CC/M/EXAM. 2020

MECHANICAL ENGINEERING

PAPER—I

Time : 3 hours] [Full Marks : 250

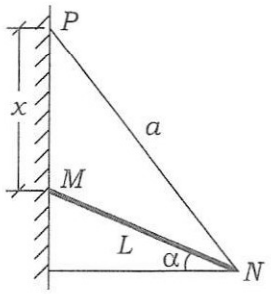
Note : Question Nos. **1** and **5** are compulsory and out of the remaining, any **three** are to be attempted choosing at least ONE question from each Section. The number of marks carried by a question/part is indicated against it.

SECTION—A

1. Answer *any* **five** of the following questions : 10×5=50

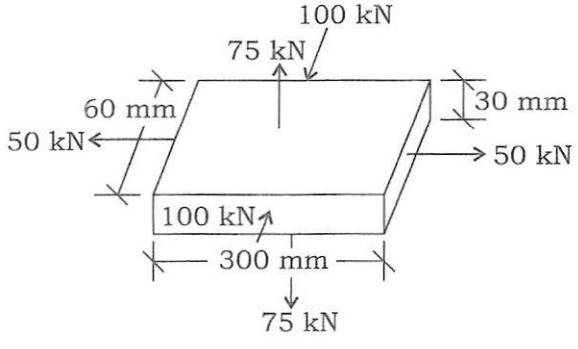
(a) State the conditions for the equilibrium of a rigid body acted upon by a number of non-concurrent and non-parallel forces in the same plane.

A heavy metal rod, of weight 150 N and length L, is supported at one end N by a guy-wire NP and rests at M vertically below P as shown in the figure. If the length of the wire is a and the wall is smooth, express the distance PM or x as a function of a and L when the system is in static equilibrium.



(b) Define 'lateral strain' and 'linear strain' in case of deformable bodies. Write the S.I. units of stress and strain.

A metal flat plate is of size 300 mm × 60 mm × 30 mm is subjected to normal forces in mutually orthogonal directions as shown in the figure given below. If the Young's modulus $E = 2\times10^5$ N-mm^{-2} and Poisson's ratio = 0·3, calculate volumetric strain.



(c) Explain why a small flywheel is required instead of a bigger one in the case of multi-cylinder engines.

An engine flywheel has a mass of 6000 kg and radius of gyration 2 m. If the maximum and minimum speeds are 150 r.p.m. and 140 r.p.m. respectively, calculate the maximum fluctuation of energy in the flywheel.

(d) Name the instrument for precise measurement of the internal diameter of an automotive engine sleeve.

With the help of a schematic, explain how you can control the diameter of the sleeve in the range of $\phi 50 \pm 0 \cdot 02$ mm during manufacturing process.

(e) What are the machine, tools and equipments needed during the process of making V-thread?

Given original bar diameter of 25 mm low carbon steel, explain the process of making V-thread of size M-20×2 mm. Also mention the cutting conditions.

(f) What are the methods for assessing life of cutting tools used for machining metals?

Using Taylor's tool life equation, calculate percentage change of cutting speed required to give 40% reduction in tool life, given the value of Taylor's exponent $n = 0{\cdot}20$.

(g) What is the sign of degeneracy in a transportation problem in Operations Research? How would you resolve it?

Write the general mathematical formulation of transportation problem where there are m sources and n destinations.

2. Answer the following questions :

(a) What is Systematic Layout Planning (SLP)? Taking the case of a workshop for manufacturing C.I. cylinder blocks where molding, casting and machining will be done. Apply the steps of SLP to develop a layout plan to minimize distance travelled by movable items and resources. 20

(b) Consider the construction of PERT network and determine the expected length of the critical path. Also calculate the probability of project completion if the due date is same as the critical path length. 15

Activity		*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*
Immediate predecessor		–	–	–	*a*	*a*	*a*	*b*, *c*	*c*	*d*	*e*, *g*	*f*, *h*	*f*, *h*	*i*, *j*, *k*	*l*
Duration (days)	Optimistic	4	1	2	1	1	1	1	4	2	6	2	5	1	6
	Most likely	4	2	5	4	2	5	2	4	2	7	2	5	2	7
	Pessimistic	10	9	14	7	3	9	9	4	8	8	8	5	9	8

(c) What is the meaning of Materials Requirement Planning (MRP)? Discuss the inputs needed for MRP, MRP processing and MRP output. 15

3. Answer the following questions :

(a) What are the meanings of primary unbalance and secondary unbalance in the case of a reciprocating engine?

