Indian Forest Service (Main)
Examination, 2024

JBNV–U–MCHE

MECHANICAL ENGINEERING

PAPER—I

Time Allowed : Three Hours	Maximum Marks : 200

QUESTION PAPER SPECIFIC INSTRUCTIONS

Please read each of the following instructions carefully before attempting questions

There are EIGHT questions in all, out of which FIVE are to be attempted.

Question Nos. **1** and **5** are compulsory. Out of the remaining SIX questions, THREE are to be attempted selecting at least ONE question from each of the two Sections A and B.

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.

All questions carry equal marks. The number of marks carried by a question/part is indicated against it.

Answers must be written in ENGLISH only.

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

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

Neat sketches may be drawn, wherever required.

SECTION—A

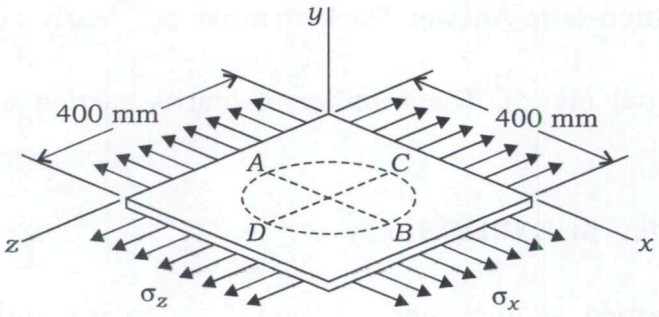
1. *(a)* A compressor of AC having diameter 1 m at 300 r.p.m. requires 160 kW. The power is transmitted to the compressor by an electric motor through V-belt drive. The motor runs at 1000 r.p.m. Consider the diameter of pulley of the compressor as 1 m and the centre distance between the shafts as 2 m. The belt speed should not exceed 25 m/s. Taking the cross-sectional area of each belt as 350 mm^2, density 1050 kg/m^3, allowable tensile stress of belt material 2·5 MPa, pulley groove angle 30° and coefficient of friction between belt and pulley as 0·3, determine the number of V-belts required to transmit the power. 8

(b) The springs in a combined form of a vehicle are compressed 0·1 m under its own weight. The vehicle is travelling over a road with a profile approximated by a sine wave of amplitude 0·08 m and wavelength of 16 m. Determine the following assuming damping factor zero :

(i) The critical speed of the vehicle in km/hr

(ii) The amplitude of vibration at 60 km/hr 8

(c) A circle of diameter $d = 250$ mm is scribed on an unstressed aluminum plate of thickness $t = 25$ mm as shown in the figure below. The forces acting in the plane of the plate later cause normal stresses $\sigma_x = 90$ MPa and $\sigma_z = 150$ MPa. If the elastic modulus and Poisson's ratio are 70 GPa and $\frac{1}{3}$ respectively, determine the change in *(i)* the length of diameter *AB*, *(ii)* the length of diameter *CD*, *(iii)* the thickness of the plate and *(iv)* the volume of the plate : 8



(d) With the help of neat sketch of the curve between coefficient of friction vs. bearing characteristic number, describe the stable region. 8

(e) What do you understand by 'defects' in crystalline materials? What is a 'solid solution'? Briefly explain the 'point' and 'line' defects with the help of neat sketches. 8

2. *(a)* A two-cylinder, uncoupled, 90° crank phase difference, inline locomotive engine has its inside cylinders 1·0 m apart. The balancing masses are 2·0 m apart and placed on driving wheels which are symmetrical about the centreline. The crank radius for each cylinder is 0·3 m. The $\frac{2}{3}$ of reciprocating mass of 285 kg are to be balanced by balancing mass placed on the driving wheels. When the engine runs at 120 km per hour, determine the following when wheel diameter is 1·2 m : 15

(i) The maximum hammer blow

(ii) The maximum variation in tractive effort

(iii) The maximum swaying couple

(b) A thin cylinder of 80 mm internal diameter, 300 mm long with walls 2·4 mm thick is subjected to an internal pressure of 8 MN/m^2. Determine the change in internal diameter and the change in length.

