

# MECHANICAL ENGINEERING

*Time Allowed: 3 hours*

*Maximum Marks: 200*

*Candidates should attempt any five questions  
Assume suitable data if necessary and indicate them clearly.*

*All questions carry equal marks*

*For air  $R = 0.287 \text{ kJ/kg K}$ ;*

*$c_p = 1.005 \text{ kJ/kg K}$ ;  $\gamma = 1.4$ .*

*Assume  $1 \text{ bar} = 1 \text{ kfg/cm}^2$ , if necessary.*

## PAPER – I

1. (a) A tank containing 40 kg of water, initially at  $40^\circ\text{C}$ , has one inlet and one exit with equal mass flow rates. Water enters the tank at  $40^\circ\text{C}$  at the rate of 200 kg/hr. Energy is removed from the water at the rate of 8 kW by means of a cooling coil immersed in the water. The water is well mixed by a mechanical stirrer that the water temperature in the tank is uniform. The power input to the water from the stirrer is 0.3 kW. Derive an expression for the variation of water temperature in the tank with time. The specific heat of water is  $4.2 \text{ kJ/kg. K}$ . Neglect kinetic and potential energy effects.
- (b) A closed system executes a reversible cycle 1-2-3-4-5-6-1 consisting of six processes. During processes 1-2 and 3-4 the system receives 1000 kJ and 800 kJ of heat, respectively, at constant temperatures of 500 K and 400 K, respectively. Processes 2-3 and 4-5 are adiabatic expansions in which the system temperature is reduced from 500 K to 400 K and from 400 K to 300 K, respectively. During process 5-6 the system rejects heat at a constant temperature of 300 K. Process 6 - 1 is an adiabatic compression process. Determine the work done by the system during the cycle and the thermal efficiency of the cycle.
2. (a) A rigid vessel is divided into two parts A and B by means of a frictionless, perfectly conducting piston. Initially, part A contains  $0.4 \text{ m}^3$  of air (ideal gas) at 10 bars pressure and part B contains  $0.4 \text{ m}^3$  of wet steam at 10 bars. Heat is now added to both parts until all the water in part B is evaporated. At this condition the pressure in part B is 15 bars. Determine the initial quality of steam in part B and the total amount of heat added to both parts.
- (b) A parallel shaft gearbox receives 800 kW through the high speed shaft but, owing to friction, delivers 784 kW through the low speed shaft. Heat transfer takes place from the outer surface of the gearbox to the environment at a rate given by  $hA(T_b - T_o)$  where  $h = 0.2 \text{ kW/m}^2. \text{ K}$ ,  $A = 2 \text{ m}^2$  and  $T_o$ , the environment temperature, equals 288 K. The outer surface temperature of the gearbox,  $T_b$ , is uniform. Determine the irreversibility rate for the gearbox in kW assuming steady state operation.
3. (a) Atmospheric air at  $40^\circ\text{C}$  dry bulb temperature and 55% relative humidity is passed over a cooling coil at the rate of  $600 \text{ m}^3/\text{min}$ . At exit from the coil the air is saturated and its temperature is  $8^\circ\text{C}$ . The condensate also leaves at  $8^\circ\text{C}$ . Determine the amount of condensate leaving the coil per minute and the refrigeration required in kW. The specific heat of superheated steam may be assumed to be  $1.88 \text{ kJ/kg. K}$ . Solve the problem without the use of Psychometric chart.
- (b) A vapor compression heat pump is driven by a power cycle having a thermal efficiency of 25%. For the heat pump, refrigerant 12 is compressed from saturated vapor at 2.0 bars to the condenser pressure of 12 bars. The isentropic efficiency of the compressor is 80%. Saturated liquid enters the expansion valve at 12 bars. For the power cycle, 80% of the heat rejected by it is transferred to the heated space which has a total heating requirement of  $500 \text{ kJ/min}$ .

Determine the power input to the heat pump compressor. The following data for refrigerant 12 may be used.

Pressure bar	Temperature °C	Enthalpy, Liquid	k/kg Vapor	Entropy, Liquid	k/kg. K Vapor
2.0	-12.53	24.57	182.07	0.0992	0.7035
12.0	49.31	84.21	206.24	0.3015	0.6799

