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.

Section A

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

20 x 3 = 60

(a) (i) Distinguish between higher and lower pairs with examples.

(ii) What is meant by inversion? Describe the possible inversions obtained out of double slider crank chain.

(b) (i) How is the magnitude and direction of Gyroscopic couple fixed?

(ii) Describe the effect of gyroscopic couple on pitching, rolling and steering of a ship with neat sketches indicating the direction of couple vector, spin vector and precession vector.

(c) Derive the formula for minimum number of teeth on the pinion to avoid interference.

(d) (i) Discuss the effect of inertia force on the reciprocating engine mechanism by drawing the free-body diagram of each link.

(ii) What is the effect of partial primary balancing of a reciprocating engine?

2. (a) The connecting rod of an oil engine weighs 60 kgf. The distance between the bearing centers is 1 meter. The diameter of the big-end bearing is 12 cm and of the small-end bearing is 7.5 cm. When suspended vertically with a knife cage through the small end it makes 100 oscillations in 190 secs and with knife edge through the big end it makes 100 oscillations in 165 secs. Find the moment of inertia of the rod in kgf cm sec^2 and distance of CG from the small-end centre.

(b) (i) State the conditions required for two-mass system to be dynamically equivalent to the rigid body.

(ii) A 50 kgf body is initially stationary on a 45° incline. The coefficient of dynamic friction μ between the block and incline is 0.5. What distance along the incline must the weight slide before it attains a speed of 15 m/sec?

3. (a) In a winch the rope supports a load W and is wound round a barrel 450 mm dia. A differential band brake acts on a drum 800 mm dia which is keyed to the same shaft as the barrel. The two ends of the bands are attached to pins on opposite sides of the fulcrum of the brake lever and at distances of 25 mm and 100 mm from the fulcrum. The angle of lap of the brake hand is 250° and μ is 0.25. What is the maximum load W which can be supported by the brake when a force of 75 kgf is applied to the lever at a distance of 3000 mm from the fulcrum?

(b) A vertical double-acting steam engine has a cylinder 300 mm dia and 450 mm stroke and runs at 200 r.p.m. The reciprocating parts weigh 225 kgf and piston rod is 50 mm dia and the connecting rod is 1200 mm long. When the crank has turned through 125° from the top dead centre, the steam pressure above the piston is 3 kgf/cm^2 and below the piston 0.15 kgf/cm^2 gauge. Calculate the effective turning moment on the crank-shaft.

4. (a) A shaft 12 cm external diameter and 8 cm internal diameter is subjected to a bending moment of 300 kgf-m, twisting moment of 100 kgf-m and a direct thrust of 10000 kgf. Determine the maximum principal stress and direction in which it acts with reference to the axis of the shaft at the end points P and Q of diameter PQ as shown in Fig. 1.

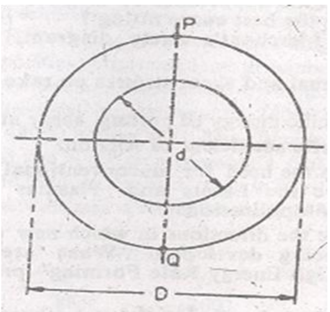

Fig. 1

(b) A compound cylinder is formed by shrinking a tube 16 cm external dia and 12 cm internal dia on to another tube which has an internal dia of 8 cm. If after shrinking, the radial compression at the common surface is 300 kgf/cm^2, find the circumferential stress at the inner and outer surfaces and at the common surface.

Section B

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

(a) What is the principle of Location? Explain the various locating and clamping devices used in practice and their choice.

(b) Explain the field of application of carbides, coated carbides, ceramics and diamonds as cutting tool materials. Mention their relative advantages and performances.

(c) Where do you use the comparators? Mention the names of the various comparators used in practice. Explain the construction and working of sigma-comparator.

(d) Explain the importance of Regression Analysis. How is it suitable for the best curve fitting?

6. (a) Using Merchant's circle diagram, derive the equations to find—

(i) normal and shear stresses on rake and shear planes;

(ii) specific energy of cutting, shear and friction;

(iii) kinetic coefficient of friction.

(b) Explain the need for unconventional machining processes. How are the Lasers and Plasmas produced? Mention their field of application.

(c) Indicate the directions in which new metal-forming processes are being developed. What are the main advantages of the 'High Energy Rate Forming' processes and their applications?

7. (a) With the help of a neat sketch, show the different zones of an operating characteristics curve (OC) for an attribute sampling plan, and explain the characteristics of the curve.

(b) What are the limitation of $\bar{X}$ and R charts and how do you compare p chart with and R chart?

(c) Plot the control charts for $\bar{X}$ and R, using the following sample data and sample size of five. From the chart see if the process is under control for the averages. Also find the process capability. (Give d_2 = 2.326)

Sub Group No.	1	2	3	4	5	6	7	8	9	10
$\bar{X}$	5.004	5.204	5.014	5.008	5.009	5.016	5.030	5.010	5.016	5.010
R	0.02	0.08	0.03	0.04	0.04	0.09	0.04	0.04	0.05	0.07

8. (a) Define the following terms applied to linear programming problem:

(i) Uniqueness

(ii) Degeneracy.

