DO NOT OPEN THIS TEST BOOKLET UNTIL YOU ARE ASKED TO DO SO

23-0009-AR TEST BOOKLET

MECHANICAL ENGINEERING

PAPER – I

Time Allowed: 3 hours | **Maximum Marks: 300**

INSTRUCTIONS TO CANDIDATES

Read the instructions carefully before answering the questions: -

1. This Test Booklet consists of 20 (twenty) pages and has 75 (seventy-five) items (questions).
2. IMMEDIATELY AFTER THE COMMENCEMENT OF THE EXAMINATION, YOU SHOULD CHECK THAT THIS BOOKLET *DOES NOT* HAVE ANY UNPRINTED OR TORN OR MISSING PAGES OR ITEMS ETC. IF SO, GET IT REPLACED BY A COMPLETE TEST BOOKLET.
3. **Please note that it is the candidate's responsibility to fill in the Roll Number and other required details carefully and without any omission or discrepancy at the appropriate places in the OMR Answer Sheet and the Separate Answer Booklet. Any omission/discrepancy will render the OMR Answer Sheet and the Separate Answer Booklet liable for rejection.**
4. Do not write anything else on the OMR Answer Sheet except the required information. Before you proceed to mark in the OMR Answer Sheet, please ensure that you have filled in the required particulars as per given instructions.
5. Use only Black Ball Point Pen to fill the OMR Answer Sheet.
6. This Test Booklet is divided into 4 (four) parts – Part – I, Part – II, Part - III and Part – IV.
7. All three parts are Compulsory.
8. **Part-I consists of Multiple Choice-based Questions.** The answers to these questions have to be marked in the OMR Answer Sheet provided to you.
9. **Part-II, Part-III and Part-IV consist of Conventional Essay-type Questions.** The answers to these questions have to be written in the separate **Answer Booklet** provided to you.
10. In Part-I, each item (question) comprises of 04 (four) responses (answers). You are required to select the response which you want to mark on the OMR Answer Sheet. In case you feel that there is more than one correct response, mark the response which you consider the best. In any case, choose ***ONLY ONE*** response for each item.
11. After you have completed filling in all your responses on the OMR Answer Sheet and the Answer Booklet(s) and the examination has concluded, you should hand over to the Invigilator ***only the OMR Answer Sheet and the Answer Booklet(s)***. You are permitted to take the Test Booklet with you.
12. **Penalty for wrong answers in Multiple Choice-based Questions:**

THERE WIL BE **PENALTY** FOR WRONG ANSWERS MARKED BY A CANDIDATE.

(i) There are four alternatives for the answer to every question. For each question for which a wrong answer has been given by the candidate, one-third of the marks assigned to the question will be deducted as penalty.

(ii) If a candidate gives more than one answer, it will be treated as a wrong answer even if one of the given answers happens to be correct and there will be same penalty as above to the question.

(iii) If a question is left blank. i.e., no answer is given by the candidate, there will be no penalty for that question.

DO NOT OPEN THIS TEST BOOKLET UNTIL YOU ARE ASKED TO DO SO

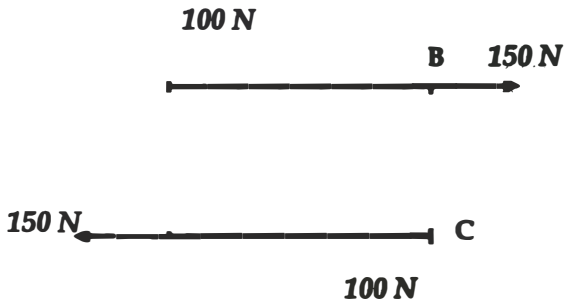
PART-I
(Multiple Choice-based Questions)

Instructions for Questions 1 to 50:

- *Choose the correct answers for the following questions.*
- *Each question carries 3 marks.*
- *No Data Books/Tables are allowed; assume the data if required anywhere.*

[3 x 50 = 150]

1. A rectangle ABCD has sides AB = CD = 80 mm and BC = DA = 60 mm. Forces of 150N each act along AB and CD, and forces of 100 N each act along BC and DA as shown in the figure below.



