MECHANICAL ENGINEERING PAPER I

Time allowed: 3 hours **Maximum marks: 300**

INSTRUCTIONS

Each question is printed both in Hindi and in English.
Answers must be written in the, medium specified in the Admission.
Certificate issued to you, which must be stated clearly on the cover of the answer-book in the space provided for the purpose.
No credit will be given for the answers written in a medium other than that specified in the Admission Certificate.
Candidates should attempt Questions **1** *and* **5** *which are compulsory and any* ***THREE*** *of the remaining questions selecting at least* ***ONE*** *question from each Section.*
All questions carry equal marks.
If any data is considered insufficient, assume suitable value.
Newton may be converted to kg using the equality 1 kilonewton (1 kN) =100 kg, if found necessary.

Section A

1. Answer any three of the following: (Each answer should not exceed 200 words):

20 x 3 = 60

(a) (i) Define a general case of forces acting on a rigid body. State clearly and precisely the equations of equilibrium for this body. How do these equations change when applied to a particle? 8

(ii) A smooth hollow cylinder of radius r open at both ends rests on a smooth horizontal plane. Two smooth spheres of weights W_1 and W_2 and radii r_1 and r_2, respectively are placed inside the cylinder, with the larger sphere (radius r_2) resting on the horizontal plane as shown in Fig. 1.
Determine the minimum weight W of the cylinder that will prevent the cylinder from tipping over. 12

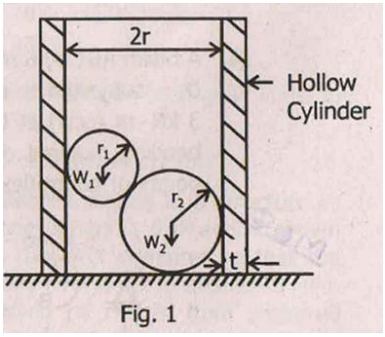

Fig. 1

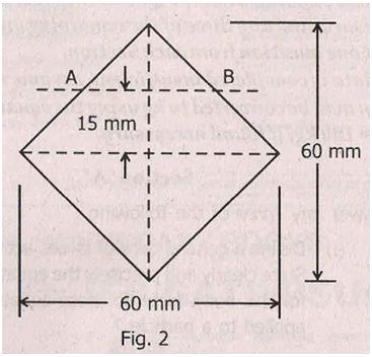

Fig. 2

(b) (i) A beam is of square section with diagonals 60 mm long, vertical and horizontal, as shown in Fig. 2. Shear force at a particular section is 5 kN. What is the shear stress at layer AB as shown? 15

(ii) A beam ABCD, 6 m long, hinged at both ends A and D, is subjected to moments 6 kN-m (cw) at B and 3 kN-m (ccw) at C as shown in Fig. 3. Sketch the bending moment diagram of the beam. How many points of contraflexure are there in the beam? 5

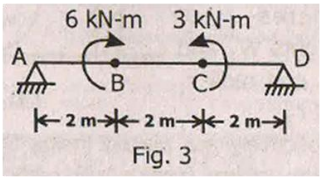

Fig. 3

(c) (i) In an orthogonal crystal structure with lattice parameters $a \neq b \neq c$, draw the direction [2 1 2]. 10

(ii) Show that in a hexagonal close-packed structure, atomic packing factor is 0.74. Take dimension $c = 1.633\ a$. 10

(d) (i) What is meant by whirling or critical speed of shaft? 4

(ii) Calculate the whirling speed in case of a rotating steel tube simply supported in short bearings 2 m centre- to-centre. The external and internal diameters of the tube are 35 mm and 25 mm, respectively. The weight of steel may be taken as 78 kN/m^3 and Young's modulus of elasticity for steel is 200 GPa. 16

2.(a) (i) State why gear teeth have to be undercut. 4

(ii) The following data refers to two 20° involute spur gears in mesh externally:

Velocity ratio = 3

Module = 3 mm

Addendum = 1.1 module

If the pinion rotates at 120 r.p.m., find -

(1) the minimum number of teeth on each gear wheel to avoid interference;

(2) The number of pairs of teeth in contact. 16

(b) A plate is riveted to a channel section in a structure as shown in Fig. 4. An eccentric load of 12.5 kN acts as shown on the plate. Determine the rivet diameter so that the maximum shear stress in any rivet is not to exceed 40 MPa. Diameter of the rivet should be chosen from preferred series.