(b) A soft drinks firm has two bottling plants, one located at M and the other at N. Each plant produces three different soft drinks, A, B and C. The capacities of the two plants in number of bottles per day are as given in the Table. A market survey indicates that during the month of April there will be a demand for 24000 bottles of A, 16000 bottle of B and 48000 bottles of C. The operating costs, per day of running plants M and N are respectively Rs. 600 and Rs. 400. How many days should the firm run each plant in April so that production cost is minimized while still meeting the market demand?

		Plant	
		M	N
Product	A	3000	1000
	B	1000	1000
	C	2000	6000

MECHANICAL ENGINEERING PAPER II

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.

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) Discuss the fundamental relationship between heat transfer and thermodynamics.
(b) Give reasons for the unpopularity of Gas Turbines for use in automobiles.
(c) Discuss the basic difference between rocket propulsion and jet propulsion.
(d) A large air tank has a volume of 3.37 m^3. Determine the number of small containers that can be filled from the air tank. Given t_{tank} = 26.6°C; P_{tank} = 6.5 kg/cm^2,$V_{container}$ = 0.028 m^3, $t_{container}$ = 21°C and $P_{container}$ = 1.35 kgf/cm^2. For air, assume R = 29.7 kgm/kgK.

2. Determine the theoretical horse-power of an Otto cycle engine with a maximum cycle temperature of 1395°C. The engine has a bore of 87.32 mm and a stroke of 108 mm. The clearance volume is 108.15 cm^3. The engine operates of a 4-stroke cycle at a speed of 3600 rpm. The pressure and temperature of the surrounding air are 1 kg/cm^2 and 4.5° C respectively. The engine has 6 cylinders and the volumetric efficiency is 80%.
To increase the mass of air intake the above engine has been equipped with a super changer that raises the inlet pressure to 122 cm of Hg (absolute). Determine the new theoretical HP of the engine and the effective cycle efficiency. Assume R_{air} = 29.7 kg m/kg K and C_v = 0.24. **60**

3. (a) A spherical thin walled metallic container is used to store liquid nitrogen at 77 K. The container has a diameter of 0.5 m and is covered with an evacuated reflective insulation system composed of silica powder. The insulation is 25 mm thick and its outer surface is exposed to ambient air at 300 K. The convection coefficient is known to be 17.2 kcal/hm^2K. The latent heat of vaporization and density of liquid nitrogen are 47.85 kcal/kg and 804 kg/m^3 respectively.
(i) What is the rate of heat transfer to liquid nitrogen?
(ii) What is the rate of liquid boil-off?
Thermal conductivity of evacuated silica powder at 300 K = 0.001462 kcal/mKh. **30**

(b) A conical section has been fabricated out of pyroceram. It is of circular cross-section with diameter D = ax, where a = 0.25. The small end is located at x_1 = 50 mm and the large end at x_2 = 250 mm. The end temperatures are T_1 = 400 K and T2 = 600 K while the lateral surface is well-insulated.

(i) Derive an expression for the temperature distribution T(x) assuming one-dimensional condition.

(ii) Calculate the heat rate q_x through the cone.

Assume, for pyroceram (500K) k = 2.97 kcal/ mh°C. **30**

4. (a) A shell and tube heat exchanger must be designed to heat 2.5 kg/s of water from 15°C to 85°C. The heating is to be accomplished by passing hot engine oil which is available at 160°C, through the shell side of the exchanger. The oil is known to provide an average convection coefficient of 345 kcal/m^{2}h°C on the outside of the tube. Ten tubes are used to pass the water through the shell. Each tube is thin-walled of diameter 25 mm and makes eight passes through the shell.

(i) If the oil is to leave the exchanger at 100°C, what must be its flow rate?

(ii) How long must the tubes be to accomplish the desired heating?

For engine oil: C_v = 560 cal/kg°C

For water: C_v = 1000 cal/kg °C

Viscosity = 548 x 10^6 kg/s m

Thermal conductivity = 0.553 kcal/ m^{2}hºC; Pr = 3.56.

Assume that the correction factor = 0.87 **25**

(b) Air at a pressure of 612 kgf/m^2 and a temperature of 300°C flows with a velocity of 10 m/s over a flat plate of length 0.5 m. Estimate the cooling rate per unit width of plate needed to maintain it at a surface temperature of 27°C. Assume that for air at the stated conditions ν = 5.21 X 10^{-4} m^2/s; Pr = 0.687; K = 0.0313 kcal/mh°C. **25**

(c) The temperature profile at a particular x location in a thermal boundary layer is given by $T(y) = A - By + Cy^2$, where A, B and C are constants. Obtain an expression for the corresponding local heat transfer coefficient. **10**

Section B

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

(a) Give a list of the thermometers you would employ to measure temperatures ranging between -100° C and 3000° C.

