Engineering Services (Main)
Examination, 2026

SNCS–T–MCHN

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.

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

Question Nos. **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.

Wherever any assumptions are made for answering a question, they must be clearly indicated.

Diagrams/Figures, wherever required, shall be drawn in the space provided for answering the question itself.

Unless otherwise mentioned, symbols and notations have 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.

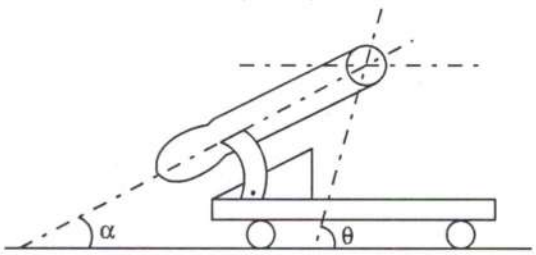
Any page or portion of the page left blank in the Question-cum-Answer (QCA) Booklet must be clearly struck off.

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

SECTION—A

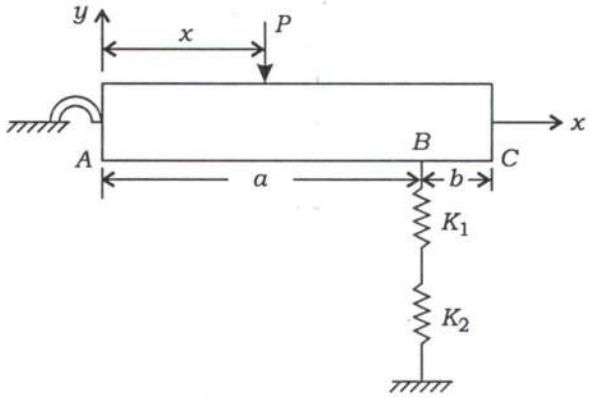
1. *(a)* A gun is mounted on a gun carriage movable on a smooth horizontal plane, and the gun is elevated at an angle α to the horizontal. A shot is fired and leaves the gun in a direction inclined at an angle θ to the horizontal. If the mass of the gun and its carriage be n times that of the shot, show that

$$\tan\theta = \left(1+\frac{1}{n}\right)\tan\alpha$$



12

(b) A very rigid beam ABC is supported at point A by an elastic hinge and at point B by two springs connected in series. Load P acts at a variable distance x. Determine *(i)* the reaction at support B and *(ii)* the angular displacement of the beam about the hinge at A. Given that the resistance against angular displacement (M_A) at A is $K_3\theta_A$:



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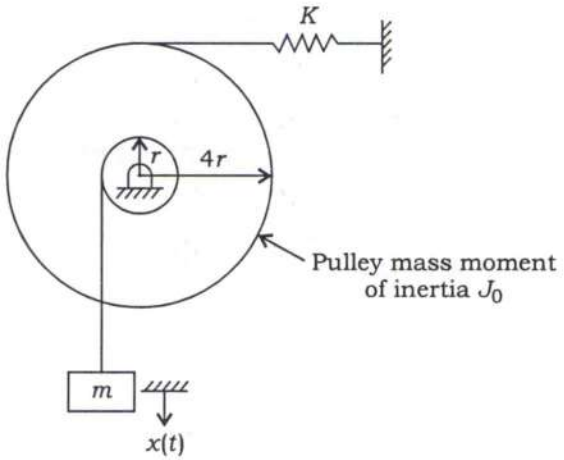
(c) Derive the equation of motion using the principle of energy conservation for the system shown below :



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(d) Distinguish between a kinematic chain, a mechanism and a machine. What are the most commonly used kinematic chains consisting of lower pairs? 12

(e) Explain the following terms as applied to gears :

