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| <b>CSM – 54 / 15</b>          |
| <b>Mechanical Engineering</b> |
| <b>Paper – I</b>              |

*Time : 3 hours*

*Full Marks : 300*

*The figures in the right-hand margin indicate marks.*

*Candidates should attempt Q. No. 1 from Section – A and Q. No. 5 from Section – B which are compulsory and **three** of the remaining questions, selecting at least **one** from each Section.*

*No Data Books/Tables are allowed, assume the data if required anywhere.*

**Section – A**

1. Answer any **three** of the following :  $20 \times 3 = 60$ 
  - (a) In a quick return motion mechanism of crank and slotted lever type, the ratio of maximum velocities is 2. If the length of stroke is 25 cm, find (i) the length of slotted lever, (ii) the ratio of times of cutting and return strokes and

- (iii) the maximum cutting velocity per second if the crank rotates at 30 r.p.m.
- (b) A door 200 cm high, 75 cm wide and 4 cm thick and weighing 35 kg is fitted with an automatic door closer. The door opens against a spring with a modulus of 1 kg-cm/radian. If the door is opened  $90^\circ$  and released, how long will it take the door to be within  $1^\circ$  of closing? Assume the return spring of the door to be critically damped.
- (c) A steel plate of constant thickness 10 mm is having a breadth of 100 mm at one end and uniformly varying to the breadth of 50 mm at the other end. The length of the plate is 500 mm. Find the total contraction in the longitudinal direction, due to an axial compression of 60 kN at the end. Derive the expression for longitudinal contraction. Take  $E = 200 \text{ kN/mm}^2$ .
- (d) Iron and vanadium both have the BCC crystal structure and vanadium forms a substitutional

solid solution in Iron for concentrations upto approximately 20 wt% vanadium at room temperature. Determine the concentration in weight percent of vanadium that must be added to iron to yield a unit cell edge length of 0.289 nm.

2. (a) Four masses A, B, C and D are completely balanced. Masses C and D make angles of  $90^\circ$  and  $195^\circ$  respectively with that of mass B in the counter-clockwise direction. The rotating masses have the following properties : 30

$$m_b = 25 \text{ kg}$$

$$m_c = 40 \text{ kg}$$

$$m_d = 35 \text{ kg}$$

$$r_a = 150 \text{ mm}$$

$$r_b = 200 \text{ mm}$$

$$r_c = 100 \text{ mm}$$

$$r_d = 180 \text{ mm}$$

Planes B and C are 250 mm apart.

Determine the :

- (i) Mass A and its angular position with that of mass B.
  - (ii) Positions of all the planes relative to plane of mass A.
- (b) In a spring-controlled governor, the controlling force curve is a straight line. The balls are 400 mm apart when the controlling force is 1500 N and 240 mm when it is 800 N. The mass of each ball is 10 kg. Determine the :
- 30
- (i) Speed at which the governor runs when the balls are 300mm apart.
  - (ii) How much should the initial tension be increased to make the governor isochronous ?
  - (iii) What is the isochronous speed ?
3. (a) A railway wagon moving at a velocity of 1.5 m/s is brought to rest by a bumper consisting of two helical spring arranged in

parallel. The mass of the wagon is 1500 kg, the springs are compressed by 150 mm in bringing the wagon to rest the spring index can be taken as 6. The springs are made of oil-hardened and tempered steel wire with ultimate tensile strength of  $1250 \text{ N/mm}^2$  and modulus of rigidity of  $81370 \text{ N/mm}^2$ . The permissible shear stress for the spring wire can be taken as 50% of the ultimate tensile strength.

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Calculate the following :

- (i) Wire diameter
  - (ii) Mean coil diameter
  - (iii) Total number of coils
  - (iv) Solid length
  - (v) Free length
  - (vi) Pitch of the coil
- (b) The radius of the inner fibers of a curved bar of trapezoidal section is equal to the depth of the cross section (fig. 1). The base of the trapezium on the concave side is four times the base on the convex side. Determine the

ratio of the stresses in the extreme fibers of the curved bar to the stresses in the same fibers of a straight bar subjected to the same bending moment :