(b) Explain the salient features of Clapeyron equation. Calculate the change in melting point of ice when it is subjected to a pressure of 100 atmospheres.

Density of ice = 0.917 gm/cm^3

Latent heat of ice = 80.3 cal/gm.

(c) Compare the performance of various types of fuel injectors for fuel injection in Combustion Chambers of gas turbines.

(d) In relation to steam turbines explain the purpose of the following:

(i) Velocity compounding

(ii) Pressure compounding

(iii) Pressure-Velocity compounding.

6. (a) Explain the principle of working of the following: **20**

(i) Once through, Super critical boiler

(ii) Steam generation by nuclear reactor.

(b) Steam is supplied to a turbine at a pressure of 71.5 kgf/cm^2 and a temperature of 500° C Steam is bled for feed heating at pressures of 20.4 kgf/cm^2 and 5.10 kgf/cm^2. The condenser pressure is 0.510 kgf/cm^2. The stage efficiency of each section of the turbine can be taken as 82%. In the feed heaters the feed water has its liquid enthalpy raised to that of the bled steam. The bled steam is condensed, but not undercooled and in this state, on leaving the feed heater is pumped into the feed main, Determine:

(i) The effect of reheating on the plant efficiency

(ii) Mass of steam bled to each feed heater in kg/kg of supply steam

(iii) Thermal efficiency of the arrangement. **30**

(c) Steam enters a group of convergent-divergent nozzles at a pressure of 22.5 kgf/cm^2 and with a temperature of 260°C. Equilibrium expansion through the nozzles to an exit pressure of 4.1 kgf/cm^2. Up to the throat of the nozzle the flow can be considered as frictionless. From the throat to the exit, however, there is an efficiency of expansion of 85%. The rate of steam flow through the nozzles is 11 kg/s. Determine the throat and exit velocities and the throat and exit areas. **10**

7. (a) By means of a neat sketch describe the working of a solar air conditioning system and discuss the following: **25**

(i) Design of solar collectors

(ii) Choice of refrigerants.

7. (a) By means of a neat sketch describe the working of a solar air conditioning system and discuss the following: **25**

(i) Design of solar collectors

(ii) Choice of refrigerants.

(b) A turbine model having the following specifications has been constructed to predict the behavior of an actual turbine:

Power = 15 HP , Head = 12 m, N = 474 r. p. m., n = 10

Determine the speed of the actual turbine runner and its power if the overall efficiency of turbine is equal to that of the model. Find the type of turbine for which the model was constructed. **20**

(c) An axial compressor is fitted with half-reaction blading, the blade inlet and outlet angles being 50° and 15° when measured from the axial direction. The mean diameter of a certain blade pair is 85 cm and the rotor turns at 5500 r. p. m. Calculate the necessary isentropic efficiency of the stage if the pressure ratio of compression is to be 1.4 and the inlet air temperature is 25° C. [C_p = 0.24, γ = 1.4] **15**

8. (a) Discuss the essential differences in working principles off heat engine, heat pump and refrigerating machine. **12**

(b) Describe a summer air conditioning system with ventilation. An air handling unit in air conditioning plant supplies a total of4500 m^3/s of dry air which comprises by weight 20% fresh air at 40° C DBT and 27° C WBT and 80% re-circulated air at 25° C DBT and 50% RH. The air leaves the cooling coil at 13° C saturated. Calculate the total cooling load and room.

The following data can be used:

Condition	DBT °C	WBT °C	RH %	Sp. Hu. $\frac{\text{gm of water vapour}}{\text{kg of dry air}}$	Entholpy kcal/kg d.a.
Outside	40	27		17.2	20.3
Inside	25		50	10.0	12.15
ADP	13		100	9.4	8.85

Sp volume of air entering the cooling coil = 0.869 m^3/kg d.a. **20**

(c) A vapour compression refrigerator uses methyl chloride and operates between pressure limits of 180.54 kgf/m^2 and 986.3 kgf/ m^2. At entry to the compressor the methyl chloride is dry saturated and after compression has a temperature of 102°C. The compressor has a bore and stroke of 75 mm and runs at 8 rev/s with a volumetric efficiency of 80%. The temperature of the liquid refrigerant as it leaves the condenser is 35° C and its specific heat cap city is 0.388 kcal/kgºC. The specific heat capacity of the super-heated vapour may be assumed to be constant. Determine **28**

(i) refrigerator COP.

(ii) mass flow rate of refrigerant.

(iii) cooling water required by the condenser if its temperature rise is limited to 12° C.

Specific heat capacity of water = 1 kcal/ kg°C Relevant properties of methyl chloride are as follows:

Sat. Temp °C	Press kgf/m^2	Spec. Vol. m^3/kg		Spec. Enthalpy kcal/kg		Spec. Entropy kcal/kg °C	
		v_f	v_g	h_f	h_g	s_f	s_g
-10	180.54	0.00102	0.233	10.8	110.0	0.044	0.42
45	986.3	0.00115	0.046	31.8	115.6	0.116	0.38