MECHANICAL ENGINEERING Paper I

Time Allowed: Three Hours **Maximum Marks: 200**

INSTRUCTIONS

Please read each of the following instructions carefully before attempting questions.

Candidates should attempt **FIVE** *questions in all. Question No,* **1** *is compulsory.*
Out of the remaining **SIX** *questions attempt any* **FOUR** *questions.*
The number of marks carried by a part of a question are indicated against it.
Answers must be written in **ENGLISH** *only.*
Assume suitable data, if necessary, and indicate the same clearly.
For air R = 0.287 *kJ/kg-K,* C_p = 1.005 *kJ/kg-K,* γ = 1.4, M = 28.97 *kg/kg-mole, Universal gas constant* R = 8.314 *kJ/kg mole-K.*
Unless otherwise mentioned, symbols and notations have their usual standard meanings.
Neat sketches may be drawn, wherever required.
Attempts of questions shall be counted in chronological order. Unless struck off, attempt of a question shall be counted even if attempted partly.
Any page or portion of the page left blank in the answer book must be clearly struck off.
A psychrometric chart is attached to this question paper for necessary use by the candidate.

1. (a) If u = f (T,v) and h = f(T,p) prove that 15

$$du = C_v dT + \left(\frac{T\beta}{k} - P\right)dv$$

$$dh = C_p.dT + (1 - T\beta).dP$$

(b) A house is to be maintained at 25° C in summer as well as in winter. For this purpose, it is proposed to use a reversible device as a refrigerator in summer and as a heat pump in winter. The ambient temperature is 40°C in summer and 3°C in winter. The energy losses as heat from the roof and the walls is estimated at 5 kW per degree Celsius temperature difference between the room and the ambient conditions. Calculate the power required to operate the device in summer and in winter. 10

(c) A cylindrical water tank of 50 cm diameter and 120 cm height is initially filled with water. The top of the tank is open to the atmosphere. A discharge plug is fitted at the bottom of the tank. When the plug near the bottom of the tank is pulled out, a water jet streams out of the tank with a jet diameter of 1 cm. The mean velocity of the jet is given by v = $\sqrt{2gh}$ where h is the height of the water in the tank measured from the centre of the hole. Determine how long will it take for the water level in the tank to drop to 60 cm level from the bottom. Neglect the distance between the bottom of the tank and the centre of the hole compared to the total water height. 15

2. (a) What are the advantages and disadvantages of using hydrogen as an I.C. Engine fuel? Explain one method by which hydrogen can be used in C.I. Engine. 10

(b) Mention three problems related to environment that are created by exhaust emissions from the I.C. Engine. What are the major exhaust emissions? 6

(c) What is delay period? Mention the various factors affecting the delay period. Discuss any four of them. 10

(d) Discuss the advantages and disadvantages of using LPG in S.I. Engine. 6

(e) Air at 25 kPa and 230 K enters a turbojet engine with a velocity of 250 m/sec. The pressure ratio across the compressor is 12. The turbine inlet temperature is 1400 K and the pressure at the nozzle exit is 25 kPa. The diffuser, compressor, turbine and nozzle processes are isentropic and there is no pressure drop for flow through the combustor. Under steady state operating conditions, determine (i) the velocity at the nozzle exit, and (ii) the pressures & temperatures at each state. State the assumptions made. Draw the line diagram indicating all the components & show the processes on a T- s diagram.

3. (a) Heat losses from the windows are to be reduced by covering them from inside with a polystyrene insulation (k_{ins} = 0.027 W/m-K). Consider application of 25 mm-thick windows (k_w = 1.4 W/m-K). The contact resistance between the glass and the insulation may be approximated as ($R''_{t,c}$ =0.002 m²-K/W), while the convection coefficient at the outside surface of the window is nominally losing heat (h_0 = 20 W/m²-K).

With the insulation, the convection coefficient at the inner surface is h_i = 2 W/m²-K; without the insulation it is h_i = 5 W/m²-K. '

(i) What is the percentage reduction in heat loss associated with the use of insulation?

