Indian Forest Service
(Main) Exam, 2020

JKLO-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.*

*Questions no. **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.

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

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

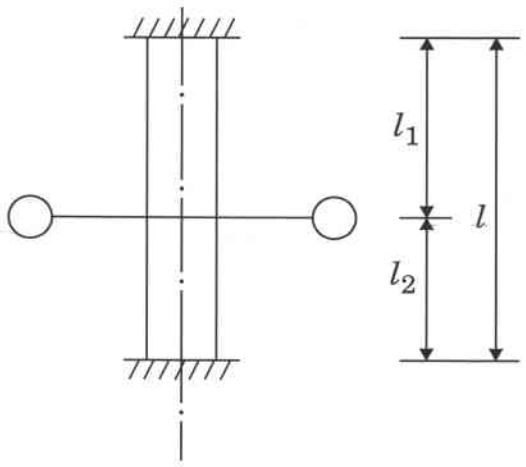
Neat sketch may be drawn, wherever required.

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

SECTION A

Q1. (a) A V-belt of 6·5 cm^2 cross-section has a groove angle of 30° and an angle of lap of 160° with coefficient of friction (μ) = 0·3. The mass of the rope is 1·5 kg/m. The maximum safe stress is 850 N/cm^2. Calculate the power that can be transmitted at 25 m/s. *8*

(b) A flywheel is mounted on a vertical shaft as shown in the figure. The ends of the shaft are being fixed. The shaft is 50 mm in diameter, the length l_1 is 900 mm and l_2 is 600 mm. The weight of the flywheel is 0·5 ton and its radius of gyration is 500 mm. Calculate the natural frequency of the longitudinal vibration of the system. Take Young's modulus (E) = 210 GPa. *8*

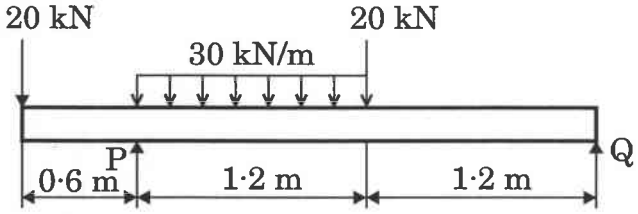


(c) A steel rod 5 m long and 20 mm in diameter is subjected to an axial pull of 50 kN. Determine the change in volume of the rod. Take Young's modulus (E) = 210 GPa and Poisson's ratio (ν) = 0·3. *8*

(d) What are the difficulties in hardening low carbon steel through heat treatment ? How can surface hardness be imparted through carburizing, nitriding and cyanide-hardening ? *8*

(e) What is the difference between an alloy and a composite ? Explain with the help of suitable examples. Also, cite the differences in strengthening mechanism for large particle and dispersion-strengthened composites. *8*

Q2. (a) Determine the deflection at a point 1·2 m from the left hand end of the overhanging beam loaded as shown in the figure below, using Macaulay's method. Take EI = 0·75 MNm^2. *15*



(b) A solid circular shaft is used to transmit simultaneously a twisting moment of 3000 Nm and a maximum bending moment of 2500 Nm. Determine the safe radius of the shaft that can be used if maximum $\sigma \leq 120$ MPa and maximum $\tau \leq 60$ MPa. *15*

(c) Explain strengthening in metals by way of grain size reduction. Also, discuss the mechanism of solid solution strengthening. *10*

Q3. (a) In a machine, the intermittent operations demand the torque to be applied as follows :

(i) During the first half-revolution, the torque increases uniformly from 800 Nm to 3000 Nm.

(ii) During the next one revolution, the torque remains constant.

(iii) During the next one revolution, the torque decreases uniformly from 3000 Nm to 800 Nm.

(iv) During the last one and a half revolution, the torque remains constant.

Thus, a cycle is completed in 4 revolutions. The motor to which the machine is coupled exerts a constant torque at a mean speed of 300 rpm. A flywheel of mass 2000 kg and radius of gyration of 500 mm is fitted to the shaft. Determine the power of the motor and total fluctuation of speed of the machine shaft. *15*

(b) A back gear is required for a lathe to give a reduction from cone-pulley speed to spindle speed of 9 to 1. The diametral pitch of the teeth on the high-speed pair is 7 and of those on the low-speed pair is 5. The centre distance is 7 cm. Determine the number of teeth on each of the four wheels if the pinions are to have as nearly as possible, equal number of teeth. Also, find the pitch circle diameter of the pinion on the cone pulley. *15*

(c) A cylinder has an internal diameter of 230 mm, has wall thickness of 5 mm and is 1 m long. It is found to change in internal volume by 12×10^{-6} m^3 when filled with a liquid at a pressure p. If Young's modulus (E) = 210 GPa and Poisson's ratio (ν) = 0·3, and assuming rigid end plates, determine (i) the values of hoop and longitudinal stresses, and (ii) the modifications to the above values of stresses if joint efficiencies of 45% (hoop) and 85% (longitudinal) are assumed. *10*

Q4. (a) How can theoretical density of a material be calculated using the properties of the crystal structure ? Determine the density of BCC iron, which has a lattice parameter of 0·2866 nm by using the properties of crystal structure. If actual measured density is 7·850 g/cm^3, state the reason for this difference.

Avogadro's Number $N_A = 6{\cdot}02 \times 10^{23}$ atoms/mol.

