ZLX-D-MCH

MECHANICAL ENGINEERING

Paper II

Time Allowed : Three Hours

Maximum Marks : 300

Question Paper Specific Instructions

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

There are **EIGHT** questions divided in **TWO** sections.

 ̴ndidate has to attempt **FIVE** questions in all.

Questions No. **1** and **5** are **compulsory** and out of the remaining, **THREE** are to be attempted choosing at least **ONE** question from each section.

The number of marks carried by a question / part is indicated against it.

Answers must be written in the medium authorized in the Admission Certificate which must be stated clearly on the cover of this Question-cum-Answer (QCA) Booklet in the space provided. No marks will be given for answers written in a medium other than the authorized one.

Assume suitable data, if considered necessary and indicate the same clearly.

Unless otherwise mentioned, symbols and notations carry their usual standard meanings.

Attempts of questions shall be counted in sequential 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 Question-cum-Answer Booklet must be clearly struck off.

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

SECTION A

Q1. **(a)** A 100 N block A rests on a 150 N block B, which rests on a rough horizontal plane. The block A is tied with a weightless horizontal cord to a wall. A force P is applied to the block B at 45° to the horizontal as shown in the figure. If the coefficient of friction is 0·25 between the blocks and 0·3 between block B and the floor, determine the tension T in the cord and the value of the force P so that block B is at the point of sliding.

12
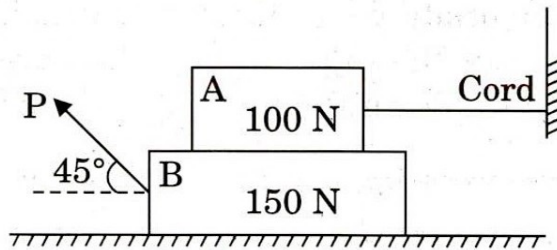
(b) **(i)** Find the maximum flexural stress developed in a steel wire 2·00 mm in diameter, if it is coiled over a drum 0·5 m in radius (it is assumed that the limit of proportionality is not exceeded due to coiling). What is the bending moment to which the wire is subjected ? Take E = 200 GPa.

6

(ii) If the ratio of Young's modulus to the modulus of rigidity is 2·5 for a certain material, find its Poisson's ratio and the ratio of Young's modulus to bulk modulus.

6

(c) An aeroplane flying at 300 km/h turns towards the left and completes a quarter circle of 80 m radius. The mass of the rotary engine and the propeller of the plane is 500 kg with a radius of gyration of 300 mm. The engine speed is 2000 r.p.m. clockwise when viewed from the nose end (front end). Determine the gyroscopic couple on the aircraft and state its effect whether the nose end is raised or depressed.

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(d) **(i)** Define the following terms for the governor :
- Sensitiveness
- Stability
- Isochronous
- Hunting

(ii) Draw the controlling force (F_c) vs. radius of rotation of balls (r) for spring controlled governors for the above conditions.

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(e) A gear set consists of an 18-tooth pinion driving a 45-tooth gear. The module is 10 mm. The gears are cut using a pressure angle of 20°. In mounting the gears, the centre distance was incorrectly made 8 mm larger. Compute the new values of the pressure angle and pitch circle diameter. If the pinion transmits 20 kW and rotates at 950 r.p.m., determine the forces on the tooth for mounted gears.　　　　*12*

Q2. (a) A beam of uniform section and length (L + 2a) is simply supported over a span L with two equal overhanging lengths 'a'. Compute the deflection at mid span due to a uniformly distributed load w/unit length when covering the length L between the supports and when covering only two overhanging lengths. EI is the flexural rigidity of the beam.　　　　*20*

(b) A cam operates a roller reciprocating follower with the following data :

Minimum radius of the cam = 24 mm

Lift = 30 mm

Roller diameter = 16 mm

The cam lifts the follower for 120° with SHM followed by a dwell period of 40°. Then the follower lowers down during 150° of the cam rotation with uniform acceleration and deceleration followed by a dwell period.