Vapor specific heat at constant pressure = 0.7 kJ/kg. K

4. (a) In a Brayton cycle gas turbine power plant the minimum and maximum temperatures of the cycle are 300 K and 1200 K. The compression is carried out in two stage of equal pressure ratio with intercooling of the working fluid to the minimum temperature of the cycle after the first stage of compression. The entire expansion is carried out in one stage only. The isentropic efficiency of the compressors is 0.85 and that of the turbine is 0.9. Determine the overall pressure ratio that would give the maximum net work per kg working fluid.  
Derive the expression you use.  $\gamma = 1.4$ .
- (b) Air enters a constant-area combustion chamber at a March number of 0.25 with a total pressure of 5.5 bars. Combustion gas leaves the chamber with a March number of 0.35. Neglecting friction and the mass of the fuel, determine the drop in total pressure of air in the combustion chamber.  
Assume  $C_p/C_v = 1/35$ .
5. Steam enters the first stage of a turbine at 100 bars, 500°C and expands isentropically to 10 bars. It is then reheated to 500°C and expanded in the second stage to the condenser pressure of 0.1 bars. Steam is bled from the first stage at 20 bars and fed to a closed feed water heater. Feed water leaves the closed heater at 100 bars, 200°C (enthalpy = 856.8 kJ/kg) while the condensate exits as saturated liquid at 20 bars. This condensate is supplied to the open heater into which steam is bled at 4 bars pressure. Saturated liquid at 4 bars exits from the open heater and enters the closed heater. The condensate from condenser enters the open heater. The net output of the turbine is 50 MW.  
Assuming the turbine and pump processes to be isentropic determine the mass of steam bled at each feed water heater per kg of steam entering the first stage, the mass of steam entering the first stage per second, and the thermal efficiency.
6. (a) A chemical reaction is being carried out at constant pressure in a packed bed between two coaxial cylinders with radii of 1.2 cm and 1.8 cm. The entire inner wall is at a uniform temperature of 500°C and there is almost no heat transfer from this surface. The reaction releases heat at a uniform rate of 500 kW/m<sup>3</sup> through out the reactor. The effective thermal conductivity of the packed bed is 0.55 W/m. K. Determine the temperature of the outer wall.
- (b) Determine the radiant heat exchange in W/m<sup>2</sup> between two large parallel steel plates of emissivities 0.8 and 0.5 held at temperatures of 1000 K and 500 K, respectively, if a thin copper plate of emissivity 0.1 is introduced as a radiation shield between the two plates.  
 $\sigma = 5.67 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4$ .
7. Derive an expression for the effectiveness of a parallel flow heat exchanger in terms of the number of transfer units, NTU, and the capacity ratio  $C_{\min}/C_{\max}$   
In a parallel-flow double-pipe heat exchanger water flows through the inner pipe and is heated from 20° C to 70° C. Oil flowing through the annulus is cooled from 200° C to 100° C. It is desired to cool the oil to a lower exit temperature by increasing the length of the heat exchanger. Determine the minimum temperature to which the oil may be cooled.
8. (a) Calculate the diameter and speed of the runner of a Kaplan turbine developing 6000 kW under an effective head of 5 m. Overall efficiency of the turbine is 90%. The diameter of the boss is 0.4, times the external diameter of the runner. The turbine speed ratio is 2.0 and flow ratio 0.6. What is the specific speed of the turbine?
- (b) When a fluid flows over a flat plate, the velocity profile within the boundary layer may be assumed to be

$$V_x = V_o \left[ \frac{3}{2} \left( \frac{y}{\delta} \right) - \frac{1}{2} \left( \frac{y}{\delta} \right)^3 \right] \text{ for } y \leq \delta$$

and  $V_x = V_o$  for  $y \geq \delta$

Where  $V$  is a constant and the boundary layer thickness  $\delta$  is a function of  $x$  given by

$$\delta = 5 \left( \frac{\mu x}{\rho V_o} \right)^{1/2}$$

Here  $\mu$  and  $\rho$  denote the viscosity and density of the fluid, respectively. Derive an expression for the variation of  $V$  across the boundary layer.

# MECHANICAL ENGINEERING

**Time Allowed: 3 hours**

**Maximum Marks: 200**

*Candidates should attempt Question 1 in Section A, any TWO in Section B and any TWO in Section C.*

*Question 1 is of short answers type, limiting answer of each part to 30 words.*

## PAPER - II

### SECTION A

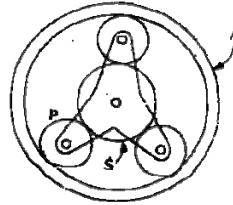
1.
  - (a) Distinguish between Austempering and Martempering of steel.
  - (b) What do you understand by the term proof stress? What is the value of strain for 0.2 percent proof stress?
  - (c) Expand the following (i) CPM           (ii) PERT
  - (d) Give two methods of joining two pieces of metal by heating alone.
  - (e) What is Scleroscope?
  - (f) What is 'killed' steel?
  - (g) What is 'Lost Wax' method?
  - (h) What is Kennedy's theorem?
  - (i) What are Mitre wheels?
  - (j) What is 'hunting' of a governor?
  - (k) In which machine tool the Whitworth Quick return mechanism is used?
  - (l) What is coefficient of restitution?
  - (m) Kinetically equivalent systems must satisfy three requirements, give any two of them.
  - (n) The method which gives the acceleration of the elements of a connecting rod of a slider crank mechanism by a simple graphical form is known as
  - (o) Indicate the arc welding process which is more suitable for overhead welding. Justify your answer.
  - (p) What is a dummy activity in network models?
  - (q) Expand the abbreviations:   (i) DNC           (ii) CNC
  - (r) Expand the abbreviations:   (i) ECM           (ii) HSS
  - (s) Name four parts of an automobile where cast iron is used.
  - (t) How sand cores are supported?