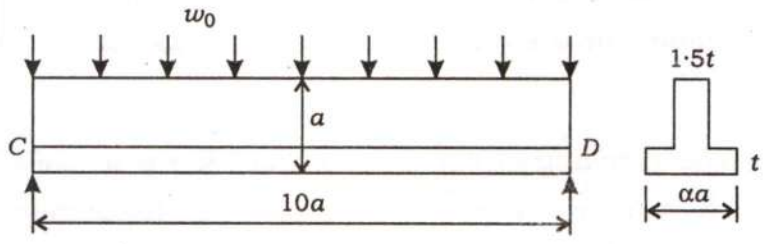
(i) Module

(ii) Pressure angle

(iii) Addendum

(iv) Interference 12

2. (a) A cast iron beam *CD* has an inverted T-section. The tensile strength σ_t of cast iron is almost one-third of its compressive strength σ_c. Determine α so that the extreme fibre stresses are σ_t and σ_c simultaneously. The uniformly distributed load acting on the beam is w_0 per unit length :



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(b) An electric motor weighing 3500 N and running at 1800 r.p.m. is supported on four steel helical springs, each of which has eight active coils with a wire diameter of 0·0065 m and a coil diameter of 0·08 m. The rotor has a weight of 500 N with its centre of mass located at a distance of 0·2 mm from the axis of rotation. Find the magnitude of vibration of the motor and the force transmitted through the springs to the base. Take $G = 83$ GPa. 20

(c) A four-wheel vehicle of mass 3000 kg has a wheelbase 3 m, track width 1·8 m, and height of centre of gravity 0·6 m above the ground level and lies at 1 m from the front axle. Each wheel has an effective diameter of 0·8 m and a moment of inertia of 0·8 kg-m^2. The drive shaft, engine flywheel and transmission are rotating at four times the speed of road wheels, in clockwise direction when viewed from the front, and is equivalent to a mass of 80 kg having a radius of gyration of 100 mm. If the vehicle is taking a right turn of 50 m radius at 50 km/h, find the load on each wheel. 20

3. *(a)* In a spring-loaded governor of the Hartnell type, the weight of each ball is 6 kg and the lift of the sleeve is 6 cm. The speed at which the governor begins to float is 250 r.p.m. and at this speed, the radius of the ball path is 10 cm. The working speed of the governor is 20 times the range of speed when friction is neglected. If the lengths of ball and roller arm of the bell crank lever are 12 cm and 9 cm respectively, and if the distance between the centre of pivot of bell crank lever and axis of the governor spindle is 14 cm, determine the initial compression of the spring, taking into account obliquity of arms. 20

(b) A beam of symmetrical I-section is simply supported at each end and loaded at the centre of its 4 m span with a concentrated load of 150 kN. The dimensions of the cross-section are : flanges 150 mm wide by 30 mm thick; web 30 mm thick; overall depth 200 mm. For the transverse section at the point of application of the load and considering a point at the top of the web where it meets the flange, calculate the magnitude and nature of the principal stresses and maximum shear stress. Neglect the self-mass of the beam. 20

(c) A centrifugal clutch, transmitting 25 kW at 750 r.p.m., consists of four shoes. The clutch is to be engaged at 500 r.p.m. The inner radius of the drum is 160 mm. The radius of the centre of gravity of the shoes is 135 mm, when the clutch is engaged. The coefficient of friction is 0·25, while the permissible pressure on friction lining is 0·08 N/mm^2. Calculate the mass of each shoe and dimensions of friction lining. 20

4. *(a)* A shaft 750 mm long is simply supported on bearings at its ends and carries two pulleys of weight 2 kN each at a distance of 250 mm from each end. Belt tension on one pulley is 10 kN and horizontal, while on the other pulley, it is also 10 kN but vertically downward. The torque transmitted between the two pulleys is 3500 N-m. If the maximum permissible shear stress for the shaft material is 50 MPa, determine the shaft diameter. 20

(b) A three-cylinder radial engine has the cylinders spaced at the angular intervals of 120°. The three connecting rods are coupled directly to a single crank. The stroke is 15 cm, the length of each connecting rod is 25 cm, and the weight of

the reciprocating parts per cylinder is 2·5 kg. Find the maximum primary and secondary forces at a crank speed of 2000 r.p.m. acting on the frame. Describe a method by which such forces may be balanced. 20