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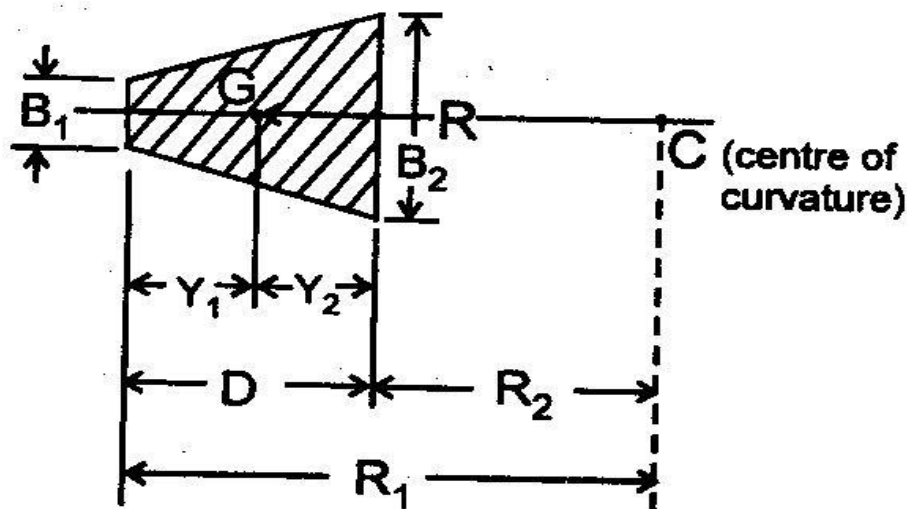


fig. 1

4. (a) Calculate the radius of a vanadium atom, given that vanadium has a BCC crystal structure, a density of  $5.96 \text{ g/cm}^3$  and an atomic weight of  $50.9 \text{ g/mol}$ . 15
- (b) Within a cubic unit cell, sketch the following directions : 15

$[101]$ ,  $[10\bar{2}]$ ,  $[3\bar{1}3]$ ,  $[\bar{1}1\bar{1}]$ ,  $[\bar{2}12]$ ,  $[3\bar{1}2]$

- (c) The kinetics of the austenite-to-pearlite transformation obey the Avrami relationship. Using the fraction transformed-time data given here, determine the total time required for 95% of the austenite to transform to pearlite : 15

| Fractional Transformed | Time(s) |
|------------------------|---------|
| 0.2                    | 280     |
| 0.6                    | 425     |

- (d) Explain the reasons why ceramic materials are, in general, harder yet more brittle than metals. 15

### Section – B

5. Answer any **three** of the following :  $20 \times 3 = 60$

- (a) Determine the dimension of an optimum cylindrical riser attached to the side of a steel plate casting having the dimensions  $250 \times 125 \times 500$  mm, assuming that the

volume shrinkage on solidification is 3% for steel and that the volume of the riser is three times that dictated by the shrinkage consideration alone.

- (b) Two 1.2 mm thick flat copper sheets are being spot welded using a current of 6000 A and a current flow time of  $t = 0.18$  s. The electrodes are 5 mm in diameter. Estimate the heat generated in the weld zone.
- (c) A cone-shaped part is to be fabricated using stereo lithography. The radius of the cone at its base = 35 mm and its height = 40 mm. The layer thickness = 0.20 mm. The diameter of the laser beam = 0.22 mm and the beam is moved across the surface of the photopolymer at a velocity of 500 mm/s. Compute an estimate for the time required to build the part, if 10 s are lost each layer to lower the height of the platform that holds the part. Neglect post-curing time.

- (d) In an I. C. engine arrangement, the displacement D is given by

$$D = r \left[ (1 - \cos \theta) + \frac{1}{2} \left( \frac{r}{\ell} \right) \sin^2 \theta + \frac{1}{8} \left( \frac{r}{\ell} \right)^3 \sin^4 \theta \right],$$

where  $\theta$  = crank angle.

Write a C-program to prepare a table for displacement of piston versus the crank shaft angle, for all angles between 0 and  $360^\circ$  in uniform increments of  $10^\circ$ .

6. (a) Develop the following equation for pulse train frequency to drive the worktable of CNC machine at specified linear travel rate.

$$F_p = V_t n_s r_g / 60p$$

where  $V_t$  = Table travel speed

$n_s$  = Steps per revolutions.