(ii) If the total surface area of the windows is A_s = 12 m², what are the heat losses associated with insulated and uninsulated windows for interior and exterior temperatures of $T_{\infty,i}$ = 20°C and $T_{\infty,0}$ = –12°C?

(iii) If the home is heated by a gas furnace operating at an efficiency of η_f = 0.80 and the natural gas is priced at C_g = Re. 1 per MJ, what is the daily saving associated with covering windows for 12 hours? 15

(b) Water at 20° C flows normal to the axis of a circular tube with a velocity of 1.5 m/sec. The diameter of the tube is 25 mm. Calculate the average heat transfer coefficient if the tube surface is maintained at a uniform temperature of 80° C. Also estimate the heat transfer rate per unit length of the tube. Properties of water at

$$T_f = \frac{20 + 80}{2} = 50°C$$

are

Specific heat, Cp = 4.1813 kJ/kg-K

Kinematic viscosity, $\nu = 0.568 \times 10^{-6}$ m²/sec

Thermal conductivity, k = 0.6395 W/m-K

Prandtl number, Pr = 3.68

Density, ρ = 990 kg/m³

Dynamic viscosity of water (μ_w) at 80° C = 3.5456×10^{-4} kg/m-sec μ_∞ at 20°C = 1.006×10^{-3} kg/m-sec. Use the relation

$$\overline{Nu} = \left(0.4\,\mathrm{Re}^{0.5} + 0.06\,\mathrm{Re}^{2/3}\right)\mathrm{Pr}^{0.4}\left(\frac{\mu_w}{\mu_\infty}\right)^{1/4}$$ 10

(c) An electrically heated sphere of 1.5 cm diameter is cooled in a quiescent medium of air at 315 K. In order to maintain the surface temperature of the sphere at 385 K, estimate the amount of heat to be supplied by the electrical heater.

D = 1.5×10^{-2} m T_∞ = 273 + 20 = 293 K

The properties of air at $\frac{315 + 385}{2}$ = 350 K are

Kinematic viscosity, v = 2.076×10^{-5} m²/sec

Prandtl number, Pr = 0.697, Thermal conductivity, k = 003 W/m-K

Coefficient of thermal expansion, $\beta = 1/T_f = 2.86 \times 10^{-3} K^{-1}$

Use the relationship

$$\overline{Nu} = 2 + 0.4 Ra_D^{1/4}$$ 5

(d) The configuration of a furnace can be approximated as an equilateral triangular duct which is sufficiently long that the end effects are negligible. The hot wall is maintained at T_1 = 1000 K and has an emissivity ε_1 = 0.8. The cold wall is at T_2 = 500 K and has an emissivity ε_2 = 0.8. The third wall is reradiating zone for which Q_3 = 0. Calculate the net radiation flux leaving the hot wall. 10

4. (a) How can the solar energy be used to obtain refrigeration effect? Explain with a

neat and clean sketch.
A geothermal well at 130° C supplies heat at a rate of 100,500 kJ/h to an absorption refrigeration system. The environment is at 30° C and the refrigerated space is maintained at –22° C. Determine the maximum possible heat removal from the refrigerated space. 15

(b) Obtain an expression for the capacity of a refrigeration system (tonnage) in terms of the rate of upper and lower pressure limits, expansion index (n), V_C/V_S (V_C = clearance volume and V_S = swept volume), N (rpm), V_C, V_1 (specific volume at the inlet to compressor) and the refrigeration effect ($h_1 - h_4$).
If the pressure ratio is 6.5, n = 11, V_C/V_S = 0.025, N = 900, V_S = 600 cc, V_1 = 0.078 m^3/kg and refrigeration effect = 150 kJ/kg, calculate the capacity of the system. 15

(c) (i) List the various refrigeration and air-conditioning controls and their functions. 4

(ii) Explain adiabatic saturation and thermodynamic wet-bulb temperature. When are the adiabatic saturation and wet-bulb temperatures equivalent for atmospheric air? 3