(c) A transmission shaft carries a pulley midway between the two bearings. The bending moment at the pulley varies from 250 N-m to 650 N-m, as the torsional moment in the shaft varies from 100 N-m to 225 N-m. The frequencies of variation of bending and torsional moments are equal to the shaft speed. The shaft is made of steel Fe E400 ($S_{ut} = 540\ N/mm^2$ and $S_{yt} = 400\ N/mm^2$). The corrected endurance limit of the shaft is 180 N/mm^2. Determine the diameter of the shaft using a factor of safety of 2. 20

SECTION—B

5. (a) A CNC machine shows dimensional inaccuracies and abnormal tool wear. Explain how fault detection and monitoring systems can be used to diagnose machine-related faults. 12

(b) A crystalline material has a body-centred cubic (BCC) structure. The lattice parameter of the unit cell is 0·286 nm. The number of atoms per unit cell is 2 and the atomic weight of the material is 55·85 g/mol. Considering Avogadro's number as $6{\cdot}022 \times 10^{23}\ mol^{-1}$, determine the following :

(i) The interplanar spacing for the (110) plane

(ii) The volume of the unit cell

(iii) The theoretical density of the material in g/cm^3 12

(c) Use graphical method to solve the following LPP and comment on the optimum solution :

$$\text{Maximize } Z = 2x_1 + 4x_2$$

subject to

$$x_1 + 2x_2 \leq 5$$
$$x_1 + x_2 \leq 4$$
$$x_1, x_2 \geq 0$$

12

(d) Provide the general block diagram of a microcontroller. How does a microcontroller differ from a microprocessor? 12

(e) A system contains a certain type of component whose time, in years, to failure is given by T. The random variable T is modeled by the exponential distribution with mean time to failure $\lambda = 5$. If 5 of these components are installed in different systems, what is the probability that at least 2 are still functioning at the end of 8 years? 12

6. (a) (i) In a project network, the longest path based on mean durations has a path mean (μ) of 27 days and path standard deviation (σ) of 1·39 days. What is the probability that the last node (event) will be realized by 30 days? If the project engineer wants to realize the last node (event) with a probability 0·95, then determine the number of days to realize it. (Use cumulative normal distribution table given in Page No. 11) 10

(ii) A cylindrical test sample of diameter 12·8 mm is tested in tension up to fracture and found to have engineering fracture strength 450 MPa. If the diameter of cross-sectional area at fracture is 10·7 mm, determine the following :

(1) The ductility in terms of percent reduction in the area

(2) The true stress at fracture

(3) The true fracture strain 10

(b) (i) Draw distinct diagrams to illustrate the following :

(1) Different classes of fit which can be obtained in a hole-based system

(2) Difference between a positional tolerance defined by toleranced coordinate dimensions and the one generally used in engineering practices 10

(ii) A solid steel shaft used in a rotating machine failed during operation. The shaft has the following specifications and operating conditions :

Diameter of the shaft = 40 mm

Applied torque = 1200 N-m

Ultimate shear strength of the shaft material = 250 MPa

Factor of safety used in design = 2

Considering the above data, compute and predict whether the shaft failure was due to static loading. If the failure was not due to static loading, then suggest the likely causes of failure. 10

(c) (i) For the following end-effector frame of a manipulator, find the values of the missing elements and complete the homogeneous transformation matrix (HTM) representation of the frame :

$$\begin{bmatrix} ? & 0 & ? & 3 \\ 0{\cdot}707 & ? & ? & 10 \\ 0 & ? & ? & 6 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

? indicates missing elements in the matrix. 10

(ii) Draw the block diagram, indicating the important elements of a digital temperature measurement system which uses MC68HC11 micro-controller. Discuss the steps necessary to prevent the fluctuation in display of temperature. 10

7. (a) A wind farm consisting of 2 MW turbines has reported downtime due to failures in the following components :

Gearbox bearings

Composite blades

Tower weld joints

(i) Identify and justify the most suitable NDT technique for monitoring each component.

(ii) Explain the application of acoustic emission in detecting blade crack.