The resultant moment of the force system is equal to:

(a) 8000 N-mm
(b) 9000 N-mm
(c) 1000 N-mm
(d) 17000 N-mm

2. **Consider the following statements:**
The effect of couple in on a body remains unchanged if the couple is

(i) Rotated through an angle in its plane
(ii) Shifted to any other position in its plane
(iii) Replaced by another pair of forces whose rotational effect is same

Which of the above statements are correct?

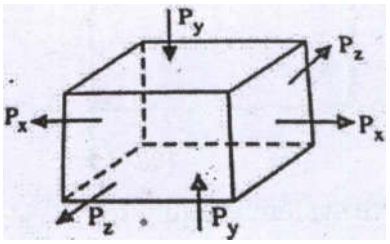
(a) (i) and (ii)
(b) (i) and (iii)
(c) (ii) and (iii)
(d) (i), (ii) and (iii)

3. The distance covered by a particle travelling on a circular path and starting from rest is given by the equation: $s = kt^2$ where k is a constant. The tangential acceleration of the particle will be equal to:

(a) $k/2$
(b) k
(c) $2k$
(d) $4k$

4. Upon rotation from an initial position of rest, the radius vector of a body executes angular rotation θ prescribed by the relation $\theta = 4t^3 - 3t^2 + 2t + 6$, where θ is in radians and t is in seconds. The angular acceleration of the body at time $t = 2\ seconds$ is equal to:
   (a) $38\ rad/s^2$
   (b) $42\ rad/s^2$
   (c) $52\ rad/s^2$
   (d) $30\ rad/s^2$

5. If a member is subjected to a tensile stress of p_x, compressive stress of p_y and tensile stress of p_z along the x, y and z directions respectively, then the resultant strain e_x along the x - direction would be given by:
   (Note: E is the Young's modulus of elasticity and μ is the Poisson's ratio):



   (a) $1/E\,[p_x + \mu p_y - \mu p_z]$
   (b) $1/E\,[p_x + \mu p_y + \mu p_z]$
   (c) $1/E\,[p_x - \mu p_y + \mu p_z]$
   (d) $1/E\,[p_x - \mu p_y - \mu p_z]$

6. A cylindrical bar of $20\ mm$ diameter and $1\ m$ length is subjected to a tensile test. Its longitudinal strain is 4 times that of its lateral strain. If the modulus of elasticity is $2 \times 10^5\ N/mm^2$, then its modulus of rigidity will be -
   (a) $8 \times 10^6\ N/mm^2$
   (b) $8 \times 10^5\ N/mm^2$
   (c) $0.8 \times 10^4\ N/mm^2$
   (d) $0.8 \times 10^5\ N/mm^2$

7. A material of Young's modulus E and Poisson's ratio μ is subjected to two principal stresses σ_1 and σ_2 at a point in a two-dimensional stress system. The strain energy per unit volume of the material is
   (a) $(\sigma_1^2 + \sigma_2^2 - 2\mu\sigma_1\sigma_2)/2E$
   (b) $(\sigma_1^2 + \sigma_2^2 + 2\mu\sigma_1\sigma_2)/2E$
   (c) $(\sigma_1^2 - \sigma_2^2 + 2\mu\sigma_1\sigma_2)/2E$
   (d) $(\sigma_1^2 - \sigma_2^2 + 2\mu\sigma_1\sigma_2)/2E$

8. A round bar made of same material consists of 3 parts each of $100\ mm$ length having diameters of $40\ mm$, $50\ mm$ and $60\ mm$ respectively. If the bar is subjected to axial load of $10\ kN$, the total elongation of the bar would be:
   (Note: E is the modulus of elasticity in kN/m^2)

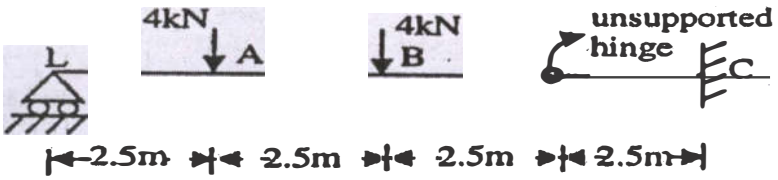
(a) $\frac{0.4}{\pi E}\left[\frac{1}{16}+\frac{1}{25}+\frac{1}{36}\right] mm$

