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 considered insufficient, assume suitable value.
Newton may be converted into 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) What are the different types of vibrations which a mechanical system may be subjected to? How is the damping of a door closer selected of the resilient element for an effective vibration isolation?

(b) Show the various inversions of a kinematic chain with four binary links having two revolute and two prismatic pairs. How do the relative dimensions of the links determine the movability of a four-bar linkage?

(c) How is the displacement diagram drawn for cam with parabolic motion of its follower if the motion is with uniform acceleration? Explain the pressure angle for a cam-follower system. How does pressure angle influence the jamming of the translating follower?

(d) Explain how can a rigid link be replaced by dynamically equivalent massless link with two point masses at its ends? Explain how the correction can be applied to the expression for turning moment on crank-shaft of a reciprocating engine to account for non-compliance of moment of inertia requirement of dynamic equivalence?

2.(a) Use the principle of virtual work to find the magnitude of force B to keep the frame subjected to force P shown in Fig. 1 in static equilibrium. 20

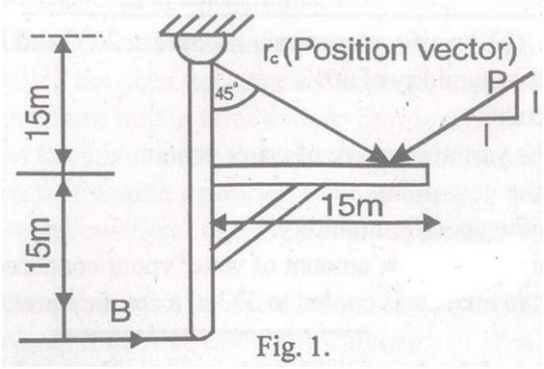

Fig. 1.

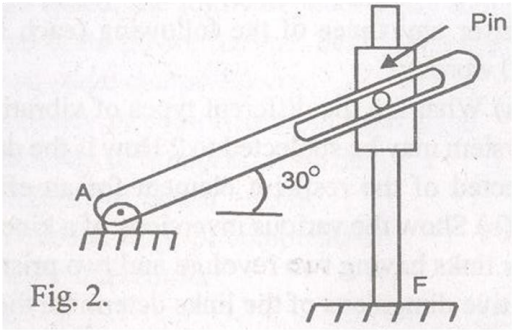

Fig. 2.

(b) Bar AB is connected by pin C to slider D that slides along the fixed vertical rod EF as shown in Fig. 2. Find the velocity and acceleration of the slider D if the bar AB rotates at a constant angular velocity of 10 rad/s in counter clockwise direction. 20

(c) The static deflection of an automobile on its springs is 10 cm. Find the critical speed when the automobile is travelling on a road which can be approximated by a sine wave of amplitude of 8 cm and a wavelength of 15m. Assume the damping factor to be 0.05. Also determine the amplitude of vibration at 75 kmph. 20

3.(a) In the epicyclic gear train shown in Fig. 3, the compound wheels E and F rotate freely on shaft A which carries the planet carrier G. The planets B and C are compounded gears. The number of teeth on each gear are: $N_E = 30$, $N_H = 15$, $N_B = 20$, $N_C = 18$, and $N_D = 68$. The shafts A and K rotate in the same direction at 250 r.p.m. and 100 rpm respectively. Determine the speed of shaft J. 20

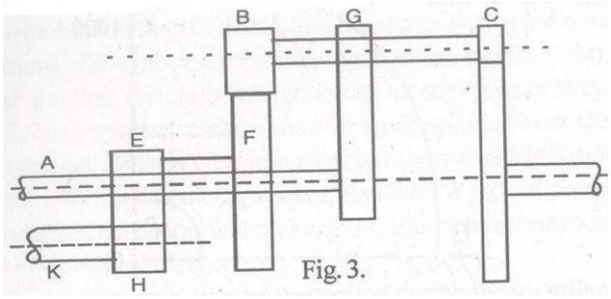

Fig. 3.

(b) A machine punching 3.8 cm diameter holes in a 3.2 cm thick plate does 600 J of work per square cm of sheared area. The punch has a stroke of 10.2 cm and punches 6 holes per minute. The maximum speed of the flywheel at its radius of gyration is 27.5 m/s. Find the mass of the flywheel so that its speed at the same radius does not fall below 24.5 m/s. Also determine the power of the motor driving this machine. Assume velocity of the punching tool to be constant during punching operation. 20

(c) An automobile is traversing along a curved track of 200 m mean radius. Each of the four road wheels have a mass of 80 kg, with a radius of gyration of 0.4 m. The rotating parts of the engine have a mass moment of inertia of 10 kg m2. The crank-shaft rotates in the same direction as the road wheels. The gear ratio of the engine to the back wheels is 5:1. The vehicle has a mass of 3000 kg, and its centre of gravity is 0.5 m above the road level. The width of the track of the vehicle is 1.5 m. Calculate the limiting speed of the vehicle around the curve for all four wheels to maintain contract with the road surface. 20