(i) Draw the profile of the cam.

(ii) If the cam rotates at a uniform speed of 160 r.p.m., calculate the maximum velocity and acceleration of the follower during the descent period.　　　　*20*

(c) A rotating shaft shown in the figure below is supported in ball bearings at A and D and loaded by a non-rotating force of 6·8 kN. The shaft is made of 40 C8 steel (σ_y = 360 N/mm^2, σ_u = 650 N/mm^2). Endurance limit σ_e may be taken as 55% of σ_u. The shaft is machined. The reliability is 90% (reliability factor c_r is 0·897). Static stress concentration at BB may be taken as 1·5 and at CC 1·4. The notch sensitivity factor q may be taken as 0·95.
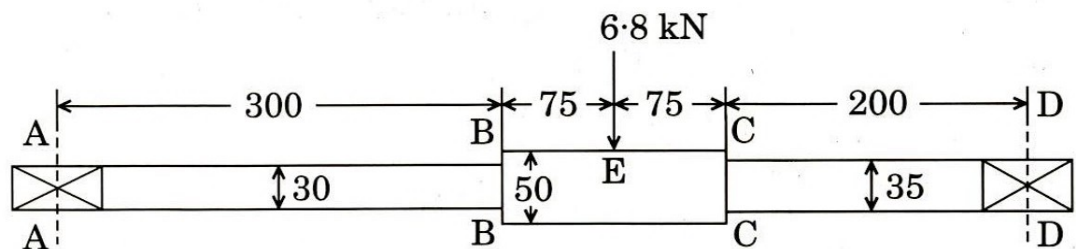
All dimensions are in mm

Find out the critical section and factor of safety.　　　　*20*

Q3. **(a)** **(i)** Draw the shear force and bending moment diagram for the given simply supported beam with moment loads as shown in the figure. Show the magnitude of shear force and bending moments at the respective points of the beam, i.e., at A, B, C, D and E. *10*
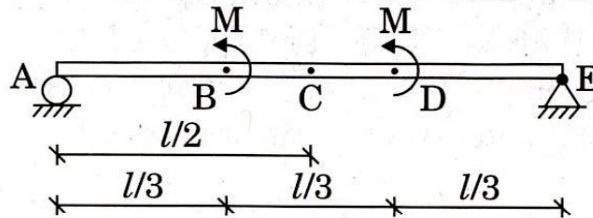
(ii) Determine the maximum shear stress values for the given set of principal stresses. Draw the Mohr's stress circle for each case and show the maximum shear stress on it. *10*

(A) $\sigma_1 = \sigma,\ \sigma_2 = \sigma/2,\ \sigma_3 = 0$

(B) $\sigma_1 = \sigma,\ \sigma_2 = -\sigma,\ \sigma_3 = 0$

(C) $\sigma_1 = \sigma,\ \sigma_2 = 0,\ \sigma_3 = 0$

(D) $\sigma_1 = \sigma_2 = \sigma_3 = \sigma$

(b) **(i)** Derive the expression for minimum number of teeth on a pinion for involute rack in order to avoid interference.

(ii) A pinion of 30 involute teeth and 4 mm module drives a rack. The pressure angle is 20°. The addendum of both, the pinion and the rack is the same. What is the permissible value of the addendum to avoid interference ? *15+5=20*

(c) A pair of spur gears with pressure angle 20° consists of a 24-tooth pinion which rotates at 950 r.p.m. and transmits power to a 60-tooth gear. The module is 6 mm and face width is 60 mm. Both the gears are made of 45 C8 steel (σ_y = 330 N/mm², σ_u = 680 N/mm² and σ_e = 0·55 σ_u). Take surface endurance limit 1500 N/mm². Assuming overload factor as 1·8, dynamic factor as 2·5 and taking factor of safety of 2·5, determine :