Preferred rivet diameters (in mm): 12, 14, 16, 18, 20, 22, 24, 27, 30, 33, 36, 39, 42, 48. 40

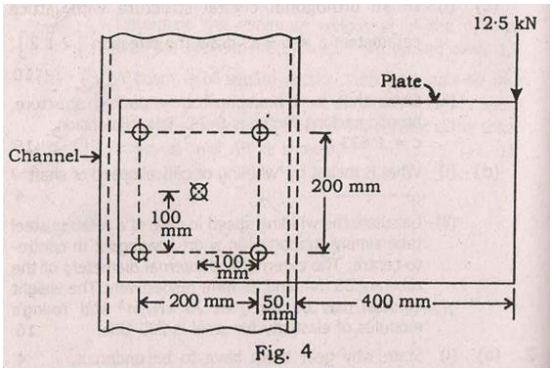

Fig. 4

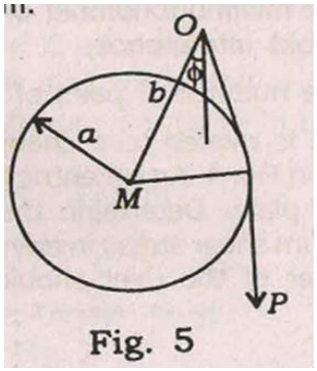

Fig. 5

3.(a) (i) A homogeneous ball of weight Q and radius a as well as weight P are suspended by cords from a point O as shown in Fig. 5. The distance OM is b. Find the inclination φ of OM with the vertical when the system is in equilibrium. 8

(ii) A body A of weight 10 kN is connected to an another body B of weight 50 kN, resting on a smooth table of weight 200 kN through an inextensible thread, passing over a freely rotating pulley mounted on a corner of the table. Find the vertical component of the reaction of the ground on the table when the bodies A and B are in motion. Does the reaction change with time? The system is shown in Fig. 6. 12

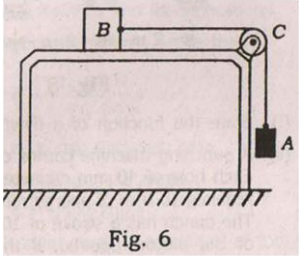

Fig. 6

(b) Stresses on two perpendicular planes, at a point, are given in Fig. 7. What are the directions of principal planes with respect to plane BC? What are the principal strains on principal planes, if E = 67 kN/mm^2, ν = 0.33? 20

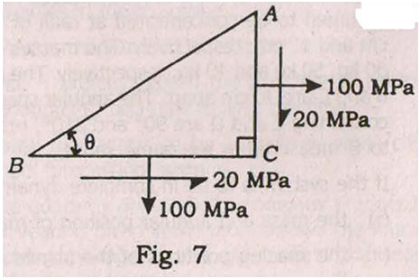

Fig. 7

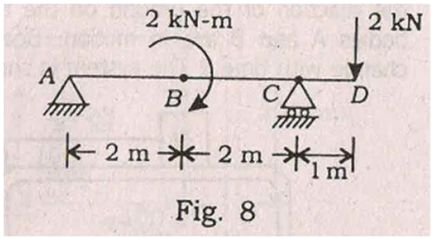

Fig. 8

(c) A beam ABCD, 5 m long, is supported at A and C as shown in Fig. 8. It carries a point load of 2 kN at end D, and a moment of 2 kN-m (cw) at B. What is the flexural rigidity (EI) of the beam, if deflection at D is not to exceed 1 mm? 20

4.(a) (i) State the function of a flywheel. 4

(ii) A punching machine carries out 5 holes per minute. Each hole of 40 mm diameter in 40 mm thick plate requires 10 N-m of energy/mm^2 of the sheared area. The punch has a stroke of 100 mm. Find the power of the motor required, if the mean speed of the flywheel is 25 m/s. If the total fluctuation of speed is not to exceed 4% of the mean speed, determine the mass of the flywheel. 16