(b) $\frac{4}{\pi E}\left[\frac{1}{16}+\frac{1}{25}+\frac{1}{36}\right] mm$

(c) $\frac{4\sqrt{2}}{\pi E}\left[\frac{1}{16}+\frac{1}{25}+\frac{1}{36}\right] mm$

(d) $\frac{40}{\pi E}\left[\frac{1}{16}+\frac{1}{25}+\frac{1}{36}\right] mm$

9. The bending moments at points A, B, and C of the beam shown in the Figure will be -



(a) **10 kN-m, 10 kN-m & 10 kN-m**

(b) **10 kN-m, 10 kN-m & -10 kN-m**

(c) **20 kN-m, 10 kN-m & -10 kN-m**

(d) **10 kN-m, -10 kN-m & 20 kN-m**

10. In case a thin cylindrical shell of diameter $\boldsymbol{d}$ and metal thickness $\boldsymbol{t}$ is subjected to internal fluid pressure $\boldsymbol{p}$, the volumetric strain is given by:

(a) $\frac{pd}{2tE}\left[\frac{5}{2}-2v\right]$

(b) $\frac{pd}{tE}\left[\frac{5}{2}-2v\right]$

(c) $\frac{pd}{2tE}[5-2v]$

(d) $\frac{pd}{4tE}\left[\frac{5}{2}-2v\right]$

11. A shaft of diameter $\boldsymbol{d}$ is subjected to Bending moment $\boldsymbol{M}$ and twisting moment $\boldsymbol{T}$. The developed principal stress will be

(a) $\pm\frac{16}{\pi d^3}\times\sqrt{M^2+T^2}$

(b) $\frac{16}{\pi d^3}[M\pm\sqrt{M^2+T^2}$

(c) $\frac{16}{\pi d^3}[T\pm\sqrt{M^2+T^2}$

(d) $\frac{16}{\pi d^3}\sqrt{M^2+T^2}\pm M$

12. A hollow circular column of internal diameter $\boldsymbol{d}$ and external diameter $\boldsymbol{1.5d}$ is subjected to compressive load. The maximum distance of the point of application of the load from the center for no tension is -

(a) $d/8$

(b) $13d/48$

(c) $d/4$

(d) $13d/96$

13. At a point in a steel member, the major principal stress is $200\ MPa$ (tensile) and the minor principal stress is compressive. If the uniaxial tensile yield stress is $250\ MPa$, then according to maximum shear stress theory, the magnitude of minor principal stress (compressive) at which yielding will commence is -
    (a) $200\ MPa$
    (b) $100\ MPa$
    (c) $50\ MPa$
    (d) $25\ MPa$

14. A cube is subjected to equal tensile stress on all the three faces. If the yield stress of the material is σ_y, then based on strain energy theory, the maximum tensile stress will be:
    (a) $\frac{\sigma_y}{\sqrt{3(1-2\mu)}}$
    (b) $\frac{\sigma_y}{\sqrt{3(2-\mu)}}$
    (c) $\frac{\sigma_y}{\sqrt{3(1-\mu)}}$
    (d) $\frac{\sigma_y}{\sqrt{3(1+\mu)}}$

15. Consider the following questions regarding the crystal:
    (1) Covalent Crystal Lattice is composed of atoms
    (2) Covalent Crystal Lattice is composed of ions
    (3) Covalent Crystal Lattice is composed of molecules

    Which one or more of the above statements are correct? Answer using the codes given below.
    (a) 1 and 2 only
    (b) 1 and 3 only
    (c) 2 and 3 only
    (d) 1 only

16. Match **List I** with **List II** and select the correct answer using the codes given below the lists:

List I (Crystal structure)	List II Atomic	factor
P) Simple cubic	1	74%
Q) Body-centred cubic		74%
R) Face-centred cubic	3	52%
S) Hexagonal close- acked	4	68%

Co es:

	P	Q	R	S
(a)	3	4	2	1
(b)	4	3	2	1
(c)	3	2	1	4
(d)	4	3	1	2

17. Match **List I** with **List II** and select the correct answer using the codes given below the lists:

List I (Ferrous materials)	**List II (Carbon content)**
P) Mild Steel	1) 0.6 to 1.7%
Q) High carbon steel	2) Less than 0.3%
R) Cast Iron	3) 6.7%
S) Cementite	4) 2 to 4.5%

