MECHANICAL ENGINEERING PAPER I

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

INSTRUCTIONS

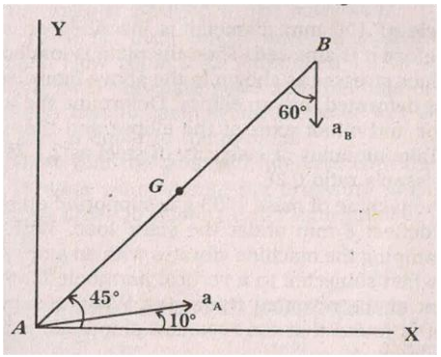
Each question is printed both in Hindi and in English.
Answers must be written in the, medium specified in the Admission.
Certificate issued to you, which must be stated clearly on the cover of the answer-book in the space provided for the purpose.
No credit will be given for the answers written in a 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.

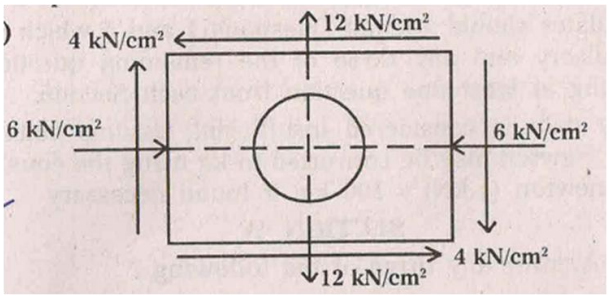
Section A

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

20 x 3 = 60

(a) The link AB of a mechanism is 40 cm long and weights 10 N. It is undergoing plane motion in X-Y plane and the accelerations of its ends are: a_A= 12 m/sec^2 at 10° from X-axis in counter clockwise direction, a_B =20 m/sec^2 at 60° in counter clockwise direction from AB (Refer the figure). The centre of gravity of the link is at G where AG = 20 cm. The radius of gyration of the link about Z-axis through G is 12 cm. Determine the forces F_A and F_B applied at A and B respectively to give above-mentioned accelerations, if F_A has a horizontal component of 60 N towards right.





(b) A circle of 100 mm diameter is inscribed on a steel plate before it is stressed. Then the plate is loaded so as to produce stresses as shown in the figure and the circle is deformed into an ellipse. Determine the lengths of major and minor axes of the ellipse and their directions. Take modulus of elasticity of steel as 2.1 MN/cm^2 and Poisson's ratio 0.28.

(c) A machine of mass 100 kg is supported on springs which deflect 8 mm under the static load. With negligible damping the machine vibrates with an amplitude of 5 mm when subjected to a vertical harmonic force at 80percent of the resonant frequency. When a damper is fitted it is found that the resonant amplitude is 2 mm. Determine:

(i) the damping coefficient
(ii) the critical damping coefficient
(iii) damping ratio
(iv) logarithmic decrement

(v) the damping force.

(d) What is 'heat treatment'? Differentiate clearly between 'Annealing' and 'Normalising'.

2.(a) A shaft carries four masses in parallel planes A, B, C and D in order. The masses at B and C are 18 kg and 12.5 kg respectively and each has an eccentricity of 6 cm. The masses at A and D have an eccentricity of 8 cm. The angle between the masses at B and C is 100°and that between the masses at B and A is 190° (both angles measured in the same sense). The axial distance between the planes A and B is 10 cm and between B and C 20 cm. If the shaft is in complete dynamic balance, determine

(i) the masses at A and D

(ii) the distance between the planes C and D.

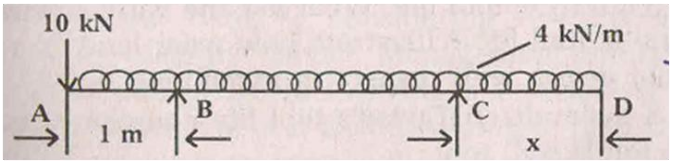
(iii) the angular position of the mass at D. 30

(b) Explain the term 'interference' as applied to involute gears. How could it be eliminated? Two standard full depth 14½° involute gears have module of 5 mm. The pinion has 15 teeth while the gear has 60 teeth. Addendum is equal to the module.