Atomic Mass of Iron = 55·847 g/mol. *15*

(b) A uniform T-section beam is 100 mm wide and 150 mm deep with a flange thickness of 25 mm and a web thickness of 12 mm. If the limiting bending stresses for the material of the beam are 84 MPa in compression and 168 MPa in tension, find the maximum uniformly distributed load that the beam can carry over a simply supported span of 5 m. *15*

(c) A rotor has a mass of 15 kg and is mounted midway on a 24 mm diameter horizontal shaft supported at the ends by two bearings. The bearings are 1 m apart. The shaft rotates at 2500 rpm. If the centre of mass of the rotor is 0·11 mm away from the geometric centre of the rotor due to a manufacturing defect, find the amplitude of the steady-state vibration and the dynamic force transmitted to the bearing. Take Young's modulus (E) = 210 GPa. *10*

SECTION B

Q5. (a) In EDM process, why is the rate of material removal from the cathode comparatively less than that from anode ? State the basic requirements of an ideal dielectric fluid used in EDM process. *8*

(b) Enlist the difficulties encountered in conventional NC machines. Also, discuss the advantages of Computer Numerical Control (CNC) over conventional Numerical Control (NC). *8*

(c) The inter-arrival time of passengers at a railway ticket booking counter is exponentially distributed and is equal to 12 minutes. The ticket booking time for each passenger is 3 minutes and is exponentially distributed.

(i) What is the probability that a passenger arriving at the ticket counter will have to wait ?

(ii) The management will start a second ticket booking counter when each arrival would expect waiting for at least 3 minutes for ticket booking. By how much should the arrival rate of passengers increase to justify the second counter ?

(iii) What is the average length of the queue ?

(iv) What is the probability that the queue size will exceed 2 ? *8*

(d) The annual demand and unit price of some inventory items are given below :

Item No.	Annual Demand	Unit Price (₹)	Item No.	Annual Demand	Unit Price (₹)
1001	500	3·00	1009	500	1·20
1002	125	1·00	1010	300	1·80
1003	75	7·00	1011	15	30·00
1004	150	1·00	1012	5	20·00
1005	50	1·50	1013	500	5·00
1006	350	1·60	1014	1500	3·00
1007	250	7·00	1015	50	0·80
1008	10	5·00	—	—	—

Based on ABC analysis, classify these items in Class-A, Class-B and Class-C, considering A – 60 to 70%, B – 71 to 90%, C – 91 to 100%. *8*

(e) Draw a flowchart for finding the first 100 prime numbers. To determine whether a number is prime, you may call the function "Is This Number Prime" from the already made libraries. *8*

Q6. (a) In rolling operation, explain the condition of biting i.e. the condition for unaided entry of the workpiece in the rolls.

A 40 mm thick plate is to be reduced to 30 mm in one pass in a rolling operation. Entrance speed = 16 m/minute. Roll radius = 300 mm and Rotational speed = 18·5 rev/minute.

Determine : (a) the minimum required coefficient of friction that would make this rolling operation possible, (b) exit velocity under the assumption that the plate widens by 2% during the operation, and (c) forward slip. *15*

(b) Solve the following Linear Programming Problem using Big-M method : *15*

Maximize $z = 2x_1 + x_2$

subject to

$$3x_1 + x_2 = 3$$

$$4x_1 + 3x_2 \geq 6$$

$$x_1 + 2x_2 \leq 4$$

and $x_1, x_2 \geq 0$

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

$$\frac{1}{\lfloor 1} + \frac{2}{\lfloor 2} + \frac{3}{\lfloor 3} + ... + \frac{N}{\lfloor N}$$

Q7. (a) With the help of free body diagrams of forces, explain the construction of Merchant's circle. State all the assumptions that are made while deriving Merchant's circle equation. Also, derive this equation. *15*

(b) A production manager wants to fix the number of workstations required in an assembly line. The information related to the activities and time consumption (in seconds) are given below :

Activities	Immediate predecessor	Task time (sec)
A	None	50
B	A	20
C	A	32
D	B	57
E	C,D	12
F	E	18

If 50 products are to be assembled per hour, compute the following : *15*

(i) Draw the precedence (network) diagram

(ii) Cycle time

(iii) Theoretical and actual number of workstations required

(iv) The efficiency and balance delay

(c) The efficiencies of five different workers (A, B, C, D and E) on five different machines (I, II, III, IV and V) are recorded as given below :

Workers	Efficiencies (%)				
	I	II	III	IV	V
A	50	50	45	35	60
B	52	40	26	35	37
C	60	58	50	70	60
D	30	29	30	28	35
E	68	70	69	65	63

To maximize the overall efficiency, assign the workers on the different machines. (One worker is to be assigned on one machine only). *10*

Q8. (a) Explain the mechanism of material removal during ultrasonic machining process. With the help of neat sketches, show the effect of critical parameters (frequency, amplitude, tool material, grit size, abrasive material, feed force, slurry concentration, slurry viscosity) on material removal rate. Also, discuss its application and limitations. *15*

(b) A company is concerned with CPU (Central Processing Unit) manufacturing. The information related to manufacturing capacity, sales, and costs is given below :

Manufacturing capacity = 80,000 units

Margin of safety = 50% of Break-Even Point (BEP)

Contribution margin = 25%

Unutilized capacity at present is 5,000 units

Sales price = ₹ 1,500 per unit.

Find

(i) Break-even point in sales volume

(ii) Fixed and variable costs

(iii) Margin of safety

(iv) If the fixed cost is decreased by ₹ 1,00,000, to what extent can the price be reduced to maintain the same profit level. *15*

(c) Samples of fabric from a textile mill, each 100 m^2, are selected, and the number of occurrences of foreign matter is recorded. Data for 25 samples are shown in the following table. Construct a suitable control chart for the number of defects and plot the graph. *10*

Sample	Defects	Sample	Defects
1	5	14	11
2	4	15	9
3	7	16	5
4	6	17	7
5	8	18	6
6	5	19	10
7	6	20	8
8	5	21	9
9	16	22	9
10	10	23	7
11	9	24	5
12	7	25	7
13	8		