Name : .....

Roll No. : .....

Invigilator's Signature : .....

CS/B.Tech/OLD/SEM-2/ME-201/2013

2013

MECHANICAL SCIENCE

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 any *ten* of the following :

$10 \times 1 = 10$

i) The first law of thermodynamics furnishes the relationship between

a) heat, work, and properties of the steam

b) various properties of steam

c) various thermodynamic processes

d) heat and internal energy.

ii) The most effective way of increasing efficiency of a Carnot engine is to

a) increase higher temperature

b) decrease higher temperature

c) increase lower temperature

d) decrease lower temperature.

iii) The Hagen-Poisseullie relation as applied to flow through pipes is applicable for

a) laminar flow b) turbulent flow

c) unsteady flow d) compressible flow.

iv) Mercury is used in barometers on account of its

a) negligible capillary effect

b) high density

c) very low vapour pressure

d) low compressibility.

v) A stagnation point is a point in fluid flow where

a) pressure is zero

b) velocity of flow is zero

c) total energy is zero

d) total energy is maximum.

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

e) volume does not change.

vii) A refrigerator and a heat pump operate between the same temperature limits. If the COP of the refrigerator is 4, the COP of the heat pump would be

a) 3 b) 4

c) 5 d) cannot be specified.

viii) A Pitot tube is used for the measurement of

a) state of flow

b) density of fluid

c) velocity of fluid

d) volumetric flow rate of fluid.

ix) Streamlines, pathlines, and streaklines are identical when

a) the flow is uniform b) the flow is steady

c) the flow velocities do not change with time

d) the flow is neither steady or uniform.

x) Which fluid does not experience shear stress during flow ?

a) Pseudoplastic b) Dilatant

c) Inviscid d) Newtonian.

xi) Dynamic viscosity has dimensions of

a) MLT^{-2} b) $ML^{-1}T^{-1}$

c) $ML^{-1}T^{-2}$ d) $M^{-1}L^{-1}T^{-1}$.

xii) The expression $\int P\mathrm{d}V$ may be applied for obtaining work of

a) non-flow reversible process

b) steady-flow reversible process

c) steady-flow non-reversible process

d) steady-flow adiabatic reversible process.

xiii) The latent heat of vaporization at critical point is

a) less than zero b) greater than zero

c) equal to zero d) all of these.

xiv) Reynolds number is expressed as

a) $\rho v.D/\mu$ b) v^2D/ρ

c) $v\rho^2D/v$ d) v^2D^2/v.

GROUP – B
(Short Answer Type Questions)

Answer any *three* of the following. $3 \times 5 = 15$

2. a) What is a quasi-static process ?

   b) Derive an expression for displacement work in a process where PV^n = constant 2 + 3

3. a) Explain the first law of thermodynamics for a closed system undergoing a change of state.

   b) Explain the thermodynamic equilibrium. 2 + 3

4. a) In a cold winter night, you've switched on the electric room-heater. What kind of interaction it will be if the system is

      i) the heater

      ii) air in the room

      iii) heater and room air

      iv) the whole room including the heater ?

   b) A few potatoes taken in a borosilicate glass bowl is placed in an infrared oven and baked at a temperature of 450K. Can you model it a heat transfer or work transfer ? 3 + 2

5. a) The heat added to a closed system during a certain reversible process is given by $Q = \alpha T + \beta T^2$ where, α and β are constants. Derive the expression from change of entropy of the system as heating changes its temperature from T_1 to T_2.

b) A heat engine operates on Carnot cycle and executes 630 cycles per minute. It absorbs heat from two reservoirs – one at 1200K and the other at 800K–while discharging 3200 kJ of heat per minute to a sink at 400K. If it develops 100 kW, calculate the ratio of heat drawn Q_{1200K}/Q_{800K} from the two reservoirs. 2 + 3

6. The fluid flow is given by $V = x^2.yi + y^2zj - (2xyz + yz^2)\ k$, where V represents velocity vector and i, j, k represents unit vectors along x, y, z axes respectively. Show that this is the case of a possible steady incompressible flow. Calculate the velocity and acceleration at (2, 1, 3). 5

7. a) Explain the no-slip condition of a viscous fluid.

b) State and prove Pascal's law of hydrostatics. 2 + 3

GROUP – C

(Long Answer Type Questions)

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

8. a) State the Clausius inequality and explain its significance.

b) Define the coefficient of performance of refrigerator and a heat pump. Establish the relation : $COP_{HP} = COP_R + 1$.