Codes:

	P	**Q**	**R**	**S**
(a)	2	4	1	3
(b)	1	2	4	3
(c)	2	1	4	3
(d)	2	1	3	4

18. Match **List I** with **List II** and select the correct answer using the codes given below the lists:

List I Heat treatment	**List II (Effect**
P Annealin	1) Refines grain structure
Q) Nitriding	2) Improves the hardness of whole mass
R) Martempering	3) Increases surface hardness
S) Normalising	4) Increases ductili

Codes:

	P	**Q**	**R**	**S**
(a)	4	3	2	1
(b)	1	3	4	2
(c)	4	2	1	3
(d)	2	1	3	4

19. For medical applications requiring frequent sterilization, which of the following plastic would you recommend?
    (a) Polyethersulfone
    (b) HDPE
    (c) ABS
    (d) Polycarbonate

20. Match **List I** with **List II** and select the correct answer using the codes given below the lists:

List I (Materials)	**List II A lications**
P) Engineering ceramics	1) Refines grain structure
Q) Fibre reinforced plastics	2) Control Rods in nuclear reactors
R) Synthetic carbon	3) Aerospace industry
S) Boron	4 Electrical insulator

Codes:

	P	Q	R	S
(a)	1	2	3	4
(b)	1	4	3	2
(c)	2	3	1	4
(d)	4	3	1	2

21. The Grübler's criterion for determining the degrees of freedom (F) of a mechanism having n links and p pairs is given by:
    (a) $F = 3(n-1) - 2p$
    (b) $F = 6(n-1) - 2p$
    (c) $F = 5n - 2p$
    (d) $F = 3(n+1) - 2p$

22. Coriolis component of acceleration is considered in case of -
    (a) Quick Return Motion Mechanism
    (b) Slider crank mechanism
    (c) Four bar mechanism
    (d) None of the above

23. Two intersecting coplanar shafts are connected by -
    (a) Spur gearing
    (b) Helical gearing
    (c) Bevel gearing
    (d) Spiral gearing

24. The swaying couple is maximum or minimum when the angle of inclination of the crank to the line of stroke is equal to -
    (a) $180°$ *and* $315°$
    (b) $45°$ *and* $135°$
    (c) $90°$ *and* $135°$
    (d) $45°$ *and* $225°$

25. In multicylinder in-line engines, an even number of cylinders are chosen so that _____.
    (a) Primary forces are balanced
    (b) Secondary forces are balanced,
    (c) Primary and secondary couples are balanced
    (d) Primary and secondary inertia forces are balanced

26. In its simplest form, a cam-follower mechanism consists of -
    (a) Three links
    (b) Two links
    (c) One link
    (d) Four links.

27. In high-speed engines, the cam follower moves with -
    (a) S.H.M.
    (b) Uniform velocity
    (c) Cycloidal motion
    (d) Uniform acceleration and retardation.

28. With usual notation, for a single degree of freedom system, the equation $m\ddot{x} + 36\pi^2 x = 0$ represents a natural frequency of -
    (a) $3\ Hz$
    (b) $3\pi\ Hz$
    (c) $6\ Hz$
    (d) $6\pi\ Hz$

29. A spring of stiffness s is displaced from a position x_1 to position x_2. The work done is -
    (a) $\frac{1}{2}s(x_1 - x_2)^2$
    (b) $\frac{1}{2}s(x_1 + x_2)^2$
    (c) $\frac{1}{2}sx_1^2 - \frac{1}{2}sx_1^2$
    (d) $\frac{1}{2}sx_1^2 - \frac{1}{2}sx_1^2$

30. The critical speed of a rotating shaft depends on -
    (a) Mass and stiffness
    (b) Stiffness and eccentricity
    (c) Mass and eccentricity
    (d) Mass, stiffness and eccentricity

31. Cutting power consumption in turning can be significantly reduced by -
    (a) Increasing rake angle of the tool
    (b) Increasing the cutting angle of the tool
    (c) Widening the nose radius of the tool
    (d) Increasing the clearance angle