(i) Beam strength

(ii) Wear strength

(iii) The rated power, the gears can transmit. *20*

$E = 2·1 \times 10^5$ N/mm²

Q4. **(a)** A steam turbine delivers 8200 kW of power at 1800 r.p.m. This power is received by a shaft coupled with the turbine. This shaft delivers this power to the other shaft through gear reduction unit at 90% efficiency. The other shaft rotates at 107 r.p.m. Determine the diameters of both the solid shafts. Take allowable shear stress as $3 \cdot 45 \times 10^8$ N/m^2. Further, if these shafts are replaced by hollow shafts with internal diameters half of the outer diameter, determine the internal and external diameters of both the shafts. *20*

(b) A 100 kg machine is symmetrically supported on four springs. The mass of the reciprocating parts is $2 \cdot 5$ kg which move through a vertical stroke of 100 mm with SHM.

Neglecting damping, determine the combined stiffness of the springs so that the force transmitted to the foundation is $\dfrac{1}{20}$th of the impressed force. The machine crankshaft rotates at 850 r.p.m.

If under actual working conditions, the damping reduces the amplitudes of successive vibrations by 30%, find

(i) the force transmitted to the foundation at 850 r.p.m.,

(ii) the force transmitted to the foundation at resonance, and

(iii) the amplitude of the vibration at resonance. *20*

(c) A ball bearing operates on a work cycle consisting of three parts — a radial load of 3500 N at 1440 r.p.m. for 30% of the cycle, a radial load of 6000 N, 750 r.p.m. for 35% of the cycle and a radial load of 2500 N at 1440 r.p.m. for the remaining cycle. The expected life of the bearing is 10,000 hours. Calculate the dynamic load carrying capacity of the bearing. *20*

Q5. (a) Explain briefly : Nitriding, Cyaniding, Flame Hardening and Induction Hardening. *12*

(b) Classify gating designs in respect to pouring of molten metals into the mould cavity in the casting process. Give sketches of (i) simple vertical gating, and (ii) bottom gating design provisions. *12*

(c) M/s TV Assembler needs 10,000 tubes per annum. The cost of one procurement is ₹ 80·00. The holding cost per tube is ₹ 3·00 per annum. The rush purchase of tubes, if not in stock, amounts to equivalent shortage cost of ₹ 6·00 per tube per annum.

If the order is delivered instantaneously, determine how much he should order, at what interval and what will be the total cost of inventory. *12*

(d) (i) List out any six inherent characteristics of a hydraulic actuator.

(ii) Explain the working of a gear pump with the help of a schematic diagram. Also detail its other properties. *12*

(e) Determine the missing elements of the following frame representation, if the frame is attached to an object in space. Also show the orientation and position of the frame F with respect to OXYZ shown. *12*

$$F = \begin{bmatrix} ? & 0 & -1 & 5 \\ ? & 0 & 0 & 3 \\ ? & -1 & 0 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$
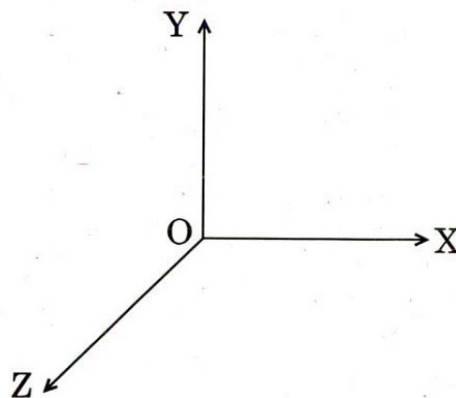
Q6. **(a)** **(i)** Explain uniform corrosion and pitting corrosion. *10*

(ii) For a 79·65 wt% Fe, 0·35 wt% C, an alloy is at a temperature just below the eutectoid. Determine the fraction of total ferrite and cementite phases, the fraction of the proeutectoid ferrite and pearlite, and the fraction of the eutectoid ferrite. *10*

(b) **(i)** The following table shows the activities of a network along with their time estimates in days :

Activity → ⟍ Estimated Time ↓	1−2	2−3	2−4	3−5	4−5	5−6
t_o	1	2	2	7	5	3
t_m	7	14	5	10	5	3
t_p	13	26	8	19	17	9