c) A refrigeration plant for food storage operates as a reversed Carnot heat engine cycle. The store is to be maintained at a temperature of -5°C and the heat transfer from the store to the cycle is at the rate of 5 kW. If the heat is transferred from the cycle to the atmosphere at a temperature of 25°C, calculate the power required to drive the plant. 5 + 4 + 6

9. a) Consider a gas contained in a piston-cylinder assemble as the system The gas is initially at a pressure of 500 kPa and occupies a volume of 0.2 m^3. The gas is taken to the final state where pressure is equal to 100 kPa, by the following two different processes.

   i) The volume of the gas is inversely proportional to the pressure

   ii) The process follows the path PV^n = constant, where n = 1.4

   Calculate the work done by the gas in each case.

   b) A turbine operates under steady-flow conditions.

   The steam enters the turbine at the following state :

   Pressure 1.2 MPa, temperature = 188°C,

   enthalpy = 2785 $kJ.kg^{-1}$, velocity = 33.3 $m.s^{-1}$ and elevation = 3m.

   The steam leaves the turbine at the following state :

   Pressure 20 kPa, enthalpy = 2512 $kJ.kg^{-1}$,

   velocity = 100 $m.s^{-1}$ and elevation = 0m.

   If the rate of steam flow through the turbine is 0.42 $kg.s^{-1}$, what is the power output of the turbine in kW ?

   Heat is lost to the surroundings at the rate of 0.29 $kJ.kg^{-1}$.

   c) At the inlet to a certain nozzle, the enthalpy of the fluid passing is 3000 $kJ.kg^{-1}$ and the velocity is 60 $m.s^{-1}$. At the discharge end, the enthalpy is 2762 $kJ.kg^{-1}$. The nozzle is horizontal and there is negligible heat loss from it. If the specific volume at the nozzle exit is 0.498 $m^3.kg^{-1}$, find the exit area of the nozzle.

3 + 3 + 4 + 5

10. a) How does a heat pump differ from a refrigerator ?

    b) A household refrigerator is maintained at a temperature of 2°C. Every time the door is opened, warm material is placed inside, introducing an average of 420 kJ, but making only a small change in the temperature of the refrigerator. The door is opened 20 times a day, and the refrigerator operates 15% of the ideal COP. The cost of work is Rs. 5 per kWh. What is the monthly bill for the refrigerator ? The atmosphere is 30°C.

    c) 10 kg of wet steam at a pressure of 2.5 bar is contained in a rigid tank of 6.058 m^3 volume. The tank is heated until the steam becomes dry saturated. Determine the final pressure and the heat transfer to the tank.

3 + 5 + 7

11. a) Derive a expression for the efficiency of an air-standard Otto cycle in terms of its compression ratio.

    b) A reversible heat engine operates between heat reservoirs *A*, *B*, and *C*. The engine receives equal quantities of heat from reservoir *A* and *B* at temperatures T_a and T_b respectively and rejects heat to reservoir *C* at temperature T_c. If the efficiency of the above mentioned engine is α times the efficiency of another reversible engine operating only between the reservoir *A* and *C* at temperatures T_a and T_c, prove that

$$\alpha = \tfrac{1}{2}\left[T_a / T_b \right] \left[(T_b - T_c)/(T_a - T_c) + (T_b / T_a) \right]$$

7 + 8

12. a) State and explain Newton's law of viscosity.

    b) Draw the rheological curve for a class of Newtonian and non-Newtonian fluids.

c) The space between two large flat and parallel walls 25mm apart is filled with a liquid of absolute viscosity of 0.7 $N.s.m^{-2}$. Within this space a thin flat plate 250mm × 250mm is towed at a velocity of $150mm.s^{-1}$ at a distance of 6mm from one wall, the plate and its movement being parallel to the walls. Assuming linear variations of velocity between the plate and the walls, determine the force exerted by the liquid on the plate.

d) A venturimeter has inlet and throat diameters of 300mm and 150mm. Water flows it at the rate of 0.065 $m^3.s^{-1}$ and the differential gage is deflected 1.2m. The specific gravity of the manometric liquid is 1.6. Determine the coefficient of discharge of the meter.

$2\frac{1}{2} + 2\frac{1}{2} + 5 + 5$

13. Distinguish between the following : 5×3

i) Laminar and turbulent flow

ii) Compressible and incompressible fluid

iii) Static pressure and stagnation pressure

iv) Viscous and inviscid fluid

v) Newtonian and non-Newtonian fluid.

14. Write short notes on any *three* of the following : 3×5

a) Pitot tube

b) Orifice meter

c) Point function and path function

d) Streamline, streakline, and pathline.