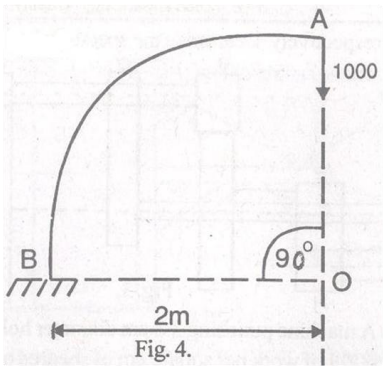

Fig. 4.

4.(a) A steel tube having outside and inside diameters of 10 cm and 6 cm respectively is bent into the form of a quadrant of 2 m radius as shown in Fig. 4. One end is rigidly attached to a horizontal base plate to which a tangent to that end is perpendicular, and the free end supports a load of 1000 N. Determine the vertical and horizontal deflections of the free end under this load using Castiglione's theorem. Given E = 2 x l011 N/m^2. 20

(b) On the outer surface of a closed thick cylinder of diameter ratio 2.5, were fixed strain gauges to measure the longitudinal and circumferential stains. At an internal pressure of

230 MN/m^2 these stains were recorded as 9.18 x 10^{-6} and 369 x 10^{-6} respectively. Determine the values of Young's modulus, modulus of rigidity and Poisson's ratio. 20

(c) A vertical column 6 m high is fixed at the base and a clockwise moment of 1.4 kNm is applied at the top of the column, a horizontal force P is applied to the column at a height of 3 m above the base so as to give a CCW moment.

Determine the value of force P so that the horizontal deflections at the top of the column and at the point of application of P shall be equal (i) when the deflections are on the same side (ii) when the deflections are on the opposite sides of the vertical line through the foot of the column. 20

Section-B

5. Answer any three of the following (each answer should not exceed 200 words): **20 x 3 = 60**

(a) What are the criteria for evaluating machineability? Define and explain machineability index. Explain the characteristics of good cutting tool materials.

(b) Explain the basic scheme of Electric discharge Machining (EDM). What are the critical parameters and limitations of the process of machining in such a machine?

(c) What are the guiding factors in designing an inventory control system? Explain the important assumptions for an Economic Order Quantity (EOQ) model. What is the purpose of sensitivity analysis?

(d) Define the nature of line-balancing system. Explain the role of precedence requirements, cycle time and capacity specifications in line balancing. Define line balance delay.

6.(a) Estimate the power required during the up milling of a mild steel block of 20 mm width using a straight slab cutter with 10 teeth, 75 mm diameter and 10 degree radial rack. The feed velocity of the table is 100 mm/min, the cutter rotates at 60 rpm, and the depth of cut is 5 mm. The coefficient of friction at the rake face and the shear stress of the work material may be assumed to be 0.5 and 400 N/mm^2 respectively. 30

(b) Give a schematic diagram of laser beam machining. Explain the interaction of laser beam with work piece. What are the critical parameters and limitations of laser beam machining? 15

(c) Explain with the help of suitable diagrams the following high energy rate forming processes:

(i) Explosive forming

(ii) Electro-hydraulic forming or Electromagnetic forming. 15

7.(a) Explain in detail the various steps involved in the Simplex method to solve the linear programs in the standard form:

Optimize: $Z = C^T X$;

Subject to: $AX = B$

with $X \geq 0$ where $B \geq 0$.

Explain the introduction of slack variables in the constraint inequalities and show how pivoting is performed in the procedure of Simplex algorithm. 20

(b) In value engineering process, discuss function Analysis System Technique (FAST). How does value engineering help in improving efficiency as well as effectiveness of products, systems and procedures? 20

(c) What are the characteristics of Single sampling plan? Explain the method and define the terms Acceptable Quality Level (AQL), Lot Tolerance percent defective (LTPD), producer's risk and consumer's risk. 20

8.(a) What are the basic step involved in a work sampling procedure? Explain the method to estimate number of observations to achieve the desired confidence and accuracy. 20

(b) What are the purposes and advantages of control charts? Explain the basic features of control charts for variables and the control charts for attributes giving examples of X chart and p chart. 20

(c) What are the advantages of employing jigs and fixtures in mass production? Explain the essential factors which must be considered in designing a jig or a fixture. 20

MECHANICAL ENGINEERING PAPER II

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Section A

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

(a) Draw the diagrammatic sketches of the following systems. Indicate the boundary Label open (or closed) system. Show the directions of heat or work or both by arrows.
(i) Automobile (ii) Pressure cooker (iii) Condenser (iv) Turbine.