(b) A shaft carries four rotating masses A, B, C and D in sequence along its axis. The masses A, B, C and D are assumed to be concentrated at radii of 12 cm, 16 cm, 8 cm and 10 cm, respectively. The masses of B, C and D are 30 kg, 50 kg and 40 kg, respectively. The planes containing B and C are 30 cm apart. The angular spacing of the planes containing C and D are 90° and 210°, respectively relative to B measured in the same sense. If the system is to be in complete dynamic balance, find

(i) the mass and angular position of mass A;

(ii) The spacing positions of the planes containing A and B. 20

(c) Give chemical reactions and temperature ranges in the cases of cyaniding, carbonitriding and nitriding processes. What is the serious problem encountered in nitriding process? In which process is case hardened thickness maximum? 20

Section' B'

5. Attempt any three of the following:

(a) (i) Describe the properties of tungsten carbide as a cutting tool material and its applications. 5

(ii) In orthogonal machining, prove that

$$\tan\varphi = \frac{r_c \cos\alpha}{1 - r_c \sin\alpha}$$

where, r_c = chip thickness ratio α = back rake angle φ = shear angle 8

(iii) Explain 'sudden-death mechanism' of tool failure. 4

(iv) What are extreme-pressure lubricants? 3

(b) (i) Define the terms 'rose reamer' and 'feed in milling'. 2 + 2

(ii) Name four independent variables and three dependent variables in metal cutting. 5

(iii) What is the function of stepper motor? 5

(iv) With a sketch, explain the principle of working and variations of bed-type milling machine. 9

(c) (i) Name the factors to be considered while choosing a good forecasting system. 5

(ii) The quarterly demand of a company product for past six years is given in the table below. The four-quarter moving average is also given. Find the seasonality index for 3rd quarter. 15

Year	Quarter	Demand x 10s units	Four-Quarter Moving Average
1	Q_1	0.5	
	Q_2	0.8	
	----------	----------	0.875
	Q_3	2.1	
	----------	----------	0.925
	Q_4	0.1	
	----------	----------	1.025
2	Q_1	0.8	
	----------	----------	1.1
	Q_2	1.1	
	----------	----------	1.1
	Q_3	2.4	
	----------	----------	1.125
	Q_4	0.1	
	----------	----------	1.15
3	Q_1	0.9	
	----------	----------	1.25
	Q_2	1.0	
	----------	----------	1.25
	Q_3	2.8	
	----------	----------	1.20
	Q_4	0.1	
	----------	----------	1.15
4	Q_1	0.7	
	----------	----------	1.10
	Q_2	1.0	
	----------	----------	1.10
	Q_3	2.6	
	----------	----------	1.125
	Q_4	0.1	
	----------	----------	1.125
5	Q_1	0.8	
	----------	----------	1.10
	Q_2	1.0	
	----------	----------	1.10
	Q_3	2.5	
	----------	----------	1.15
	Q_4	0.1	
	----------	----------	1.20
6	Q_1	1.0	
	----------	----------	1.25
	Q_2	1.2	
	----------	----------	1.275
	Q_3	2.7	
	Q_4	0.2	

(d) (i) Explain briefly the MTM. Which basic motions does it recognize? Suggest its applications and also describe the sequence of steps of procedure to implement the same. 12

(ii) The following costs were incurred in a year in a company. Classify them into various quality costs. 8

S. No.	Head	Cost (Rs)
1	Incoming material inspection	20,000
2	Training of personnel	10,000
3	Warranty	45,000
4	Process planning	15,000
5	Scrap	13,000
6	Quality laboratory	30,000
7	Rework	25,000
8	Allowances	10,000
9	Complaints	14,000

6.(a) (i) What do you mean by 'inter-changeable manufacture' and 'combination set'? 8

(ii) What is the difference between a plug gauge and a ring gauge? 4

(iii) Discuss, with figure(s), pneumatic gauges and their applications. 8

(b) (i) How does inventory level depend on service level? 5

(ii) 4000 spare parts are required annually. A set-up cost of Rs 100 and a carrying cost of 25% per year is charged on the item cost of Rs 320. The production facility is open for 5 days per week and 50 weeks per year. The lead time of this product is 9 days and the standard deviation of the demand is 2 units per day. The company wants to have a 95% service level for this spare parts.