(2 × 20)

### SECTION - B

2.
  - (a) A motor drives a main shaft by means of a flat belt. The diameters of the pulleys on the motor shaft and the main shaft are 450 mm and 750 mm respectively. Another pulley of diameter 500 mm drives a counter shaft having a pulley of diameter 700 mm. The pulley of diameter 500 mm is mounted on the main shaft. If the slip on each drive is 3 percent, calculate the speed of counter shaft if motor runs at 1400 rpm.
  - (b) In an epicyclic gear of the sun and planet type shown in Fig. 1 the pitch circle diameter of the annular wheel 'A' is to be nearly equal to 216 mm, and the module  $s$  4 mm. When the annular wheel is stationary, the spider which carries three planet gears 'P' of equal size, has to make one revolution for every five revolutions of the driving spindle carrying 'S' gear. Determine the number of teeth on all the wheels and also the exact pitch circle diameter of 'A'

Fig. 1



3. (a) A 'U' tube as shown in Fig. 2 contains a liquid of density one  $\text{kg/m}^3$ . Determine the equation of motion and find the natural frequency of the liquid column.

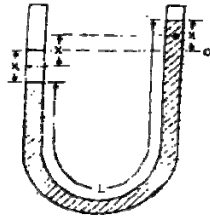


Fig. 2

- (b) The arms of a Porter governor are pivoted on the governor axis and are each 250 mm long. Mass of each ball is 0.5 kg and mass of sleeve is 2 kg. The arms are inclined at an angle of  $30^\circ$  to the governor axis in the lowermost position, of the sleeve. Lift is equal to 50 mm. Determine the force of friction if the speed at the moment the sleeve starts lifting from the lowermost position is the same as the speed at the moment it falls from the uppermost position.
- 20
4. (a) Do you think that a plane stress system gives rise to a plane strain system always? Give reasons for your answer. Three principal stresses  $\sigma_{11}$ ,  $\sigma_{22}$ ,  $\sigma_{33}$ , are acting on the three faces of a cube respectively. Express the resulting three principal strains in terms of the principal stresses.
- 10
- (b) A one mm diameter steel wire is wound around a copper tube with external and internal diameters of 140 mm and 120 mm respectively, to increase the strength of the tube against internal pressure. Find, what initial tension must be given to the wire, so that maximum allowable stresses for the tube and wire materials namely 90 and 200 mega pascals respectively are reached simultaneously. Assume ' $\mu$ ' for copper and steel to be 0.3 and wire winding as a thin cylinder. Modulus of elasticity for copper and steel may be assumed as  $10^6$  and  $2 \times 10^6$  mega pascals respectively. The tube is open at the ends.

30

### SECTION - C

5. (a) Give the percentages of carbon in the following
- Low carbon steels
  - Medium carbon steels
  - High carbon steels
- 6
- (b) Give the percentages of the alloying elements in
- Low alloy steels
  - High alloy steels
- 4
- (c) All cast irons contain at least six elements. Name these elements.
- 6
- (d) When will you recommend carburizing of steel? Give the salient features of the process.

- |    |                                                                                                                                                                                                                                                                                                                                                                                                               |    |
|----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
|    | (e) Give the composition and use of the following alloys                                                                                                                                                                                                                                                                                                                                                      | 12 |
|    | (i) Bronze                                                                                                                                                                                                                                                                                                                                                                                                    |    |
|    | (ii) Duralumin                                                                                                                                                                                                                                                                                                                                                                                                |    |
|    |                                                                                                                                                                                                                                                                                                                                                                                                               | 12 |
| 6. | (a) Name five casting defects. How they are caused and what are the remedies?                                                                                                                                                                                                                                                                                                                                 | 15 |
|    | (b) Explain the following forging operations                                                                                                                                                                                                                                                                                                                                                                  |    |
|    | (i) Drawing out                      (ii) Upsetting                                                                                                                                                                                                                                                                                                                                                           | 5  |
|    | (c) How is acetylene stored?                                                                                                                                                                                                                                                                                                                                                                                  | 10 |
|    | (d) What is the principle of resistance welding? What are the various components of the joint resistance?                                                                                                                                                                                                                                                                                                     | 10 |
| 7. | (a) Ahuja furniture company manufactures tables and chairs using wood and labour only. Wood for one table is 30 units and for chair is 20 units and the labour spent on table is 5 units and for chair is 10 units. Total units of wood available are 300, and of labour are 110. The unit profit for chair is Rs. 8 and for table is Rs. 6. How many chairs and tables should be made to get maximum profit? | 20 |
|    | (b) A store sells 5200 cases of a cold drink per year. The supplier charges Rs. 100 for each delivery, regardless of how many cases have been ordered; delivery always occurs the day after ordering and the average carrying cost is Rs. 10.40 per unit per year. Find the number of cases per order.                                                                                                        | 20 |