32. A dynamometer is a device used for the measurement of -
    (a) Chip thickness ratio
    (b) Forces during metal cutting
    (c) Wear of the cutting tool
    (d) Deflection of the cutting tool

33. CNC control system is based on -
    (a) Decimal system
    (b) Binary system
    (c) Semi binary system
    (d) Binary decimal system

34. The Software system used for translating neutral instructions from the CAM system into the specific instructions required by the NC machine is:
    (a) Post-Processor
    (b) CIM Software
    (c) CAD/CAM Software
    (d) Operating System

35. Which one is correct for ultrasonic machining process:
    (a) The material removal rate will be higher for materials with higher toughness.
    (b) The material removal rate will be higher for materials with higher ductility.
    (c) The material removal rate will be higher for materials with lower toughness.
    (d) The material removal rate will be higher for materials with higher fracture strain.

36. The tool of Electro-Discharge Machining (EDM), is made-up of:
    (a) Cast iron
    (b) High speed steel
    (c) Copper
    (d) Diamond

37. The material removal In Electro Chemical Machining (ECM), is due to -
    (a) Ion displacement
    (b) Erosion
    (c) Fusion
    (d) Corrosion

38. Match **List I** with **List II** and select the correct answer using the codes given below the lists:

List I	**List II**
P) Welding of aluminium alloy	1) Submerged arc welding
Q) Ship building	2) Electron beam welding
R) Joining of HSS drill bit to carbon steel	3) TIG welding
S) Deep penetration precision welds	4) Flash butt welding

Codes:

	P	**Q**	**R**	**S**
(a)	1	2	3	4
(b)	3	1	4	2
(c)	2	3	1	4
(d)	4	3	1	2

39. In a friction stir welding (FSW) process _____
    (a) A rotating consumable tool is used.
    (b) A rotating non-consumable tool is used.
    (c) A rotating filler material is used.
    (d) None of the above.

40. A Basic Hole has _____
    (a) zero lower deviation
    (b) zero tolerance
    (c) both the deviations are positive
    (d) both the deviations are negative

41. Linear programming is suitable, for which of the following situations?
    (a) Scheduling of production to meet sales forecast.
    (b) Material selection Problems.
    (c) Product design problems.
    (d) Quenching Problems.

42. What will be the most Economical order quantity of a manufacturing company which places a semi-annual order of 24,000 units at a price of Rs. 20/- per unit. Its carrying cost is 15% and the order cost is Rs. 12/- per order.
    (a) Approximately 520 units
    (b) Approximately 620 units
    (c) Exactly 720 units
    (d) Exactly 240 units

43. 70 per cent or more of a manufacture product's cost is determined by its -
    (a) Raw materials.
    (b) Design.
    (c) Staff strength.
    (d) Machines.

44. The application of set of techniques to an existing product with a view to improving its value is known as _____
    (a) Value analysis
    (b) Value engineering
    (c) Value stream mapping
    (d) None of the above

45. While designing work place, anthropometric data are taken into considerations for:
    (a) Layout
    (b) Ergonomics
    (c) String diagram
    (d) None of the above

46. In which type of scheduling are semi-active schedules are generated?
    (a) Single machine
    (b) Flow shop
    (c) Job shop
    (d) None of the above

47. Capacity modification is a part of _____
    (a) Progress reporting
    (b) Corrective action
    (c) Total capacity
    (d) None of the above

48. C-chart is a quality control chart used to monitor -
    (a) a variable type of data.
    (b) an attribute type of data.
    (c) a fixed type of data.
    (d) None of the above.

49. Operating characteristic curve is associated with -
    (a) P-chart
    (b) C-chart
    (c) Sampling plan
    (d) None of the above

50. Which way of thinking has philosophy of Selling price – Cost = Profit?
    (a) Poka yoke
    (b) QFD
    (c) Lean
    (d) None of the above

PART-II
(Short Answer-type Questions)

Instructions for Questions 51 to 63:

- *Write the answers in short for any 10 (TEN) out of the thirteen questions.*
- *Each question carries 5 marks.*
- *No Data Books/Tables are allowed; assume the data if required anywhere.*
- *Unless otherwise mentioned, symbols and notations have their usual meaning.*

[5 x 10 = 50]

51. What is meant by concurrent forces in space? State the conditions of equilibrium for a particle in space.

52. A thin-walled spherical pressure vessel of diameter d and metal thickness t is subjected to internal fluid pressure p. Show that the increase in volume of the vessel is given by –

$$\delta V = \left\{ \frac{\pi d^3 (1 - v) p}{8Et} \right\}$$

where v = Poisson's ration and E = modulus of elasticity.