(1) If the company were using continuous review system (Q-system) of inventory control, compute the order quantity and reorder level. Interpret the results.

(2) If the company were using periodic review system (P-system) of inventory control, give the specific decision rule. 15

(c) (i) Briefly state the intermittent process layout problem. 5

(ii) Five departments are currently arranged in the following manner:

1	2	3
4	5	

New products have been added and the movements between the departments have changed substantially since the existing arrangement was made. The movement between the departments is on rectangular path. The monthly number of trips, cost/trip and distance of each trip are given below:

	Between the Departments									
Item	1-2	1-3	1-4	1-5	2-3	2-4	2-5	3-4	3-5	4-5
Trips/month	100	200	100	400	200	500	300	100	100	200
Cost/trip	12	34	56	34	57	25	17	43	63	52
Distance units	1	2	2	3	1	1	2	2	1	1

(1) Calculate the monthly cost of travel between the departments.

(2) How much is the saving in monthly cost of travel between the departments, if departments 1 and 3 are interchanged?

(3) A one-time cost of Rs 22,500 is associated with interchanging the positions of departments 1 and 3, and if this cost is to be recovered within two months, should the change be made? 15

7.(a) (i) Name the various alloying elements used with tungsten for GTAW. Give the approximate content of any two used in GTAW process. Enumerate applications of GTAW process. 4

(ii) Define the term 'keyholding' used in laser welding. 3

(iii) What is 'dip transfer' in GMAW? 3

(iv) Write the differences between coining and embossing. 4

(v) What are the advantages of isothermal forging? 3

(vi) What is the difference between extrusion and drawing? 3

(b) (i) Define 'slack'. 5

(ii) A project consists of six activities. The precedence relationship of activities and the three time estimates of completion of activities in days are tabulated below:

S. No.	Activity	Immediate Precedent Activity	Estimate Time of Completion (days)		
			Optimistic	Pessimistic	Most likely
1	A	-	0.5	1.5	1.00
2	B	A	1.0	3.0	2.00
3	C	B	2.0	2.0	2.00
4	D	A	2.9	4.1	2.75
5	E	A	1.5	4.0	1.63
6	F	C, D, E	3.0	6.0	3.75

(1) Draw the arrow diagram.

(2) Which of the six activities is most uncertain?

(3) What is the probability that the project will be completed within 10 days? Refer the SND chart (Cumulative Distribution Function for the Standard Normal Distribution) attached at tin end. 15

(c) (i) A company uses a decision rule to determine production level in *t*-th period, as under:

$$P_t = P_t - 1 + [A(F_t - P_t{-}1)]$$

where P_t, F_t denote production and forecast for *t*-th period and A is smoothing constant.

(1) Given the information in the table below, find the appropriate production level for period 2 using a smoothing constant of 0.5:

Period *t*	Production level	Forecast
1	36000	
2		42000
3		48000

(2) Assuming that actual production for period 2 will be equal to the value as determined in case (1) above, determine the production levels for period 3 using (A) chase, (B) level and (C) intermediate strategies. 10

(ii) A company manufactures two products A and B. The manufacturing and marketing data for the two products is given below:

Departments	Product A	Product B	Capacity
Welding	2.0 man-hr	2.5 man-hr	1000 man-hr
Machines	3.0 man-hr	1.5 man-hr	1200 man-hr
Assembly	1.5 man-hr	4.0 man-hr	1200 man-hr
Profit	Rs 120	Rs 100	

(1) Formulate the problem.