The three cylinders of an air compressor have their axes 120° to one another and their connecting rods are coupled to a single crank. The stroke is 100 mm and length of each connecting rod is 150 mm. The mass of reciprocating parts per cylinder is 1·5 kg. Find the maximum primary and secondary forces and couples acting on the frame of the compressor when the speed is 3000 r.p.m. 20

(b) Two shafts *A* and *B* are co-axial. The gear *C* (50 teeth) is rigidly mounted on the shaft *A*. The compound gear *D-E* meshes with *C* and an internal gear *G*. *D* has 20 teeth and meshes with *C*. *E* has 35 teeth and meshes with internal gear *G*. Gear *G* is fixed and it is concentric with shaft axis. The compound gear *D-E* is mounted on a pin which projects from an arm keyed to the shaft *B*.

Sketch the arrangement and find the number of teeth on internal gear *G*, assuming that all gears have the same module. 15

(c) The arms of a Porter governor are 18 cm long and they are hinged at a distance of 4 cm from the axis of rotation. The masses of the balls are 1·5 kg each and the mass on the sleeve is 20 kg. The governor sleeve begins to rise at 280 r.p.m. when the links are at 30° to vertical. Calculate the higher and the lower speeds when arms are inclined at 45° to the vertical. 15

4. Answer the following questions :

(a) A solid rod of steel having diameter 25 mm is encased in an aluminium tube of external diameter 40 mm and 5 mm wall thickness. The composite shaft is required to transmit a torque of 150 kN-m. If both the shafts of equal lengths are rigidly welded at the ends, calculate maximum shear stress developed in each shaft material, given the moduli of rigidity of steel and aluminium are as 10^5 N-mm^{-2} and $0{\cdot}3\times10^5$ N-mm^{-2} respectively. 20

(b) The principal stresses at a point in a strained material are σ_1 and σ_2. Show that the resultant stress on a plane carrying maximum stress is

$$\sqrt{\frac{\sigma_1^2 + \sigma_2^2}{2}}$$ 15

(c) A cantilever of 6 m length is subjected to uniformly distributed load of w tonne per metre over the entire span. Assuming rectangular cross-section with the depth equal to twice the breadth, calculate the minimum dimensions of the beam so that vertical deflection at the free end does not exceed 2 cm and the maximum bending stress does not exceed 1000 kg/cm^2. 15

SECTION—B

5. Answer *any* **five** of the following questions : 10×5=50

(a) Name the various quenching media during heat treatment and explain how you can impart hardness and strength to steel components by heat treatment.

(b) Write the fundamental difference between Simplex method and Dual Simplex method. Use Dual Simplex algorithm to solve

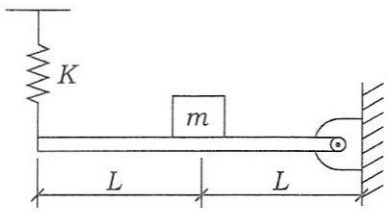
$$\text{Maximize } Z = -3x_1 - 2x_2$$

subject to

$$x_1 + x_2 \geq 1$$
$$x_1 + x_2 \leq 7$$
$$x_1 + 2x_2 \geq 10$$
$$x_2 \leq 3$$
$$\text{and } x_1, x_2 \geq 0$$

(c) Differentiate between 'work' and 'energy'. Give an example to establish how conservation of energy takes place in pure rolling of rigid body over a rough inclined plane. What difference would you find if the plane is smooth?

(d) What are the factors which affect the critical speed of revolving shaft? A concentrated load of mass m is attached at the center of a hinged cantilever rod of length $2L$ as shown in the figure given below. The rod is kept in horizontal equilibrium by a spring of stiffness K. Assuming very low amplitude of vibration, calculate the natural frequency of vibration, neglecting the mass of the rod and spring.



(e) How does Traditional Quality Management differ from Total Quality Management? Discuss any four of the Costs of Quality (COQ) encountered in the practice of Total Quality Management.

(f) Differentiate, by giving examples, between allowance and tolerance in precision measurement. Discuss with proper scientific arguments, why ± 3 sigma limits are considered as the natural tolerance limits for controlling dimensional quality.