53. Derive an expression between modulus of elasticity and modulus of rigidity.

54. The normal stress in two mutually perpendicular directions are $600\ N/mm^2$ and $300\ N/mm^2$ both tensile. The complimentary shear stresses in these directions are of intensity $450\ N/mm^2$. Find the normal and tangential stresses on the two planes which are equally inclined to the planes carrying the normal stresses mentioned above.

55. Calculate the volume of the zinc crystal structure unit cell by using the following data: pure zinc has the HCP crystal structure with lattice constants $a = 0.2665\ nm$ and $c = 0.4947\ nm$.

56. A reaction-bonded silicon nitride ceramic has a strength of $300\ MPa$ and a fracture toughness of $3.6\ MPa\sqrt{m}$. What is the largest-size internal crack that this material can support without fracturing? Use $Y = 1$ in the fracture-toughness equation.

57. Find a relation for the coefficient of fluctuation of speed in terms of maximum fluctuation of energy and the kinetic energy of the flywheel at mean speed.

58. What is the controlling force of a governor? How are the controlling force curves drawn? How do they indicate the stability of a governor? Indicate the shape of such a curve for an isochronous governor.

59. A pair of spur gears with involute tooth form have a module of m and equal addenda of m. Show that involute interference will occur if the number of teeth on the pinion is less than

$$\frac{2}{\sqrt{\{\bar{G}^2 + (1 + 2G)\sin^2\psi\}} - G}$$

where ψ is the pressure angle and G is the gear ratio.

60. What is meant by numerical control of machine tools? Explain the function of MCU in an NC machine tool.

61. What are the basic requirements of tool materials in EDM process? Name any four tool materials with their specific applications. Also explain the application of the following electrode material in Electric Discharge Machining (EDM):
    (a) Copper
    (b) Graphite

62. The data of an industrial unit is as follow:
    (a) Fixed cost of assets = Rs. 24,000/-
    (b) Variable Cost = Rs. 64,000/-
    (c) Sales price /unit = Rs. 10/-
    (d) Contribution for 8000 units= Rs. 16,000/-

    Based on the information given above, answer the following:
    (i) What is the sales volume for break-even?
    (ii) What should be selling price if the break-even quantity is to be brought down to 10000 units?

63. Alpha industry estimates that it will sell 12,000 units of its product in the forthcoming year. The ordering cost is Rs. 100/- per order and the carrying cost per unit per year is 20 per cent of the purchase price per unit. The purchase price per unit is Rs. 50/-. Find -
    (i) Economic order quantity (EOQ)
    (ii) No. of orders per year
    (iii) Time between successive orders

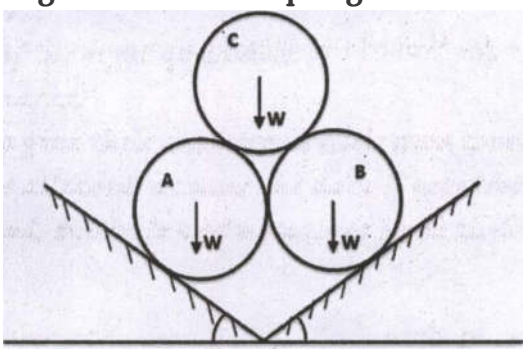
PART-III
(Long Answer-type Questions)

Instructions for Questions 64 to 71:

- *Answer any 5 (FIVE) out of the eight questions.*
- *Each question carries 10 marks.*
- *Candidates are required to give their answers in their own words as far as practicable.*
- *No Data Books/Tables are allowed; assume the data if required anywhere.*
- *Unless otherwise mentioned, symbols and notations have their usual meaning.*

[10 x 5 = 50]

64. Three identical right circular cylinders A, B and C, each of weight W are arranged on smooth inclined surfaces as shown in the figure below. Determine the least value of angle θ that will prevent the arrangement from collapsing.