(2) Find the product mix that will maximize the profit. 10

8.(a) (i) Describe the applications of abrasive-jet machining. 5

(ii) What are the differences between electrolyte and dielectric? 5

(iii) What is wire EDM process? Explain the reasons for its popularity. 10

(b) (i) With a figure, explain '3-2-1' method of location. 10

(ii) Draw leaf jig and mention its advantages. 10

(c) (i) Give the steps for sequencing n jobs through 2 machines for minimum elapsed time. 5

(ii) A foreman wants to process four different jobs on three machines A, B and C in his shop. The order of machining for all the jobs is fixed, i.e., A, B and C. The processing time for all the jobs are given in the table below:

Job	Machine		
	A	B	C
1	40	10	10
2	50	15	5
3	30	8	15
4	25	20	10

Decide the optimal sequence for the jobs to minimize the elapsed time between start of the first job to completion of the last job. 15

MECHANICAL ENGINEERING PAPER II

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If any data is considered insufficient, assume suitable value.
Wherever coordinate diagrams/graphs are to be drawn, these are to be plotted only on the answer book and NOT on separate graph sheets.

Section A

1. Answer any three of the following (Answers to each of the parts should be in about 200 words only): **20 X 3 = 60**

(a) Define 'Availability' with regard to a system. What is the other term by which this property is also referred to? Also derive an expression for "A" (the availability) for a reversible cycle in which heat 'Q' is withdrawn. The cycle works between temperatures T and T_0.

(b) Describe briefly one - dimensional isentropic flow. Represent isentropic compression (diffusers) and expansion (nozzles) processes in a Temperature (T) - Entropy (S) coordinate diagram with nomenclature.

(c) Draw the Meridional view of a single stage axial flow fan and a multistage axial flow compressor. Describe an axial flow fan with its flow configuration.

(d) The thermal conductivity of a hollow sphere of inside radius (R_i) and outside radius (R_0) is given by

$$K = K_i + (K_0 - K_i)\left(\frac{T - T_i}{T_0 - T_i}\right)$$

where, T_i = Inner surface temperature
T_0 = Outside surface temperature.

Prove that

(i) The heat flow rate is given by

$$Q = 4\pi R_i R_0 \left(\frac{K_i + K_0}{2}\right)\left(\frac{T_i - T_0}{R_0 - R_i}\right)$$

(ii) Also determine the heat loss from a spherical shell whose D_i = 25 m and covered with 30 cm of insulation. The thermal conductivity of insulation is 0.3 W/mK and 0.2 W/mK at inner and outer surface temperatures of 150°C and -15°C respectively.

2.(a) Derive equations for the change in internal energy and entropy of a gas which obeys the van- der Waals equation of state. 15

(b) Define the Joule - Thomson coefficient and prove that for an ideal gas, the value of Joule - Thomson coefficient tends to zero. 10

(c) 2 kg of air is first compressed from state 1 at 13.75 N/cm^2 and 5° C to state 2 at 48 N/cm^2 and 283 °C. It is then throttled to state 3 until its pressure is again 13.75 N/cm^2. Finally it is cooled at constant pressure to state 4 until its volume becomes 50% of that before the cooling process. Determine the net change in entropy. 20
(R = 0.291 N.m/g.K; C_p = 1.004 kJ/kg.K)

(d) Write a short note on Redlich - Kwong equation of state. 15

3.(a) Derive an expression for the Mach number after a normal shock wave occurring in a nozzle. Show the trend of this Mach number, (in the form of an *x-y* plot) with respect to the Mach number value before the shock. 15

(b) Air enters a diffuser with a velocity of 250 m/s and a temperature of 30°C. It leaves with a velocity of 90 m/s,
Neglecting friction and heat transfer determine
(i) exit temperature
(ii) exit pressure if the inlet pressure is 125 kPa and
(iii) Area ratio between the exit and entrance.
Will your answers change if there is friction present?
Explain how. 30

(c) For a circular tube, explain with the help of neat sketches.
(i) Hydrodynamic entry region and hydro-dynamically developed flows.
(ii) Thermal entry region and thermally developed flows. 15

4.(a) An oil is cooled to 100° C in a parallel flow heat exchanger by transferring its heat to cooling water, that leaves the exchanger at 30° C. However, it is now required that the oil must be cooled down to 75° C by increasing the length of heat exchanger, while oil and water flow rates, their inlet temperatures and other dimensions of the exchanger keeping constant. The inlet temperatures of water and oil are 15° C and 150° C respectively.
If the original cooler was 1 meter long, determine
(i) Outlet temperature of water in the new cooler and
(ii) Length of the new cooler. 30