(iii) What is metabolism? What is the range of metabolic rate for an average man? Why are we interested in the metabolic rate of the occupants of a building when we deal with heating and air-conditioning? 3

5. (a) Show that for a flow governed only by gravity, inertia and pressure forces, the ratio of rates of flow in two dynamically similar systems equals to the 5/2 power of the length ratio. 8

(b) The rate of flow Q of a liquid having mass density ρ and viscosity μ is to be measured by means of an orifice meter. The diameter of the orifice meter is d which is installed in a pipeline of diameter D. The pressure drop across the orifice plate is ΔP. Obtain the expression for Q by using the method of dimensional analysis. 14

(c) Derive Prandtl boundary layer equations for steady two-dimensional laminar incompressible flow. Explain the significance of Prandtl boundary layer equations in comparison with Navier Stokes equations. 14

(d) The $1/7^{th}$ power law for turbulent boundary layer is not applicable very near to the solid boundary. Do you agree? If yes, why? Justify your answer. 4

6. (a) What do you mean by Fanno flow? Show that the upper and lower branches of a Fanno curve represent subsonic and supersonic flows respectively. Prove that at the maximum entropy point Mach number is unity and all processes approach this point. 15

(b) Derive the Rankine-Hugoniot equations for flow through a normal shock. How does a normal shock differ from an oblique shock? Mention two useful applications of a normal shock. 15

(c) Mention two most important characteristics of turbulent flow. Explain the concept of Prandtl's mixing length hypothesis. 10

7. (a) The clearance volume of a single cylinder air compressor is 10% of the swept volume. The compressor has a bore of 120 mm and a stroke of 152 mm and runs at 400 rpm. Suction conditions are 1 bar and 24°C and the delivery pressure is 10 bar. Compression and re-expansion curves follow the law $PV^{1.3}$ = constant. Calculate the diagram volumetric efficiency, the rate of air delivery, and the power input required to drive the compressor assuming a mechanical efficiency of 74%. Take R = 0.287 kJ/kg- K. 10

(b) Air enters the compressor of a gas turbine at 100 kPa, 300 K with a volumetric flow rate of 5 m^3/sec. The air is compressed in two stages to 1200 kPa with intercooling to 300 K between stages at a pressure of 350 kPa. The turbine inlet temperature is 1400 K and the expansion occurs in two stages with reheat to 1340 K between the stages at a pressure of 350 kPa. The compressor and

turbine stage efficiencies are 87% and 85% respectively. Determine (i) the thermal efficiency of the cycle, (ii) the back work ratio, (iii) the net power developed in kW. Draw the schematic diagram of the cycle and indicate the process on T-s diagram. Assume effectiveness of the regenerator as 80%. Assume C_p = 1.0045 kJ/kg-K for air and gas. 20

(c) The turbine rotor has a mean blade ring diameter of 500mm and the blade angles are equal. The nozzle angle is 20° and the steam leaves the nozzles with a velocity of 900m/sec. Assuming a blade friction factor of 0.85, determine the (i) best blade angles, (ii) turbine speed in rpm, (iii) steam consumption rate in kg/hr if the turbine generates 10kW, and (iv) maximum blade efficiency. 10

8. (a) Discuss with the help of neat sketches the main difference in principle of operation between a hydraulic coupling and a hydraulic convertor. 8

(b) Mention three possible causes of trouble in case of a centrifugal pump if
(i) No water is delivered, and
(ii) Pump absorbs higher power. 6

(c) A centrifugal pump is required to discharge 600 litres of water per second and develop a head of 15 m when the impeller rotates at 750 rpm. The manometric efficiency is 80%. The loss of head in the pump due to fluid resistance being assumed to be 0.027 V^2 m of water, where V is the velocity with which water leaves the impeller. Water enters the impeller without shock or whirl and the velocity of flow is 3.2 m/sec. Determine (i) the impeller diameter and outlet area, (ii) the blade angle at the outlet edge. 14