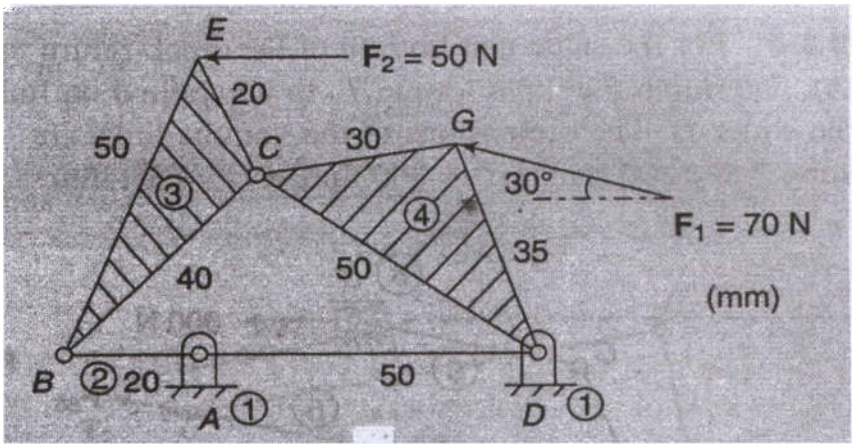
65. The stress tensor at a point in a body is given as follows:

$$\sigma_{ij=}\begin{bmatrix} 10 & 20 & 0 \\ 20 & 50 & -20 \\ 0 & -20 & 0 \end{bmatrix} MPa$$

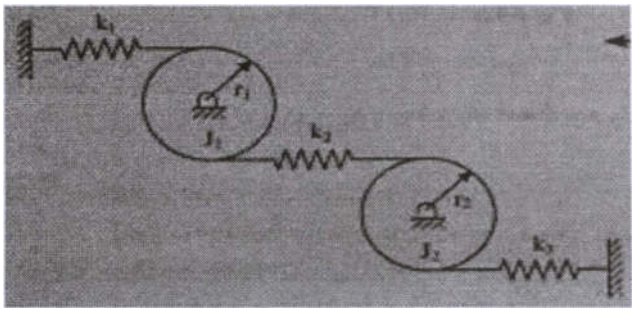
What are the strains at the point for a poison's ratio of 0.2 and modules of elasticity $2 \times 10^5 MPa$?

66. A $0.80\,percent$ C eutectoid plain-carbon steel is slowly cooled from $750°C$ to a temperature just slightly below $723°C$. Assuming that the austenite is completely transformed to α-ferrite and cementite:
    (a) Calculate the weight percent eutectoid ferrite formed.
    (b) Calculate the weight percent eutectoid cementite formed.

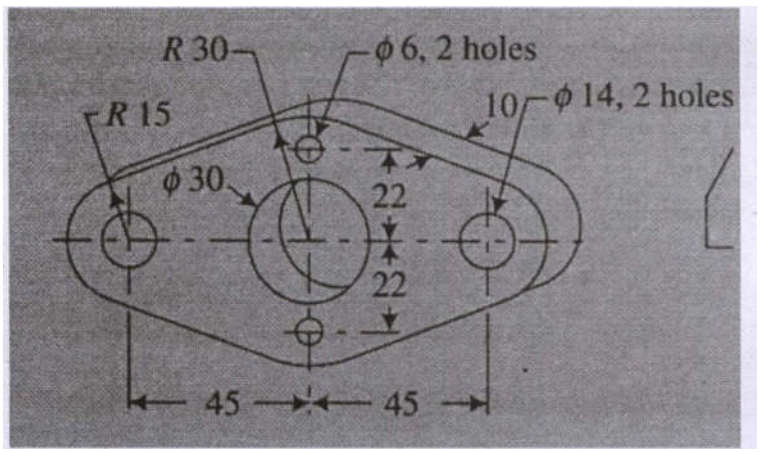
67. Find the torque to be applied on link AB, for static equilibrium of the mechanism shown in the figure below:



68. Find the frequency equation of the system shown in the figure below if:
$k_1 = k_2 = k_3 = k$,
$m_1 = m_2 = m$,
$r_1 = r_2 = r$ *and*
$J_1 = J_2 = J$.



