2021

MECHANICAL ENGINEERING

PAPER-I

Time Allowed — 3 Hours *Full Marks — 200*

If the questions attempted are in excess of the prescribed number, only the questions attempted first up to the prescribed number shall be valued and the remaining ones ignored.

Answers may be given either in ***English*** *or in* ***Bengali*** *but all answers must be in one and same language.*

Answer any five *questions.*

1. Answer the following:

(a) Consider the single degree of freedom system as shown in Figure 1. The coulomb friction is present between the block and the surface. Obtain the equation of motion for the mass. Determine the equation for the amplitude decay of the oscillation for this system. Assume that coefficient of static friction and coefficient of kinetic friction are equal. The spring is massless.

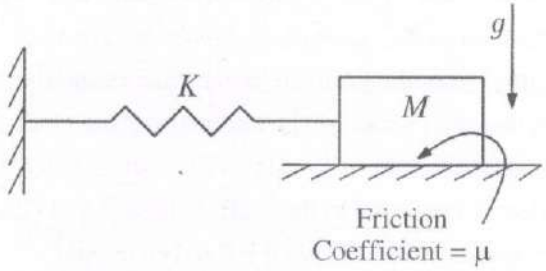

Figure 1: A single degree of freedom system with coulomb friction.

(b) A single degree of freedom system is shown in Figure 2. The dashpot and the spring are massless. Find the frequency of the base excitation (ω) for which the displacement transmissibility is independent of the damping coefficient C.

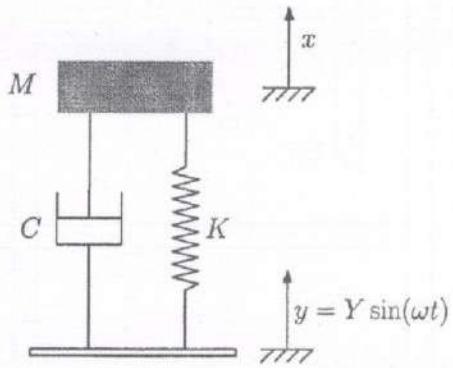

Figure 2: A spring-mass-damper (viscous) system undergoing a harmonic base excitation.

(c) Determine the effect of the mass of the spring on the natural frequency of the system shown in Figure 3. The length of the spring is L. Write down the necessary assumptions.

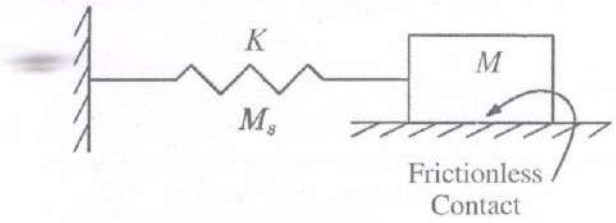

Figure 3: A single degree of freedom system with the spring having the mass = M_s.

15+10+15=40

2. Answer the following:

(a) For the gear train shown in the Figure 4, the shaft-A rotates at 100 rpm in the anti-clockwise direction as seen from your (reader's) right side. Determine the direction of rotation and the angular velocity of the shaft-B. The number of teeth corresponding to each gear is mentioned beside the gear of interest. For example gear-7 has 59 teeth. The other relevant information are listed below:

- Gear-5 and Gear-6 are rigidly connected to each other. Gear-7 and Gear-8 are rigidly connected to each other.
- Dotted lines imply that the gear can freely rotate about the shaft on which it is mounted. For example the gear-8 can freely rotate about the shaft-B. Similarly the gear-6 can freely rotate about the arm.
- Gear-2 and Gear-9 are keyed to the shaft-A. Gear-3 and Gear-4 are keyed to the shaft-C.
- The elements numbered as '1' are the fixed elements.