(i) Show that the gear will interfere with the pinion

(ii) To what value should the pressure angle be increased in order to eliminate the interference? 30

3.(a) A beam ABCD, 10 m long is supported at B, 1 m from end A and at C, *x* m from end D. The beam carries a point load of 10 kN at end A and a uniformly distributed load of 4 kN per meter run throughout its length. Determine the value of *x* if the centre of the beam is the point of contraflexure. Draw the bending moment diagram. 30



(b) A hollow circular steel shaft is subjected to a torque of 800 N-m and a bending moment of 1200 N-m. The internal diameter of the shaft is 60% of the external diameter. Determine the external diameter of the shaft according to:

(i) maximum principal stress theory

(ii) maximum shear stress theory

(iii) shear strain energy theory

Take factor of safety as 2 and the yield strength of steel as 27 kN/cm^2. 30

4.(a) Differentiate between ceramics, polymers and composites. 15

(b) What is a 'hybrid composites'? State the principal applications of hybrid composites. 15

(c) Explain the following:

(i) Process annealing

(ii) Normalising

(iii) Spheroidizing 15

(d) Explain the terms 'Natural aging' and Artificialaging'. 15

SECTION 'B'

5. Answer any three of the following:

(a) (i) Define tool life. What are the various ways of expressing tool life? Illustrate how wear land of a cutting tool grows with respect to machining time.

(ii) A generalized Taylor's tool life equation was obtained for H.S.S. tool,

$$V = \frac{C}{T^{0.13} f^{0.6} d^{0.3}}$$

A 60 min tool life was obtained using the following cutting parameters,
V = 40 m/min, f = 0.25 mm, d = 2.0 mm
Compute the effect on tool life if cutting speed, feed and depth of cut are increased by 25% and also if they are increased individually by 25%. Where, V = cutting speed; f = feed; d = depth of cut. 10 + 10

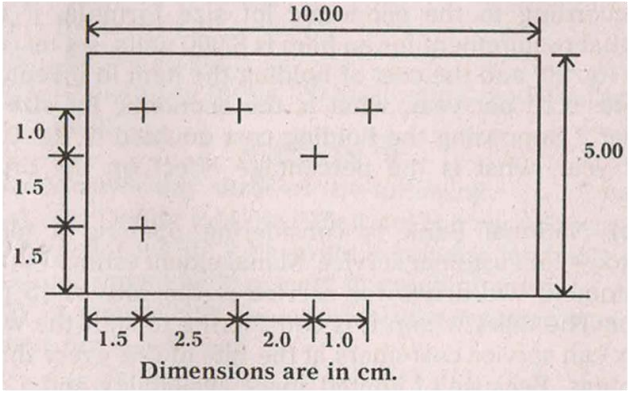
(b) Define automation. What are the features of flexible automation? Illustrate with neat sketches two configurations of automated flow lines of production. 20

(c) (i) What is the objectives of break-even analysis? The cost of producing between 1500 units and 2500 units of a product consists of Rs. 25,000 fixed cost and Rs. 10 per unit variable cost. With the selling price at Rs. 20 per unit, what is the break-even point? Suppose the price per unit was increased to Rs. 25. Illustrate with a neat sketch how does this affect the break-even point.

(ii) What are the various purposes of inventory control? According to the economic lot size formula, if the annual requirement for an item is 8,000 units, set up cost are Rs. 20, and the cost of holding the item in inventory is Rs. 0.20 per year, what is the economic lot size to order? Supposing the holding cost doubled to Rs. 0.40 per year, what is the percentage effect on the order size? 20

(d) National Bank is considering opening a teller window for customer service. Management estimates that customers will, arrive for service at the rate of 15 per hour. The teller whom it is considering to staff the window can service customers at the rate of one every three minutes. Because of limited space availability and a desire to provide an acceptable level of service, the bank manager would like to assure, with 95 per cent confidence, that not more than three customers will be in the system at any one time. Assume Poisson arrivals and exponential service, compute (i) utilization of the teller, (ii) average number in the waiting line, (iii) average number in the system, (iv) average waiting time in line, (v) average waiting time in the system. What is the present level of service for the three-person limit?
What level of utilization of the teller must be attained and what must be the service rate of the teller to assure the 95 percent level of service? 20

6.(a) (i) What are the three basic components of NC system? Explain the principle of operation of NC system with the help of a neat sketch. Why it is essential to provide co-ordinate system in NC? What is the difference between fixed zero and floating zero co-ordinate system? 20



(ii) A part program is to be written to drill the holes in the work part shown above. The part is 25 mm thick. The diameter of drill is φ 20 mm.