$r_g$  = Gear ratio

$p$  = Pitch of the lead screw

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(b) The voltage-length characteristic of a dc arc is given by  $V = (20 + 4\ell)$  volts where,  $\ell$  = length of the arc in mm. During a welding operation, it is expected that the arc length will vary between 4 mm and 6 mm. It is desired that the welding current be limited to the range 450-550 amp. Assuming a linear power source characteristic, determine the open circuit voltage and the short circuit current of the power source. 15

(c) An orthogonal cutting operation is being carried out under the following conditions :

$$t_o = 0.1 \text{ mm}$$

$$t_c = 0.2 \text{ mm}$$

$$\text{width of cut} = 5 \text{ mm}$$

$$V = 2 \text{ m/s}$$

$$\text{rake angle} = 10^\circ$$

$$F_c = 500 \text{ N}$$

$$F_t = 200 \text{ N}$$

Calculate the percentage of the total energy that is dissipated in the shear plane. 15

- (d) A laser beam with a power intensity of  $2 \times 10^5 \text{ W/mm}^2$  falls on a stainless steel sheet. Find out the time required for the stainless steel surface to reach the melting temperature, assuming that only 8% of the beam power is absorbed. Use suitable values for the thermal properties of stainless steel. Given  $\alpha = 0.071 \text{ cm}^2/\text{sec}$ ,  $K = 0.27 \text{ W/cm-}^\circ\text{C}$  and  $\theta_m = 1455^\circ\text{C}$ . 15

7. (a) Consider the following assembly network relationship of a product. The number of shifts per day are two and the number of working hours per shift are 8. The company aims to produce 80 units of the product per day. Group the activities into work stations using Rank Positional Weight Method and compute Balancing Efficiency. 15

| Operation Number | Immediate Preceding Tasks | Duration (Min) |
|------------------|---------------------------|----------------|
| 1                | —                         | 7              |
| 2                | 1                         | 2              |
| 3                | 1                         | 2              |

| Operation Number | Immediate Preceding Tasks | Duration (Min) |
|------------------|---------------------------|----------------|
| 4                | 1                         | 5              |
| 5                | 2, 3                      | 8              |
| 6                | 3, 4                      | 3              |
| 7                | 5                         | 4              |
| 8                | 5, 6                      | 7              |
| 9                | 4, 6                      | 9              |
| 10               | 7, 8, 9                   | 8              |

(b) Consider the following flow shop problem :

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| Job | Machine 1 | Machine 2 | Machine 3 |
|-----|-----------|-----------|-----------|
| 1   | 10        | 15        | 23        |
| 2   | 8         | 10        | 7         |
| 3   | 12        | 7         | 10        |
| 4   | 15        | 20        | 6         |

Find the optimal schedule for the above flow shop problem using branch and bound technique. Also determine the corresponding make span.

- (c) A time study engineer has studied the time taken to machine crank shafts. He has taken 40 observations and these are summarized in the form of frequency distribution as shown below :

| <b>Time<br/>(Minutes)</b> | <b>Frequency</b> |
|---------------------------|------------------|
| 20                        | 15               |
| 21                        | 10               |
| 22                        | 10               |
| 23                        | 5                |

The performance rating of the operator machining the crank shaft is 110 per cent. Find the standard time for machining the crank shaft by assuming allowance of 15 per cent.

- (d) Compute the adjusted exponential forecast for the first week of June for a firm with the following data. Assume the forecast for the

first week of April ( $F_0$ ) as 700 and corresponding initial trend ( $T_0$ ) as 0. Let  $\alpha = 0.15$ , and  $\beta = 0.25$ . 15

| Month |      |        |
|-------|------|--------|
| April | Week | Demand |
|       | 1    | 675    |
|       | 2    | 625    |
|       | 3    | 575    |
|       | 4    | 675    |
| May   |      |        |
|       | 1    | 650    |
|       | 2    | 650    |
|       | 3    | 725    |
|       | 4    | 740    |

8. (a) Given a quadratic equation  $ax^2 + bx + c = 0$ , draw a flow chart to find the roots of the equation. 15
- (b) Write a program in FORTRAN to compute the sum of the following series as SUM, for the five known values of X and n. 15

$$\text{SUM} = 1 + X + X^2 + X^3 + \dots X^n$$

(c) What are pointers in C-language ? Write a program using pointers to read an array of integers and print its elements in reverse order. 15

(d) Explain the following terms : 3×5 = 15

(i) Data

(ii) Database

(iii) DBMS

(iv) Database System

(v) Database Catalog

