law of thermodynamics

      c) Second law of thermodynamics

      d) Third law of thermodynamics.

iii) Which of the following parameters changes during an isothermal process ?

a) Pressure

b) Temperature

c) Internal energy

d) Pressure × Specific volume.

iv) Two reversible engines operate between 1200 K and T_2 K and T_2 K and 300 K. Both the engines will have the same efficiency if T_2 is

a) 700 K b) 600 K

c) 500 K d) None of these.

v) The correct relationship from the following is

a) $Tds = dH - Vdp$ b) $Tds = dH - Pdv$

c) $Tds = dH + Vdp$ d) $Tds = dv - Vdp$.

vi) The triple point of water is

a) 54·35 K b) 113·84 K

c) 216·55 K d) 273·16 K.

vii) The parameter that decreases with an increase in steam pressure is

a) sensible heat

b) latent heat of vaporisation

c) specific entropy

d) boiling point.

viii) Work done in a free expansion process is

a) zero b) minimum

c) maximum d) negative.

ix) Change of enthalpy of a system is the heat supplied at

a) constant pressure b) constant temperature

c) constant volume d) constant entropy.

x) Adiabatic volume expansion is associated with

a) decrease in both P and T

b) increase in both P and T

c) decrease in P but increase in T

d) increase in P but decrease in T.

GROUP – B

(Short Answer Type Questions)

Answer any *three* of the following. 3 × 5 = 15

a) What do you mean by entropy generation ?

b) Prove that the maximum work W_{max} obtainable from two finite bodies at a temperature T_1 and T_2 is $W_{max} = C_p \left(\sqrt{T_1} - \sqrt{T_2}\right)^2$. The source temperature is T_1 and sink temperature is T_2 . $(T_1 > T_2)$. 2 + 3

Prove that the maximum reversible work by an open system steady flow process exchanging heat only with surrounding is $W_{max} = \left(B_1 + \frac{mV_1^2}{2} + mgZ_1\right) - \left(B_2 + \frac{mV_2^2}{2} + mgZ_2\right)$,

where B_1 , B_2 are Keenan function.

4. A pump steadily delivers water at volumetric flow rate of $0{\cdot}05\ m^3$/sec through a pipe of diameter 18 cm located 100 m above the inlet pipe which has a diameter of 15 cm. The pressure is nearly equal to 1 bar at both the inlet and the exit, and the temperature is nearly equal to 1 bar at both the inlet and the exit, and the temperature is nearly constant 20°C throughout. Determine the power required by the pump. Take $g = 9{\cdot}81\ m/s^2$.

5. An air-water vapour mixture enters an adiabatic saturator at 30°C and leaves at 20°C, which is adiabatic saturation temperature. The pressure remains constant at 100 kPa. Determine the relative humidity and the humidity ratio of the inlet mixture.

   Given :

   a) Saturated vapour pressure of water at 20°C = 2·3 kPa

   b) Enthalpy of saturated steam at 30°C = 2556·3 kJ/kg

   c) Latent heat of water at 20°C = 2454·1 kJ/kg.

6. Derive a relationship between volumetric efficiency, clearance ratio and pressure ratio. Prove that $\eta_v = 1 + C - C\left(p_2/p_1\right)^{1/n}$.

GROUP – C

(Long Answer Type Questions)

Answer any *three* of the following $3 \times 15 = 45$

7. a) State the first law for a closed system undergoing a cycle.

   b) Define internal energy and show that energy is a property of a system.

   c) In a steady flow process, the fluid flows through a machine at the rate of 15 kg/min. Between the entrance and exit of the machine, the relevant data regarding the working fluid is at inlet, the velocity is 5 m/s, pressure is 100 kPa and specific volume is $0{\cdot}45\ m^3$/kg, at outlet the velocity is 8 m/s, pressure is 700 kPa and specific volume is $0{\cdot}125\ m^3$/kg. The working fluid leaves the machine with internal energy 160 kJ/kg greater than that at entrance and during the process 7200 kJ/min of heat is lost to the surrounding. Assuming entrance and exit pipes to be at the same level, calculate the shaft work and the ratio of inlet pipe diameter to outlet pipe diameter. 3 + 4 + 8

8. a) Prove that the COP of a reversible refrigerator operating between two given temperatures is the maximum.

b) A heat engine is working between the starting temperature limits of T_1 and T_2 of two bodies. Working fluid flows at rate m kg/s and has specific heat at constant pressure as C_p. Determine the maximum obtainable work from engine.

c) A reversible heat engine operates between two reservoirs at 827°C and 27°C. Engine drives a Carnot refrigerator maintaining – 13°C and rejecting heat to reservoir at 27°C. Heat input to the engine is 2000 kJ and the network available is 300 kJ. How much heat is transferred to refrigerant and total heat rejected to reservoir at 27°C ? 4 + 4 +

9. a) Air at 15°C and 1·05 bar occupies 0·02 m^3. The air is heated at constant volume until the pressure is 4·2 bar and then cooled at constant pressure back to the original temperature. Calculate the net heat flow to or from the air and the net entropy change. Sketch the process on a T-s diagram.

b) A heat engine is supplied heat at the rate of 1700 kJ/min. and gives an output of 9 kW. Determine the thermal efficiency and the rate of heat rejection.

c) Prove that the net entropy generation of a system is always positive. 6 + 5 +

10. Draw the p-v and T-S diagram of Otto cycle, diesel cycle, dual cycle and give examples of each cycle's practical applications. What are the assumptions we make to simplify air cycle analysis ?

In a diesel cycle, maximum and minimum temperatures are 1500 K and 300 K respectively. Exhaust temperature is 700 K and minimum pressure is 1 bar. Calculate :

i) maximum pressure

ii) compression ratio and

iii) air standard efficiency. 5 + 5 + 5

11. a) In a Rankine cycle, the steam at inlet to turbine is saturated at a pressure of 35 bar and the exhaust pressure is 0·2 bar. Determine

i) pump work

ii) turbine work

iii) Rankine efficiency

iv) condenser heat flow

v) dryness at the end of expansion

vi) specific steam consumption (steam rate)

vii) work ratio.