Draw the project network and find the probability of completion of the project in 40 days. *10*

Normal Distribution Table
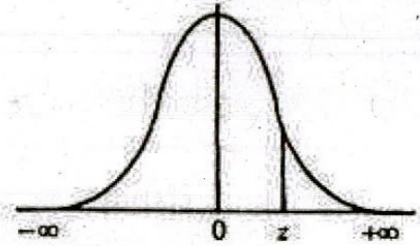
	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
.7	.7580	.7611	.7642	.7673	.7704	.7734	.7764	.7794	.7823	.7852
.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	.9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	.9987	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990
3.1	.9990	.9991	.9991	.9991	.9992	.9992	.9992	.9992	.9993	.9993
3.2	.9993	.9993	.9994	.9994	.9994	.9994	.9994	.9995	.9995	.9995
3.3	.9995	.9995	.9995	.9996	.9996	.9996	.9996	.9996	.9996	.9997
3.4	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9998

(ii)   Describe with an illustrative sketch the "Ultrasonic Welding" process.

10

(c)   Answer the following :

4+16=20

    (i)   Explain the following control strategies :

        (A)   Proportional Control (P)

        (B)   Derivative Control (D)

        (C)   Integral Control (I)

        (D)   PID Control

    (ii)   (A)   Derive the forward kinematics equations for the given figure of two degrees of freedom planar robot. Assign the coordinate frames based on D-H representations, prepare the D-H parameter table, prepare the individual transformation matrices and finally the composite transformation matrix depicting the F-K equations.

        (B)   If the link lengths are a_1 = 15 units and a_2 = 10 units, determine the final position and orientation of tool point (e.e.) frame for θ_1 = 45° and θ_2 = 45° (measured in counter-clockwise sense).
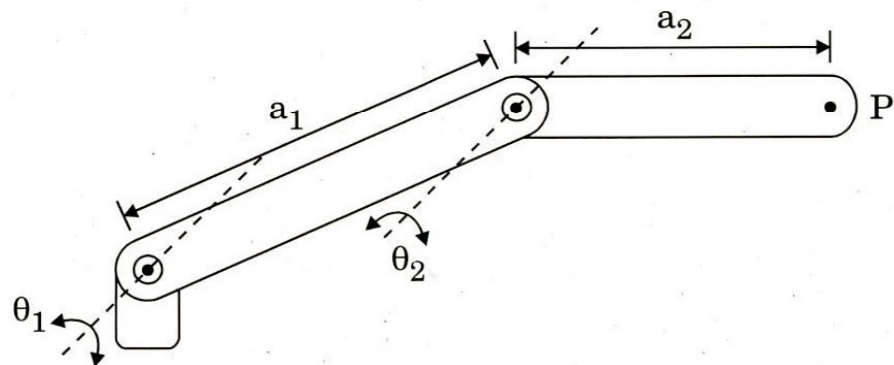
2 Link 2-DOF planar robot arm

Q7. (a) (i) Describe the stress – strain behaviour and glass transition temperature for polymers. **10**

(ii) Define the term hardenability and the factors affecting it. Also name various hardening methods. **10**

(b) (i) For a deterministic inventory model assuming uniform rate of supply and fixed demand, (A) illustrate the model graphically, (B) derive the expression for optimum order quantity, (C) also derive the expression for the optimum time for ordering, and (D) derive the expression for the cost of inventory. **10**

(ii) Give a schematic diagram of a piezoelectric accelerometer for shock and vibration measurement and briefly explain how it works. **10**

(c) Answer the following : **5+15=20**

(i) Describe in brief the following forms of memory units :

ROM, PROM, EPROM, EEPROM, RAM

(ii) Determine and compare the coordinates of a point $P(5, 3, 1)^T$ attached to a moving frame F_{uvw}, which undergoes the following two sets of successive transformation :

Set A : 1. First a rotation of (– 90°) about Z-axis.
2. Followed by translation of [5 – 3 4] about the X, Y and Z axes respectively.
3. Finally a rotation of (– 90°) about Y-axis.