69. Locate and clamp the work piece shown in the figure below. Use the holes as locating points.



70. Show schematically the Merchant's force circle in orthogonal cutting. Derive the equation for shear and friction forces in terms of the material properties and cutting-process parameters. Give in detail the assumptions made while arriving at the final equation.

71. Alpha company has the following sales pattern. Compute the sales forecast for the ***Year* 10**.

Year	1	2	3	4	5	6	7	8	9
Sales (in lakhs)	6	8	11	23	29	34	40	45	56

PART-IV
(Essay-type Questions)

Instructions for Questions 72 to 75:

- *Answer any 2 (TWO) out of the four questions.*
- *Each question carries 25 marks.*
- *No Data Books/Tables are allowed; assume the data if required anywhere.*
- *Unless otherwise mentioned, symbols and notations have their usual meaning.*

[25 x 2 = 50]

72. A uniform ladder **3 *m*** long and weighing **200 *N*** is placed against a wall making an angle of **60°** with the ground. The ladder, in addition to its own weight has to support a **800 *N*** weight of a man standing at its upper end. Presuming that coefficient of friction between the wall and ladder is **0.3** and that between the ground and ladder is **0.4**, make calculations for the horizontal force ***P*** to be applied at the ground level to prevent slipping. If the force ***P*** is not applied, what should be the minimum inclination of the ladder with the horizontal so that there is no slipping of it with the man standing its upper end.

73. A solid circular copper shaft is required to transmit **60 *horse power*** at **200 *rpm***. Determine the diameter of the shaft if the maximum shear stress is not to exceed **60 N/mm^2**. The solid shaft is now replaced by a hollow copper shaft with the internal diameter equal to **75%** of the external diameter. Determine the external diameter of the shaft if it is required to transmit the same horse power at the same rpm and the maximum shear stress produced is also the same. Find the weight of the material saved per metre length of the shaft, if copper weighs **8.9 *gm/c.c***.

74. The springs of an automobile trailer (Fig. - 1) are compressed **0.1 *m*** under its own weight. Find the critical speed when the trailer is passing over a road with a profile of sine wave whose amplitude is **80 *mm*** and wavelength is **14 *m***. Also find the amplitude of vibration at a speed of **60 *km/hr***.

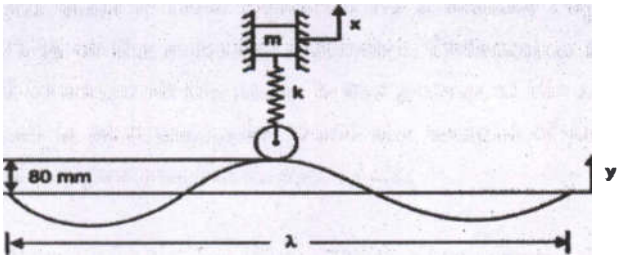


Fig. - 1

75. **The precedence network of eight work elements and their times (in minutes) are shown in Fig. – 2. The desired cycle time is 25 *minutes*. The number of workstations formed using RPW method for this problem is 4, which is treated as the maximum number of workstations.**

(i) **Formulate a zero-one programming model to allocate the work elements to workstations such that the number of workstations is minimized.**

(ii) **Solve the model and obtain the results.**

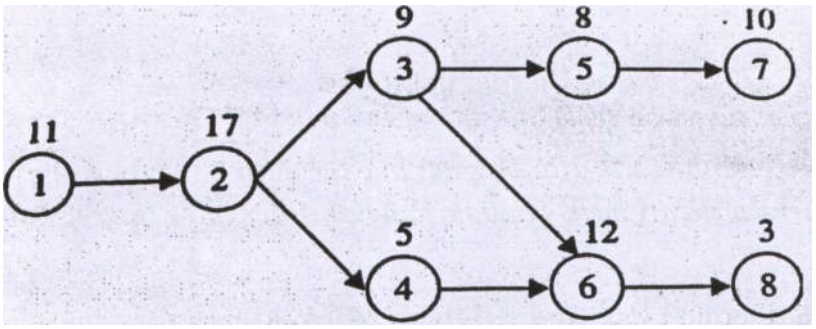


Fig. – 2: Precedence network along with task times

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