(d) Laboratory tests are required to be performed on a 1/10 scale model to find the best design for a hydraulic turbine. The turbine is required to develop 30,000 kW under a net head of 50 m running at 300 rpm. The head available at the laboratory is 12 m. Determine
(i) the corresponding speed,
(ii) power, and
(iii) discharge.
The overall efficiency is 88%. 12

MECHANICAL ENGINEERING Paper II

Time Allowed: Three Hours **Maximum Marks: 200**

INSTRUCTIONS

Please read each of the following instructions carefully before attempting questions:

Candidate should attempt **FIVE** *questions in all. Question No.* **1** *in Section* **A** *is compulsory.*

Out of the remaining, attempt **TWO** *from Section-***B** *and* **TWO** *from Section—***C**.

All questions carry equal marks. The number of marks carried by a part of a question is indicated against it.

Answer must be written in **ENGLISH** *only.*

Unless other-wise mentioned, symbols and notations have their usual standard meanings.

Neat sketches may be drawn, wherever required.

All parts and sub-parts of a question are to be attempted together in the answer book.

Attempts of questions shall be counted in chronological order. Unless struck off, attempt of a question shall be counted even if attempted partly.

Any page or portion of the page left blank in the answer book must be clearly struck off.

SECTION—A

1. Answer all 20 parts of the question each part carries 2 marks.

(a) Two hollow shafts of same diameter are used to transmit same power. One shaft is rotating at 1000 rpm while the other at 1200 rpm. What will be the nature and magnitude of the stress on the surfaces of these shafts? Will it be the same in two cases or different? Justify your answer.

(b) What is auto frettage?
How does it help in increasing the pressure carrying capacity of a thick cylinder?

(c) What are statically determinate and indeterminate beams? Illustrate each case through examples.

(d) Define: (i) Kinematic chain (ii) Mechanism.

(e) Distinguish between the functions of Flywheel and Governor.

(f) For a free viscous damped vibration, state the condition for critical damping. The system has mass 'm', spring stiffness 'k' and damping coefficient 'c'.

(g) Sketch a castle nut used for locking device. State two specific advantages of this locking device.

(h) Between a flat belt drive and V-belt drive for the same coefficient of friction, arc of contact and allowable tension in the belts, which one will have more power transmission capability? Give reason to your answer.

(i) In Journal bearings distinguish between "Bearing characteristic number" and "Bearing Modulus".

(j) Why is annealing done? What does the following represent in case of tool steels:
(i) T 103 (ii) T35Mn_2MO45.

(k) Name any four materials used for making wire drawing dies, and explain the application of each of them.

(l) Classify the advantages of powder metallurgy process in terms of economics and capabilities of the process, and properties of the parts made.

(m) What is gating system? Name and show the various elements of a gating system by means of a diagram.

(n) What is standard marking of grinding wheel? What each parameter indicates?

(o) Name any four flushing methods used in EDM process. What type of flushing method is recommendable in cases of very small size hole drilling?

(p) What is the principle of angle dekkor auto collimator? What is its application?

(q) What are the six categories of queueing models as per Kendall notation?

(r) With the help of quantity-cost curve, explain the significance of Economic Order Quantity (EOQ). What are the limitations of using EOQ formula?

(s) What is a critical path? Why is the critical path of such importance in large

project scheduling and control? Can a critical during the course of project?

(t) To print the values of array a^ in the order given below, write the source code in FORTRAN and in 'C':