Set B : 1. First a rotation of (– 90°) about W-axis.
2. Followed by translation of [5 – 3 4] about the U, V and W axes respectively.
3. Finally a rotation of (– 90°) about V-axis.

Q8. (a) (i) How is the heat for electron beam welding obtained ? With the help of a diagram, discuss the working of this method of welding. **10**

(ii) Describe with neat sketch the method of cold drawing of a wire or a bar. **10**

(b) (i) The dimensions of the mating parts according to the hole system are given below :

Hole   30·0 mm   Shaft   29·98 mm
           30·05 mm   29·94 mm

Find the hole tolerance, shaft tolerance and allowance.   *10*

(ii) Illustrate and describe through a linking flow diagram, the elements of a CIM system for integrating CAD/CAM including latest communication technology to all the operational functions and information processing in manufacturing.   *10*

(c) Answer the following :   *10+10=20*

(i) Develop Forward Kinematics model for the given three degrees of freedom RPY wrist figure. Assign the frames, develop D-H parameters table, generate individual transformation matrices and overall transformation matrix. Assume $a_3 = d_3 = 0$. Determine the orientation of the last frame with reference to the {0} frame, if $\theta_1 = 0$ and $\theta_2 = \theta_3 = 90°$.
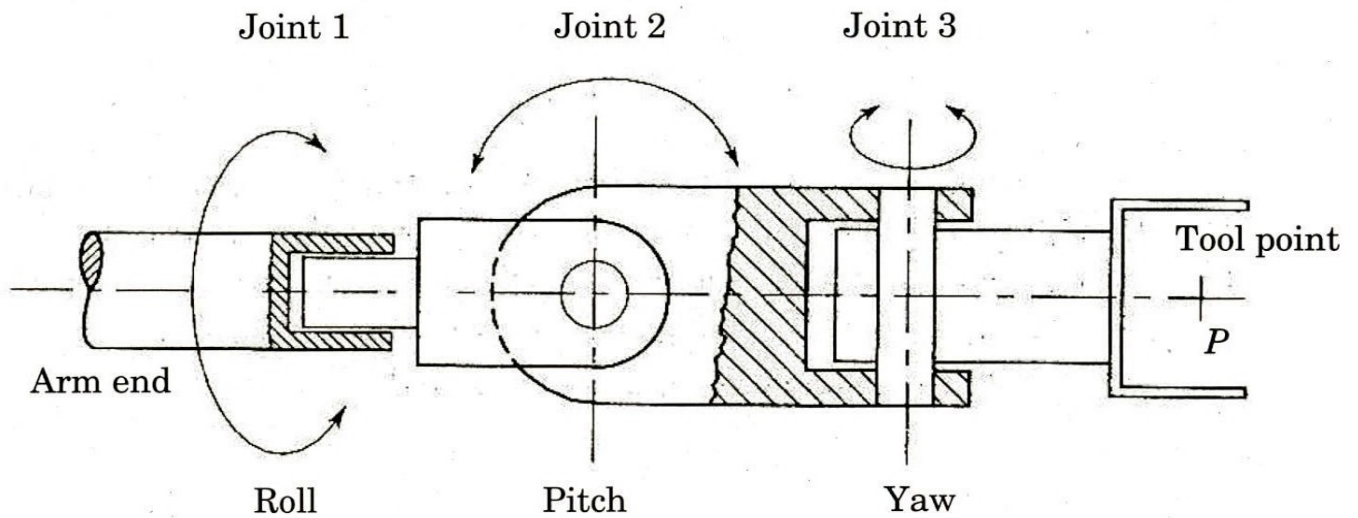
A 3-DOF freedom roll, pitch and yaw (RPY) wrist

(ii) Determine the three joint variables for a given end effector orientation matrix T_E for the RPY wrist in the figure above.

$$T_E = \begin{bmatrix} n_x & o_x & a_x & 0 \\ n_y & o_y & a_y & 0 \\ n_z & o_z & a_z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$