If, in addition to the internal pressure, the cylinder is subjected to a torque of 200 N-m, find the magnitude and the nature of the principal stresses set up in the cylinder. Take $E = 210$ GPa and $\nu = 0 \cdot 3$. 15

(c) What are cast irons? On the basis of microstructure, briefly explain why gray iron is brittle and weak in tension. Compare gray and malleable cast irons with respect to *(i)* composition and heat treatment, *(ii)* microstructure and *(iii)* mechanical characteristics. Sketch their microstructures also. 10

3. *(a)* A Hartnell governor has a central sleeve spring and two right-angled bell crank levers as usual. It operates between 280 r.p.m. and 320 r.p.m. for its sleeve lift of 16 mm. The sleeve arms and ball arms are 80 mm and 120 mm respectively. The levers are pivoted at 120 mm from the governor axis. The mass of each ball is 2·0 kg. The ball arms are parallel to the governor axis at the lowest equilibrium speed. Determine by considering obliquity—

(i) the centrifugal forces at both positions;

(ii) the stiffness of the spring. 15

(b) *(i)* What do you understand by 'strain energy'? Obtain an expression of strain energy for a uniform bar of length L and cross-sectional area A, being extended in the elastic region by a gradually applied load P. Neglect the weight of the bar and take E as the Young's modulus. 5

(ii) A closed-coil helical spring is required to absorb $3 \cdot 0 \times 10^3$ joules of energy. Determine the diameter of the wire, the mean diameter of the spring and the number of coils necessary if—

(1) the maximum stress is not to exceed 450 MN/m^2;

(2) the maximum compression of the spring is limited to 270 mm;

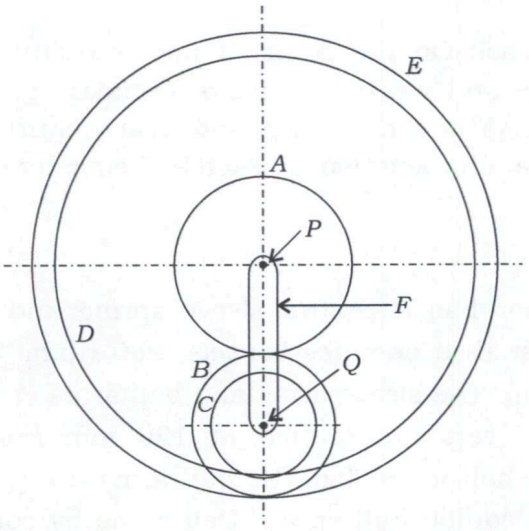
(3) the mean diameter of the spring may be assumed to nine times that of the wire.

Take $G = 72$ GPa for the material of the spring. 10

(c) A compound epicyclic gear train is shown in the figure below. The gears *A*, *D* and *E* are free to rotate on the axis *P*. The compound gears *B* and *C* rotate together on the axis *Q* at the end of arm *F*. Consider that all the gears have equal module. The numbers of teeth on the gears *A*, *B* and *C* are 36, 90 and 42 respectively. The gears *D* and *E* are annular gears. The gear *A* rotates at 120 r.p.m. counter-clockwise and the gear *D* rotates at 450 r.p.m. clockwise. Determine the speed and direction of—

(i) the arm *F*;

(ii) the gear *E*. 10

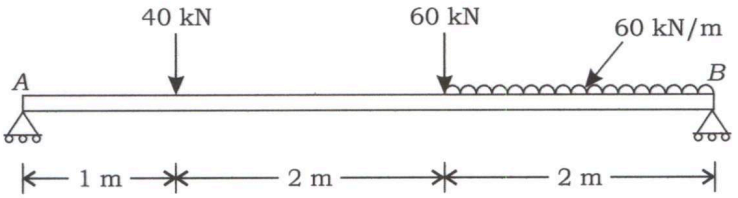


4. (a) A punching press punches 40 mm diameter holes in a plate of thickness 30 mm at the rate of 4 holes per minute. It requires 6 N-m of energy per mm^2 of sheared area. The punch has a stroke of 100 mm. The r.p.m. of the flywheel varies from 320 to 280. If the radius of gyration of the flywheel is 0·8 m, determine—

(i) the mass of the flywheel;

(ii) the power of the motor for punching machine. 15

(b) Determine the slope and deflection under 60 kN load for the beam loading shown in the figure below. Find also the position and magnitude of maximum deflection. Take $E = 200$ GN/m^2 and $I = 85 \times 10^{-6}$ m^4 : 15



(c) What is the difference between a phase and a microconstituent? Explain the development of the microstructures for an iron-carbon alloy of hypoeutectoid composition as it is cooled within the austenite phase region to below eutectoid temperature, with the help of schematic representation. 10

SECTION—B

5. (a) What corner radius should be ground on a tool with a rounded corner to give an arithmetical mean surface roughness of 10 µm when turning under ideal conditions with a feed of 0·25 mm/rev? List at least three possible ways of improving machinability. 8

(b) Find 'Go' and 'Not Go' gauge limits of a plug gauge for a $30^{+0\cdot021}_{+0\cdot000}$ mm diameter hole, if gauge tolerance is 10% of work tolerance and wear allowance is 10% of gauge tolerance. Also list at least four errors that can arise during manufacture of screw threads. 8