(1) Define the *x* and *y* axes for the job.

(2) Write manual part programming using word address format and an absolute position system. The speed and feed are manually set by the operator. 10

(b) Illustrated by the simplified diagram explain the principle of electrical-discharge-machining process. What are the dielectric fluids commonly used in EDM? How metal removal rate can be controlled? Discuss briefly about the application of EDM. 30

7.(a) (i) What do you understand by quality control by attributes and quality control by variables? 5

(ii) Where do you need a larger sample size in the above and why? 5

(iii) Four batches of products are inspected at 90 minute intervals and their percentage difference in weights from the nominal are given below:

Percentage difference on weights in sample

Batch-1	Batch-2	Batch-3	Batch-4
1.2	0.6	0.6	2.1
1.8	0.3	1.5	0.6
1.5	0.3	1.0	0.6
0.9	0.0	0.0	2.7
0.3	0.6	1.9	2.7

Assume that normal process average variation is 0.9% and process standard deviation is 0.5%, range U.C.L. is5times S.D. Plot $\bar{X}$, R chart indicating the various control limits. Is the process under control? 20

(b) A company is producing a batch of five components A, O, E, N and L using three machines X, W, M. All these parts are to be produced in the technological order X, M, W machines. The sum of the processing and set-up times, in minutes for these parts in each of these machines are given below:

Component	Time of machines, minutes		
	X	W	M
N	8	5	3
A	4	6	4
O	7	7	3
L	5	8	4
E	6	4	4

(i) Find the sequence in which parts are to be produced to minimize total make span. 10

(ii) Are there alternative sequences? 4

(iii) Represent your schedule in the form of a Gantt chart with starting and ending timings. Neglect machine to machine shifting time. 10

(iv) What are the machine utilization percentages for each machine if no other job is taken till the completion of this batch. 6

8.(a) Solve the following linear programming problem graphically:

$$x_1, x_2 \geq 0$$
$$x_1 + 4x_2 \leq 4$$
$$2x_1 + 3x_2 \leq 6$$
$$\text{Max } Z = x_1 + 1.5x_2$$

30

(b) Write a flow chart for choosing the largest of three distinct numbers X, Y and Z. 30

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) Prove the following for an ideal gas:

$$dS = \frac{dV}{V} + C_v \frac{dP}{P}$$

Using this result show that for an ideal gas undergoing an isentropic change of state with constant specific head Pv^{γ} = constant.

(b) Give the Kelvin-Planck's and Clausius' statements of Second Law of Thermodynamics and show that violation of either statement implies violation of the other.

A Carnot engine I operates between two reservoirs at temperatures of 2000 K and T K. Another Carnot engine II operates between the reservoirs at T K and 300 K. If both the engines have the same efficiency, determine the value of T.

(c) Explain the following:

(i) Why is rich mixture used during idling?
(ii) As the engine speed increases, the ignition timing should be advanced.
(iii) S.I. engines are generally not supercharged.
(iv) Two stroke cycle engines find wider applications either in small two-wheelers or in large marine propulsion engines.

(d) Determine the air-fuel ratio at 6000 m altitude in a carburetor adjusted to give an air-fuel ratio of 15 : 1 at sea level where air temperature is 27° C and pressure is 1.013 bar. The temperature of air decreases with altitude and is given by the expression

$$t = t_s - 0.0065h$$

where h is height in meters and t_s is the sea level temperature in °C.

The air pressure decreases with altitude as per the relation

$$h = 19220 \log_e \left(\frac{1.013}{P}\right)$$

where P is in bar.