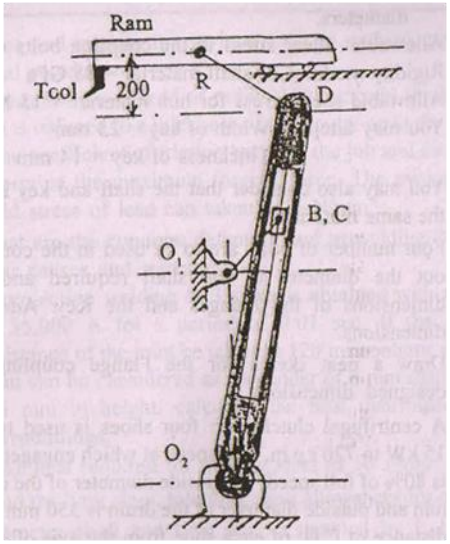
a_{11}	a_{21}	a_{31}	a_{41}	a_{51}
a_{12}	a_{22}	a_{32}	a_{42}	a_{52}
a_{13}	a_{23}	a_{33}	a_{43}	a_{53}
a_{14}	a_{24}	a_{34}	a_{44}	a_{54}

SECTION—B

2. (a) A mild steel shaft of 50 mm diameter is subjected to a bending moment of 1.5 kN-m and torque T. If the yield point of steel in tension is 210 MPa, find the maximum value of torque without causing yielding of the shaft material according to
(i) Maximum Principal stress theory and
(ii) Maximum Shear stress theory. 20

(b) A timber beam 15 cm wide and 20 cm deep carries a uniformly distributed load over a span of 4 m and is simply supported. If the permissible stresses are 30 N/mm^2 longitudinally and 3 N/mm^2 transverse shear, calculate the maximum load which can be carried by the timber beam. 20

3. (a) The dimensions of different links of the crank and slotted lever quick-return mechanism shown in Figure are given below:
O_1O_2 = 700 mm, O_1B = 250 mm
O_2D = 1250 mm, DR = 350 mm.



The crank O_1B rotates at 40 r.p.m. in the counter clockwise direction and at the present instant of consideration makes an angle of 45° with the vertical. Determine:
(i) Velocity of the ram R which moves in a horizontal direction.
(ii) Angular velocity of link O_2D. 20

(b) An intermediate parallel shaft 'Z' is used for gearing together two shafts 'X' and 'Y' which are co-axial to each other. The gear wheel connecting 'X' and 'Z' have a module of 2 and those connecting 'Z' and 'Y' a module of 3. The speed of 'Y' is to be about, but less than, 1/12 that of 'X'. If the two pinions have 24 teeth each, find suitable numbers of teeth for the gears and pinions, the actual velocity ratio and the corresponding distance of shaft 'Z' from shaft 'X'. 20

4. (a) (i) Design and draw a cast iron flange coupling for a mild steel shaft transmitting 80 kW at 220 r.p.m. with the following specifications:
Allowable shear stress in the shaft = 40 MPa
Permissible angle of twist < 1° in a length of 20 diameters.
Allowable shear stress in the coupling bolts = 30 MPa

Rigidity modulus of shaft material = 85 GPa
Allowable shear stress for hub material = 15 MPa
You may adopt, Width of key = 25 mm; Thickness of key = 14 mm
You may also consider that the shaft and key are made of the same material.
Four number of bolts are to be used in the coupling. Find out the diameter of the shaft required and the main dimensions of the Flanges and the Key. Adopt suitable dimensions.

(ii) Draw a neat sketch for the Flange coupling with designed dimensions. 20

(b) A centrifugal clutch with four shoes is used to transmit 15 kW to 720 r.p.m. The speed at which engagement begins is 80% of full speed. The inside diameter of the drum is 325 mm and outside diameter of the drum is 350 mm. The radial distance of C.G. of each shoe from the axis of shaft is 120 mm. The radial clearance between the shoe and the rim is 10 mm. The pressure exerted on the shoe during engagement is 0.1 MPa. The coefficient of friction between shoe lining and the drum is taken as 0.25. Determine:

(i) Mass of each shoe.

(ii) Size of the shoe if the angle subtended by shoe at centre is 60°.