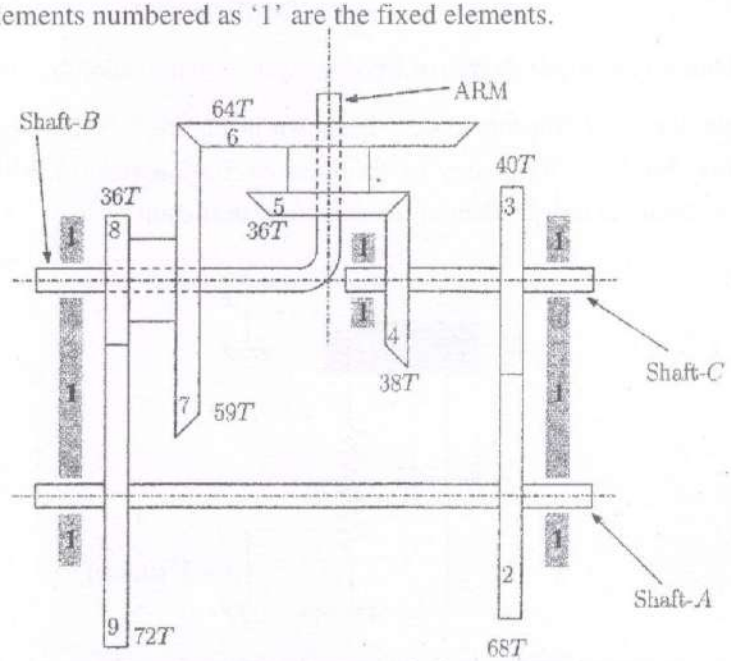

Figure 4: The schematic of a gear train.

(b) A pinion and a gear are in mesh. Both are spur gears. Obtain the expression for the minimum number of teeth on the pinion to avoid involute interference. 20+20=40

3. Answer the following:

(a) Find the deflection of the cantilever beam (Figure 5) at the point of application of the force P. The spring is unstretched when the beam is horizontal.

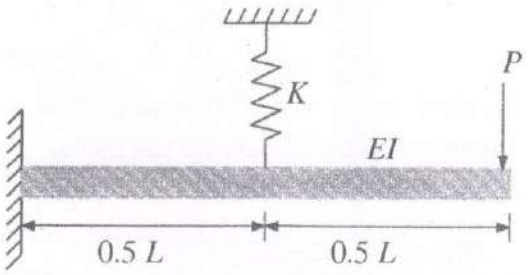

Figure 5: A cantilever beam with a spring connected at the middle.

(b) A couple of M = 70 N-m (about the longitudinal axis of the shaft and anti-clockwise as seen from the right) is applied to a 25 mm diameter aluminium-alloy shaft as shown in Figure 6. The ends A and C are built-in and prevented from rotating. Determine the angle through which the centre cross section O rotates. The shear modulus of the aluminium-alloy is 28 GPa.

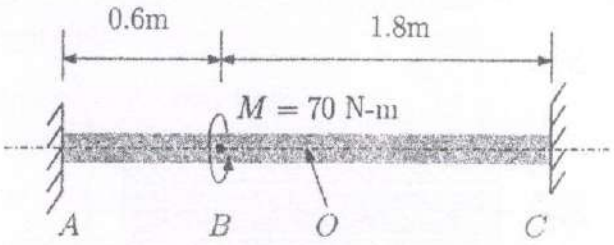

Figure 6: A circular shaft subjected to a couple about its longitudinal axis.

20+20=40

4. Answer the following:

(a) Find the elastic buckling load for the system shown in Figure 7.

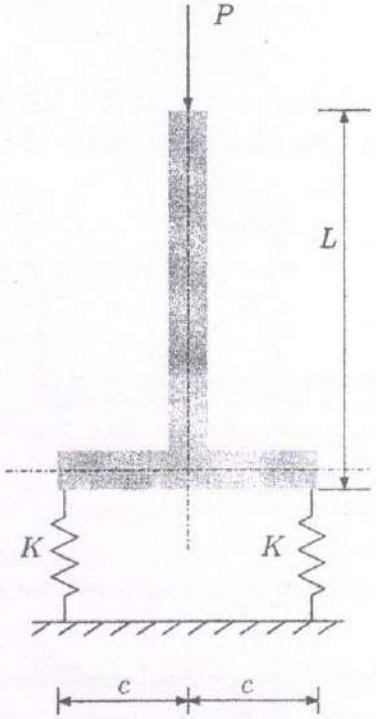

Figure 7: A rigid inverted 'T' structure supported on two linear springs.