(b) Derive Bernoulli's equation from first principles stating the assumptions. Discuss the application of Bernoulli's equation to engineering problems.

(c) Describe adiabatic and isentropic flows through a nozzle.

(d) Discuss the N TU method of designing heat exchangers.

2.(a) A six cylinder four stroke petrol engine has a swept volume of 300 cm^3 per cylinder, a compression ratio of 10, and operates at speed of 3500 rev/min. If the engine is required to develop an output of 75 KW at this speed, calculate the cycle efficiency, the necessary rate of heat addition, the mean effective pressure and the maximum temperature of the cycle. Assume that the engine operates on the Otto cycle and that the pressure and temperature before isentropic compression are 1 bar and 15° C respectively. Take $C_P = 0.718$; $\gamma = 1.4$. 30

(b) If the above engine is a compression ignition engine operating on the Diesel cycle and receiving heat at the same rate, calculate the efficiency, maximum temperature of cycle, cycle efficiency, power output and the mean effective pressure. 30

3.(a) A river brings water into a lake at a rate of 300 m3/s while another takes out a 250 m^3/s. How fast is the level of the lake rising at an instant when the water spread is 250 square kilometers. Assume evaporation and seepage are negligible. 10

(b) A paint brush is to be used with paints of different densities and viscosities. It may be assumed that the thickness (t) of a coat of paint depends on the density (ρ) viscosity (μ) and the average velocity v with which the brush is swept over the surface. Show t is inversely proportional to v and directly proportional to the kinematic viscosity of the paint. 20

(c) Check whether the potential function

$$\varphi = -2(x^2 + 2y - y^2)$$

describes a possible flow of an incompressible fluid. Find the equation of the velocity vector and the equation of lines. 30

4.(a) Explain the critical thickness of insulation around a circular wire and derive the relation $r_0 = k/h$ where k represents the thermal conductivity of insulation and h the convective heal transfer coefficient. 20

(b) Calculate the critical radius of insulation for asbestos (k = 0.17 W/m°C) surrounding a pipe and exporet to room air at 20° C with h = 3.0 W/m^{2}C. Calculate the heat loss from a 200 °C. 50 mm diameter pipe when covered with critical radius of insulation and without insulation. 40

Section-B

5. Answer any three of the following parts. (Answer to each part should not exceed 200 words): **20 x 3 = 60**

(a) Discuss the general principles of S.I. Engine combustion chamber design.

(b) Describe the functions of draft tubes in hydraulic turbines and air vessels in reciprocating pumps.

(c) Derive an expression for degree of reaction for an axial flow compressor and show for 50% reaction the blades are symmetrical.

(d) Explain fully the ways in which water may be chemically treated so that the undesirable effects of the various hardness producing substances may be nullified.

6. A two stage single acting air compressor has a capacity of 4.5 m^3 of free air delivery per min at 15°C and 1.0132 bar. Suction pressure is 1 bar (abs) and delivery pressure is 17.5 bar (abs). Temperature at the beginning of compression is 30°C and the clearance is 6% of stroke volume in LP cylinder. If the speed is 125 rpm, the index of compression and expansion is 1.25, determine for maximum efficiency of compression.

(i) indicated power

(ii) dimensions of the L.P. cylinder for L = 1.2D. 60

7.(a) Derive an expression for the pressure ratio for maximum work in an ideal simple gas turbine. 20

(b) A gas turbine unit operates with air entering the compressor at a pressure of 1 bar and a temperature of 27°C with a pressure ratio of 6. If the maximum permissible temperature is limited to 820°C. Calculate the cycle efficiency and work output per kg of air. What is the percentage change in efficiency and output if the pressure ratio is chosen for maximum work? 40

8.(a) State the purpose of ventilation. How can you determine the volume of fresh air to be supplied to a room per minute per occupant? 20

(b) A simple Freon-12 heat pump for space heating operates between temperature limits of 15 and 50°C. The heat required to be pumped is 100 mJ/h. Determine:

(i) the dryness fraction of Frcon-12 entering the evaporator

(ii) the mass flow rate of refrigerant

(iii) the theoretical piston displacement of the compressor

(iv) the theoretical power of the compressor.

The specific volume of Freon-12 saturated vapour at 15°C is 0.0354 m^3/kg, the specific heat at constant pressure C_P = 0.8. The other relevant data for Freon-12 are given below: 40

Saturation temp. °C	Pressure MN/m^2	Specific Enthalpy kJ/kg		Specific Entropy kJ/kg-K	
		h_f	h_g	s_f	s_g
15	0.491	50.1	193.8	0.1915	0.6902
50	1.219	84.9	206.5	0.3037	0.6797