(c) For a particular product, the following information is given :

Selling price per unit = ₹ 100

Variable cost per unit = ₹ 50

Fixed cost = ₹ 2,00,000

Due to inflation, the variable cost increases by 15% while the fixed cost increases by 10%. If the break-even quantity is to remain constant, by what percentage should the sales price be raised? 8

(d) "Value engineering prevents unnecessary cost buildup into the product." Comment on this statement. 8

(e) Explain the following terms with respect to C programming language : 8

(i) Expressions

(ii) Statements

(iii) Declarations

(iv) Symbolic constants

6. *(a)* *(i)* State at least four differences between laser cutting and plasma arc cutting. 8

(ii) During orthogonal cutting with a zero degree rake angle cutting tool, show that

$$\frac{\tau_s}{U_c} = \frac{r}{1+r^2}(1-\mu r)$$

where

τ_s = shear strength of work material

U_c = specific cutting energy

r = chip thickness ratio

μ = coefficient of friction 7

(b) *(i)* Why is inventory necessary? Discuss. 5

(ii) A manufacturer has to supply his customers 7200 units per year. The inventory cost amounts ₹ 2·40 per unit per annum and it costs ₹ 160 to place an order. Determine—

(1) the economic order quantity;

(2) the optimum number of orders per annum;

(3) the minimum annual inventory cost;

(4) the optimum period of supply per optimum order. 10

(c) Write the C program for the following series : 10

$$1+\frac{1}{2}+\frac{1}{3}+\frac{1}{4}+\cdots+\frac{1}{N}$$

7. *(a)* *(i)* A 12·5 mm diameter steel wire is reduced to 10 mm diameter by drawing through a conical die of 4° die angle at a speed of 100 m/min. The coefficient of friction between die and wire is 0·1 and the average strength of hot drawn steel is 300 N/mm^2. Find the power required to carry out drawing operation and the maximum degree of drawing operation. 9

(ii) List at least three functions performed by water in 'unconfined' type of explosive forming. Also list at least three advantages of high energy rate forming processes over conventional forming processes. 6

(b) A company has five jobs to be done. The following matrix shows the return in rupees of assigning ith machine ($i = 1, 2, \cdots, 5$) to the jth job ($j = 1, 2, \cdots, 5$). Assign the five jobs to the five machines so as to maximize the total expected profit : 15

Job jth → / Machine ith ↓	1	2	3	4	5
1	5	11	10	12	4
2	2	4	6	3	5
3	3	12	5	14	6
4	6	15	4	11	7
5	7	9	8	12	5

(c) Arrival rate of telephone calls at a telephone booth is according to Poisson distribution, with an average time of 15 minutes between two consecutive calls arrival. The length of telephone call is assumed to be exponentially distributed with the mean of 4 minutes. Determine—

(i) the probability that the person arriving at the booth will have to wait;

(ii) the average queue length that is formed from time to time;

(iii) the average system time;

(iv) the fraction of a day that the phone will be in use. 10

8. (a) A bar of 150 mm length and 60 mm diameter is to be turned on lathe with a feed rate of 0·25 mm/rev. The cost of labour and overhead is ₹ 150 per hour. Each regrinding of tool requires an expense of ₹ 15 and tool changing time is 1 minute. The setting and idle time is also 1 minute. Two alternative workpiece materials X and Y can be used. Their cost and tool life equation for a feed of 0·25 mm/rev are given below :

Work material	*Cost/piece* (₹)	*Tool life equation*
X	10	$VT^{0.1} = 30$
Y	12	$VT^{0.16} = 76$

Suggest which work material should be selected from minimum cost viewpoint. 15

(b) *ABC* Industries is an intermittent manufacturing facility, processing jobs to customer order. Currently, eight job orders are awaiting processing. All jobs must be processed at the same facility :

Waiting job (in order of arrival)	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*
Processing time (in days)	23	16	5	31	11	20	2	27
Due date (in days from now)	28	35	15	40	30	45	8	50

Calculate the total completion time, average flow time, average number of jobs in the system each day and the average job lateness by applying first-come-first-served (FCFS) and shortest processing time sequencing rules. 15

(c) The direct time study for a job resulted in the following times :

Cycle time (in minutes)	13·2	14·1	17·4	11·7	15·2
Number of times observed	4	5	3	2	3

The analyst rated the workers at 90%, 100% and 110% respectively, and used the firm's 0·20 allowance fraction. Determine the standard time by using all the three levels of workers' rating. 10

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