(b) A cold-rolled steel bolt passes through a hard-drawn copper tube as shown in Figure 8 and the nut at the left end is turned up just snug. Subsequently the nut is tightened up $n = \frac{1}{4}$ turn. Determine the values of the stresses generated in the bolt and tube under this condition. The cross sectional area of the steel bolt is $A_s = 3\ cm^2$, its modulus of elasticity is $E_s = 210$ GPa. For the copper tube, $A_c = 4\ cm^2$ and $E_c = 120$ GPa. The pitch of the single-start thread is $p = 3$ mm.

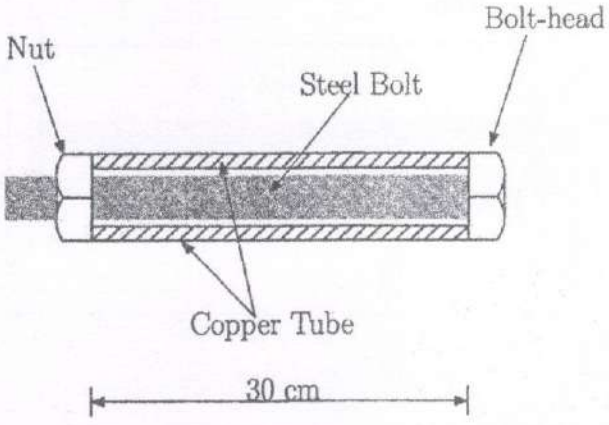

Figure 8: The steel bolt and copper tube assembly.

20+20=40

5. Answer the following:

(a) The firing order of a two-stroke six-cylinder diesel engine is I-V-III-VI-II-IV. The adjacent cylinder centrelines are 75 cm apart. Each cylinder has a connecting rod 120 cm long and a stroke 45 cm. The mass of the reciprocating parts in each cylinder is 200 kg. Determine the magnitude of the primary and secondary unbalanced forces and moments when the engine runs at a constant speed of 250 rpm.

(b) How does the train turn without the differential? 30+10=40

6. Answer the following:

(a) A hole of 10 mm diameter is drilled in a steel block of 20 mm thickness. In the drilling operation, it is observed that the tool life decreased from 40 min to 10 min due to increase in drill speed from 300 rpm to 600 rpm. What will be the tool life of that tool under the same condition if the drill speed is 400 rpm?

(b) The manager of a restaurant wants to forecast demand of pizzas based on exponential smoothing method. For the past three months, demand for pizzas has been as shown in the table below:

Month	Actual Demand
June	100
July	25
August	77

If the forecast for the month of June was 50, estimate the forecast for the month of September using Exponential smoothing method (assume smoothing coefficient = 0·20). What do you think about a 0·20 smoothing constant? 20+20=40

7. Answer the following:

(a) What do you mean by break-even analysis? For a particular product, the following information is given:

- Selling price per unit = Rs. 200,
- Variable cost per unit = Rs. 50 and
- Fixed costs = Rs. 1,00,000.

Calculate the break-even points in terms of units and sales. Suppose due to inflation the variable cost per unit has increased by 20% while fixed costs remained same. If the break-even quantity is to remain constant by what percentage should the sales price be raised?

(b) What are the different methods suitable for making through holes of diameter around 2 mm in a 2 mm thick glass plate? State briefly the working principle of laser beam machining (LBM). 20+20=40

8. Answer the following:

(a) The project activities, precedence relationships and durations are described in the table. Draw the CPM network for the activities and find the critical path. Also, calculate the total float of all the activities.

Activity	Precedence	Duration (in hours)
A	–	3
B	A	4
C	A	2
D	B	5
E	C	1
F	C	2
G	D, E	4
H	F, G	3

(b) Describe the working principle of metal removal in Plasma Arc Machining (PAM) process with the help of sketch. 20+20=40