(g) A shoe-repair operation uses a two-step sequence that all jobs in a certain category follow for the shop of jobs listed.

(i) Find the sequence that will minimize total completion time.

(ii) Make the Gantt Chart and determine the amount of idle time for workstation *B*.

	Jobs (time in minutes)				
	a	*b*	*c*	*d*	*e*
Station A	27	18	70	26	15
Station B	45	33	30	24	10

6. Answer the following questions :

(a) What is Coriolis acceleration? By assuming proper engineering symbols, give the formula for the Coriolis acceleration for a slider mounted on a revolving link.

The crank of a reciprocating engine revolves at a uniform speed of 300 r.p.m. The lengths of crank and connecting rod are 15 cm and 65 cm respectively. Calculate the velocity of the piston for crank positions from 0° to 90° from inner dead centre at intervals of 30°. 20

(b) Name the machine where tensile strength of steel can be evaluated. Describe briefly the testing procedure. During the tensile testing of an MS specimen of 40 mm diameter and 200 mm length, the following were found :

Elongation due to 40 kN load (within proportional limit) = 0·0305 mm

Yield load = 160 kN

Maximum load = 240 kN

Length of specimen at fracture = 250 mm

Based on these data, calculate *(i)* Young's modulus, *(ii)* Yield stress and *(iii)* Ultimate stress. 15

(c) Give a list of geometric tolerance symbols for the following and explain them briefly with neat sketches : 15

(i) Straightness

(ii) Angularity

(iii) Roundness

7. Answer the following questions :

(a) What is the difference of left-hand corner method and Vogel's approximation method in Operations Research?

A firm has four factories (*A*, *B*, *C*, *D*) which supply to five warehouses (*P*, *Q*, *R*, *S*, *T*) with the following unit transportation costs (Rs./Unit) and demand/ supply situation. Note that factory *D* cannot supply to warehouse *S*. By using any method of your choice, determine the optimum distribution schedule and the minimum total cost : 20

		Warehouse					Supply (Units)
		P	*Q*	*R*	*S*	*T*	
Factory	*A*	10	2	3	15	9	25
	B	5	10	15	2	4	30
	C	15	5	14	7	15	20
	D	20	15	13	—	8	30
Demand (Units)		20	20	30	10	25	

(b) With a neat sketch, describe orthogonal machining in metal cutting by labelling the diagram.

During orthogonal turning of steel with carbide tool, the rake angle of the tool = 10°, chip thickness = 0·45 mm and uncut thickness = 0·20 mm. Calculate *(i)* the shear plane angle and *(ii)* shear strain. State any assumptions made by you. 15

(c) Discuss briefly the 'errors in forecasting'.

Using a linear regression model, establish the sales pattern and forecast the expected sales for year 2023.

Using a linear regression model, establish the sales pattern and forecast the expected sales for year 1987. 15

Production of steel (in tonnes)

Year	*Y*	*X*	*XY*	X^2
2015	60	– 3	– 180	9
2016	72	– 2	– 144	4
2017	75	– 1	– 75	1
2018	65	0	0	0
2019	80	+ 1	+ 80	1
2020	85	+ 2	+ 170	4
2021	95	+ 3	+ 285	9

8. Answer the following questions :

(a) By studying the control chart in the process of statistical quality control, how would you judge that the manufacturing process is going out of control?

In the manufacturing quality control of spindles by $\bar{X}$ and R-chart, a sample size of five is taken at random on a continuous basis for measurement of the diameter. After 25 samples have been collected, the values of $\Sigma\bar{X} = 357 \cdot 50$ mm and $\Sigma R = 8 \cdot 80$ mm. Assuming the process under statistical control, if the specification limits are $14 \cdot 40 \pm 0 \cdot 40$ mm, what is your conclusion regarding the capability of the process to manufacture the spindles within specifications? Given $d_2 = 2 \cdot 236$ for sample size of five. 20

(b) A solid cylinder of mass m and radius R is released from rest on a rough ($\mu = 0{\cdot}23$) inclined plane having inclination (θ) with the horizontal. Calculate *(i)* the acceleration of the centre of mass of the cylinder, *(ii)* the maximum value of θ for which rolling without slipping occurs and *(iii)* the maximum velocity of the centre of mass of the cylinder after rolling a distance of 3 m. 15

(c) With the help of a diagram, discuss the working of electro-chemical machining. What are its applications in manufacturing industries? 15

★★★