2.(a) A pressure vessel is connected, via a valve, to a gas main in which gas is maintained at a constant pressure and temperature of 1.4 MN/m^2 and 85° C respectively. The pressure vessel is initially evacuated. The valve is opened and a mass of 2.7 kg of gas passes into the pressure vessel. The valve is closed and the pressure and temperature of the gas in

the pressure vessel are then 700 kN/m^2 and 60° C, respectively. Determine the heat transfer to or from the gas in the vessel. Determine the volume of gas before transfer.
For the gas, take C_p = 0.88 kJ/kg K, C_v = 0.67 kJ/kg K.
Neglect the velocity of the gas in the main. 30

(b) A perfectly insulated chamber is divided in two parts by a diaphragm. 1.0 kg of oxygen is stored in one part while 7.0 kg of hydrogen is stored in another part. Both the gases are at the same temperature and pressure of 450 K and 1.0 bar respectively. They are mixed together by removing the diaphragm. Determine the loss in availability after mixing if the surrounding temperature is 290 K.
The value of universal gas constant R_0 = 8314 J/kg-mol-K. 30

3.(a) The air flow to a four cylinder 4-stroke oil engine is measured by means of a 4.5 cm diameter orifice, having C_d = 0.65. During a test the following data was recorded:
Bore =1.0 cm,
Stroke =1.5 cm,
Engine speed = 1000 RPM,
Brake torque = 135 Nm,
Fuel consumption = 5.0 kg/hour,
C_{Vfuel} = 42600 kJ/kg,
Head across orifice = 6 cm of water,
Ambient temperature and pressure are 300 K and 1.0 bar respectively.
Calculate:
(i) Brake thermal efficiency
(ii) The brake mean effective pressure
(iii) The volumetric efficiency
Take R = 287 J/kg K for air. 30

(b) What are the different sources of emissions from an I.C. engine? Discuss the mechanism of formation of oxides of nitrogen and carbon monoxide. Explain various methods that can be used for the control of emissions of oxides of nitrogen. 30

4.(a) An 8-cylinder, 4-stroke diesel engine has a power output of 368 kW at 800 RPM. The fuel consumption is 0.238 kg/kW-hr. The pressure in the cylinder at the beginning of injection is 35 bar and the maximum cylinder pressure is 60 bar. The injector is adjusted to operate at 210 bar and the maximum pressure in the injector is set at 600 bar. Calculate the orifice are a required per injector if the injection takes place over 12°crank angle. Assume the coefficient of discharge for the injector = 0.6, specific gravity of fuel = 0.85 and the atmospheric pressure = 1.013 bar. Take the effective pressure difference to be the average pressure difference over the injection period. 30

(b) Describe the different phases of combustion in a S.I. engine. How should the following factors be changed to reduce the tendency of knock in a S.I. engine:
(i) Compression ratio
(ii) Distance of flame travel
(iii) Inlet mixture temperature
(iv) Turbulence
Justify your answer with proper reasoning. 30

SECTION B

5. Answer any three of the following: **20 x 3 = 60**

(a) In a double pipe counterflow heat exchanger, 10,000 kg/h of an oil, having a specific heat of 2095 J/kg K, is cooled from 80° C to 50° C by 8000 kg/h of water entering at 25° C. Determine the heat exchanger area for an overall heat transfer coefficient of 300 W/m^2 K. Take CP of water as 4180 J/kg K.

(b) The air handling unit of an air conditioning plant supplies a total 4500 cubic meter/min of dry air which comprises 20 percent fresh air at 40° C DBT and 27° C WBT and 80 percent of recirculated air at 25° C DBT and 50% RH. The air leaves the cooling coil at 13° C saturated state. Determine the total cooling load and the room heat gain. Take specific volume of air entering the cooling coil as 0.869 m^3/kg da.

Condition	DBT	WBT	RH %	Sp. humidity	Enthalpy
	°C	°C		gwv/kg da	kJ/kg da
Outside	40	27	—	17.2	85.0
Inside	25	—	50	10.0	50.8
ADP	13	—	100	9.4	37.0

Note: ADP- Apparatus dew point; wv-water vapour; da- dry air

(c) Explain what do you understand by specific speed of a turbine. Highlight its importance.

A centrifugal compressor develops a pressure ratio of 1.5 while running at 24,000 RPM and discharging 2.0 kg/s of air. The entry conditions are P_1 = 1.0 bar and T_1 = 290 K.