(iii) Discuss the integration of NDT and vibration monitoring for gearbox fault detection. 20

(b) (i) Describe the major components of computer integrated manufacturing (CIM). Explain the function of flexible manufacturing system (FMS) in a CIM environment. 10

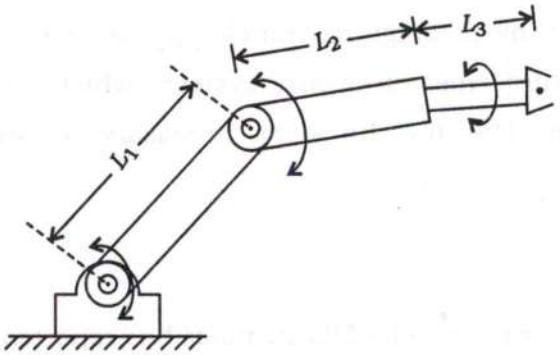
(ii) A butt-welded joint is used to connect two steel plates each of 8 mm thickness. The joint carries a tensile load of 90 kN. The allowable tensile stress in weld is 100 MPa and width of the plate is 60 mm.

(1) Determine the tensile stress developed in the weld.

(2) Determine the factor of safety of the joint.

(3) State whether the joint is safe. 10

(c) For the 3 DOF (RRT) robotic manipulator arm shown in the figure below, assign frames to the links and determine link-joint parameters and therefrom obtain the direct kinematic model :



Use

$$^{i-1}T_i = \begin{bmatrix} c\theta_i & -s\theta_i c\alpha_i & s\theta_i s\alpha_i & a_i c\theta_i \\ s\theta_i & c\theta_i c\alpha_i & -c\theta_i s\alpha_i & a_i s\theta_i \\ 0 & s\alpha_i & c\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

The symbols used here have their usual meanings in D-H convention. 20

8. *(a)* Molten aluminium is poured into a sand mould through a sprue-runner-ingate system to produce a casting of volume $1 \cdot 8 \times 10^{-3}$ m^3. Considering the pouring time 6 seconds, density of molten aluminium 2700 kg/m^3, height of molten metal in sprue 150 mm, discharge coefficient 0·8, acceleration due to gravity 9·81 m/s^2 and gating ratio 1 : 2 : 2 (sprue : runner : ingate), answer the following :

(i) Determine the mass flow rate of the molten metal.

(ii) Determine the area of the sprue base.

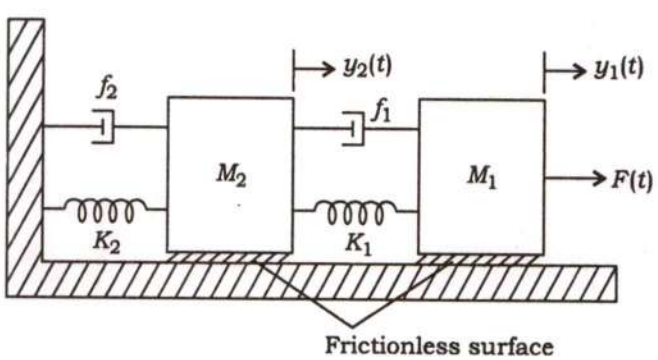
(iii) Determine the area of the runner and ingates.

(iv) Comment on the type of gating system used. 20

(b) *(i)* A vibration pickup has a damping ratio of 0·6 and a natural frequency of 10 Hz. It is mounted on a table vibrating at 50 Hz. The measured value of the relative amplitude of the mass is 2 mm. What is the amplitude of vibration of the table and the error of measurement? 10

(ii) List down the important differences between gear pump and vane pump used in hydraulic circuits, in terms of operation, leakage, pressure and flow rate. 10

(c) Consider the mechanical system shown below :



Determine the state equations in matrix form by modeling the dynamic system, where :

$y_1(t)$ = displacement of block 1

$y_2(t)$ = displacement of block 2

M_1 = mass of block 1

M_2 = mass of block 2

K_1 = spring stiffness

K_2 = spring stiffness

f_1 = coefficient of viscous friction

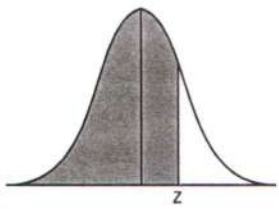
f_2 = coefficient of viscous friction

$F(t)$ = force acting on the system at free end

Assume zero initial conditions. 20

★★★

Standard Normal Cumulative Probability Table



Cumulative probabilities for POSITIVE z-values are shown in the following table :

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