Also design the helical spring used in the shoes taking the safe shear stress of spring material as 600 MPa and modulus of rigidity of the material as 80 kN/mm^2. Use the spring index of 6. 20

SECTION—C

5. (a) How are powders produced in powder metallurgy process? Name and explain the various steps in making parts from metal powder. 15

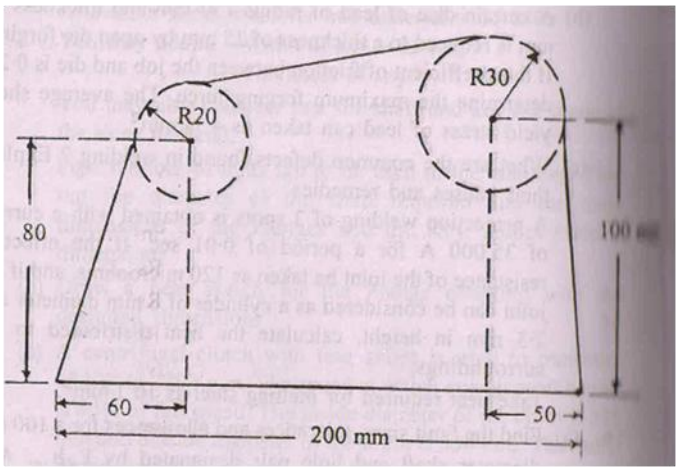
(b) A certain disc of lead of radius 150 mm and thickness 50 mm is reduced to a thickness of 25 mm by open die forging. If the coefficient of friction between the job and die is 0.25, determine the maximum forging force. The average shear yield stress of lead can taken as 4 N/mm^2. 10

(c) What are the common defects found in welding? Explain their causes and remedies.
A projection welding of 3 spots is obtained with a current of 35,000 A for a period of 0.01 sec. If the effective resistance of the joint be taken as 120 microohms, and if the joint can be considered as a cylinder of 6 mm diameter and 2.5 mm in height, calculate the heat distributed to the surroundings.
Take heat required for melting steel as 10 J/mm^3. 15

6. (a) Find the limit sizes, tolerances and allowances for a 100 mm diameter shaft and hole pair designated by F_8h_{10}. Also specify the type of fit that the above pair belongs to.
Given: 100 mm diameter lies in the diameter step range of 80 – 120 mm. The fundamental deviation for shaft designation f is $-5.5\ D^{0.41}$.
The values of standard tolerances for grades of IT8 and IT10 are 25i and 64i respectively. Also, indicate the limits and tolerance on a diagram. 15

(b) An HSS tool is used for turning operation. The tool life is 1 hr. when turning is carried at 30 m/min. The tool life will be reduced to 2.0 min if the cutting speed is doubled. Find the suitable speed in RPM for turning 300 mm diameter so that life is 30 min. 10

(c) Prepare part program to machine the contour shown in the figure using APT on CNC milling machine.



Material: MS
Thickness: 80mm 15

7. (a) Explain the need for sales forecasting. How are forecasting methods classified? The past data about the load on a machine centre is as given below:

Month	Load, Machine-Hours
1	585
2	611
3	656
4	748
5	863
6	914
7	964

(i) If a five month moving average is used to forecast the next month's demand, compute the forecast of the load on the centre in the 8th month.
(ii) Compute a weighted three month moving average for the 8th month, where the weights are 0.5 for the latest month, 0.3 and 0.2 for the other months, respectively. 10

(b) What is break-even analysis? How is it useful to the manager?
For a particular product, the following information is given:
Selling price per unit: Rs. 100
Variable cost per unit: Rs. 60
Fixed costs : Rs. 10,00,000
Due to inflation the variable costs have increased by 10% while fixed costs have increased by 5%. If the break-even quantity is to remain constant by what percentage should the Sales price be raised? 15

(c) Prepare a flow chart and write a program in FORTRAN to compute the stresses required in the following problem: For a two dimensional stress system, a point in a member is subjected to normal stresses σ_x and σ_y on two mutually perpendicular planes accompanied with shear stress τ_{xy}. Compute the normal and shear stresses on all the planes making angles from 0 to 180° with intervals of 0.10° with plane of σ_x. Also find the principal stresses based on the maximum and minimum of the normal stresses obtained on all the planes. 15