Determine the specific speed. Take γ = 1.4, R = 287 J/kg K, C_p = 1.005 kJ/kg K.

(d) A power plant of 210 MW installed capacity has the following particulars:

Capital cost = Rs. 4 crores/MW installed

Interest and depreciation = 12%

Annual load factor = 60%

Annual capacity factor = 54%

Annual running charges = Rs. 400 X 10^6

Energy consumed by power plant auxiliaries = 6%

Calculate:

(i) The cost of power generation per kWh

(ii) The reserve capacity

6.(a) A fluid at a temperature $T_{\infty 1}$ with a heat transfer coefficient *h*, flows on one side of a slab at $x = t$) and another fluid at a temperature $T_{\infty 2}$ with a heat transfer coefficient *h*, flows on the other side of the slab at x = L. Both the fluids flow in opposite directions. Develop an expression for the heat flow *Q* through an area '*A*' of the slab.

Calculate the heat transfer rate through an area of one square metre of the slab for the following data:

$T_{\infty 1}$ = 150° C, h_1 = 300 W/m^2K, $T_{\infty 2}$ = 50° C. h_2 = 600 W/m^2K, thickness of slab = 5 cm and K = 20 W/mK. 30

(b) Define the term Nusselt number and explain its significance in the case of forced convection heat transfer.

Atmospheric air at T_∞ = 275 K and a free-stream velocity u_∞ = 20 m/s flows over a flat plate L = 1.5 m long that is maintained at a uniform temperature T_w = 325 K.

(i) Calculate the average heat transfer coefficient h_m over the region where the boundary layer is laminar.

(ii) Find the average heat transfer coefficient over the entire length L = 1.5 m of the plate.

(iii) Calculate the total heat transfer rate Q from the plate to the air over the length L = 1.5 m and width W = 1 m.

Assume transition occurs at Re = 2 X10^5. 30

7.(a) A vapour compression refrigerator operates between the pressure limits of 462.47 kN/m^2 and 1785.90 kN/m^2. At entry to the compressor the refrigerant is dry saturated and after compression it has a temperature of 59°C. The compressor has a bore and stroke of 75 mm and runs at 8 rev/s with a volumetric efficiency of 80 percent. The temperature of the liquid refrigerant as it leaves the condenser is 32°C and the specific heat capacity of the superheated vapour may be assumed constant. Determine :

(i) The coefficient of performance of the refrigerator

(ii) The mass flow of the refrigerant in kg/h.

(iii) The cooling water required by the condenser in kg/h if the cooling water temperature rise is limited to 12°C.

Take the specific heat capacity of water as 4.187 kJ/kg K and the specific heat of liquid refrigerant as 1.32 kJ/kg K. The relevance properties of the refrigerant are given in the table below:

Pressure	Sat. Temp.	Sp. Enthalpy		Sp. Vol. (m^3/kg)		Sp. Entropy	
kN/m^2	t_f °C	h_f	h_g	v_f	v_g	S_f	S_g
462.47	-10	35.732	231.40	0.0008079	0.04573	0.1418	0.8614
1785.90	40	99.270	246.40	0.0009487	0.01105	0.3537	0.8093

(b) (i) Discuss the factors to be considered in the selection of a site for a hydroelectric power plant.

(ii) Differentiate between a cogeneration and a combined cycle power plant. 10 + 10

8.(a) Air at a temperature of 300 K enters a ten-stage axial flow compression at the rate of 3.5 kg/s. The pressure ratio is 6.0 and the isentropic efficiency is 90%. The process is adiabatic and the compressor has symmetrical stages. The axial velocity of 120 m/s is uniform across the stages and the mean blade speed is 200 m/s. Assume that the temperature change is same in each stage.

Determine the direction of the air at entry to and exit from the rotor and stator blades. Also find the power given to the air.

For air, take C_p = 1.005 kJ/kg and γ = 1.4. 15

(b) Sketch and explain the curves showing the variation of pressure ratio (or head) versus volume flow rate for the three types of blades generally used in centrifugal compressor. Indicate on each curve the stable range of operation. 30