(b) A hot plate of 15 cm^2 area maintained at a temperature of 200° C is exposed to still air at 30° C temperature. When the smaller side of the plate is held vertical, convective heat transfer rate is 14% higher than when the bigger side of the plate is held vertical. Determine the dimensions of the plate. Neglect internal temperature gradient of the plate thickness. Also determine the heat transfer in both the cases. 30
Use the following relations:

$$Nu = 0.59\ (Gr.\ Pr)^{0.25}$$

Take the following properties of air:

Temperature	ρ	C_P	μ	K
°C	kg/m^3	kJ/kg-K	N-s/m^2	W/m-K
30	1.165	1.005	18.6 X 10^{-6}	0.0267
115	0.910	1.009	22.65 X 10^{-6}	0.331
200	0.746	1.026	26 X 10^{-6}	0.0393

Section – B

5. Answer any THREE of the following:

(a) Draw a schematic of a pass-out turbine and explain its working. Represent the relevant process on Enthalpy-Entropy coordinates. 20

(b) How is the best balance of a CI engine often diagrammatically represented by means of the following:

(i) Pie Chart (ii) Bar Chart (iii) Sankey diagram

(iv) Graph with *x*-axis as power output in percentage and *y*-axis as total heat input in percentage. 20

(c) In what way is Velox boiler different from La Mont boiler?

Describe the working of the Velox boiler with a schematic. 20

(d) What are the components to be considered for estimating (i) cooling load, (ii) heating load for an air-conditioning system?

How do you calculate heat gain through ducts for an air-conditioning system? 20

6.(a) (i) Briefly explain "Evaporative Cooling System" which is generally used for big-capacity stationary IC engines, with a schematic diagram.

(ii) List four advantages and disadvantages each of a water-cooled system in a CI engine. 20

(b) Draw a schematic of a Benson boiler and explain its working principle, pointing out its speciality. 20

(c) Explain supersaturated flow in steam nozzles with the help of skeleton. Mollier diagram inserting nomenclatures like dry saturated line, Wilson line and supersaturated zone. List also the five effects of supersaturation in the steam nozzles. 20

7.(a) With the help of schematic and T - s diagrams explain a reheating Rankine cycle. State its advantages over ordinary Rankine cycle and define the reheat factor. 20

(b) Draw a schematic diagram of bubbling bed fluidized boiler and explain its working. 15

(c) The following observations refer to a surface condenser:

Mass flow rate of condensate = 20 kg/min

Mass flow rate of cooling water = 800 kg/min

Mean temperature of condensation = 35° C

Condenser vacuum = 0.95 kg/cm^2

Barometer reading = 1.03 kg/cm^2

Inlet cooling water temperature = 20° C

Outlet cooling water temperature = 30° C

Temperature of the hot well = 29° C

Calculate:

(i) Weight of air per unit volume of condenser.

(ii) Entering condition of steam to the condenser.

(iii) Vacuum efficiency of the condenser. 25

Properties of saturated steam:

T	P	Sp. Vol.		Enthalpy		Entropy	
°C	MPa	m^3/kg		kJ/kg		kJ/kg.K	
		v_f	v_g	h_f	h_g	s_f	s_g
35	0.0056	0.001	25.245	146.56	2565.4	0.5049	8.3543

(Use R = 0.287 kJ/kg.K)

8.(a) The outdoor summer condition for a Bank for one hundred persons is T_{db} = 310 K, and T_{wb} = 300 K. The required inside conditions are T_{db} = 295 K and φ = 60%. The room sensible heat is 4,00,000 kJ/hr. The room latent heat is 2,00,000 kJ/hr. Ventilation requirement per person is 0.0047 m3/hr. The By-pass factor is 0.15. Evaluate:

(i) Grand total heat

(ii) Effective sensible heat factor (ESHF)

(iii) Apparatus dew point

(iv) Volume flow rate of dehumidified air. 40

(b) 20 m^3 of air per minute at 30° C DBT and 60% RH is sensibly cooled to 22° C DBT. Take saturation pressure of water vapour at 30° C and 22° C temperatures to be 0.425 bar and 0.0265 bar respectively. Find heat removed from air. 20 Take atmospheric air pressure P_b = 1 bar.