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ESE 2025 : Prelims Exam
CLASSROOM TEST SERIES

MECHANICAL ENGINEERING

Test 14

Section A : Renewable Sources of Energy + Industrial & Maintenance Engineering + Robotics & Machatronics **[All Topics]**

Section B : Theory of Machines-1 **[Part Syllabus]**

Section C : Strength of Materials and Engineering Mechanics-2 **[Part Syllabus]**

Answer Key

1.	(c)	**16.**	(b)	**31.**	(a)	**46.**	(a)	**61.**	(d)
2.	(c)	**17.**	(c)	**32.**	(b)	**47.**	(b)	**62.**	(b)
3.	(b)	**18.**	(b)	**33.**	(a)	**48.**	(a)	**63.**	(d)
4.	(d)	**19.**	(b)	**34.**	(d)	**49.**	(d)	**64.**	(d)
5.	(b)	**20.**	(b)	**35.**	(b)	**50.**	(b)	**65.**	(c)
6.	(a)	**21.**	(b)	**36.**	(a)	**51.**	(a)	**66.**	(c)
7.	(c)	**22.**	(d)	**37.**	(b)	**52.**	(a)	**67.**	(d)
8.	(a)	**23.**	(c)	**38.**	(d)	**53.**	(c)	**68.**	(c)
9.	(b)	**24.**	(c)	**39.**	(b)	**54.**	(d)	**69.**	(d)
10.	(d)	**25.**	(b)	**40.**	(c)	**55.**	(a)	**70.**	(c)
11.	(a)	**26.**	(b)	**41.**	(c)	**56.**	(c)	**71.**	(b)
12.	(c)	**27.**	(b)	**42.**	(b)	**57.**	(d)	**72.**	(a)
13.	(b)	**28.**	(a)	**43.**	(b)	**58.**	(b)	**73.**	(c)
14.	(c)	**29.**	(a)	**44.**	(d)	**59.**	(c)	**74.**	(b)
15.	(a)	**30.**	(c)	**45.**	(b)	**60.**	(b)	**75.**	(c)

Section A : RSE + Industrial & Maintenance Engineering + Robotics & Machatronics

1. (c)

The normal incidence pyrheliometer, uses a long collimator tube to collect beam radiation whose field of view is limited to a solid angle of 5.5° (generally) by appropriate diaphragms inside the tube. The inside of the tube is blackened to absorb any radiation incident at angles outside the collection solid angle. At the base of the tube a wire wound thermopile having a sensitivity of approximately 8 μV/W/m² and an output impedance of approximately 200 Ω is provided.

2. (c)

It essentially consists of a glass sphere mounted on its axis parallel to that of the earth, within a spherical section.

3. (b)

Required retention time of various feed materials at 35°C.

S.No.	Raw Material	Required retention time (days)
1.	Cow dung	50
2.	Poultry droppings	20
3.	Night soil	30
4.	Rice straw	33
5.	Sugar cane tops	43
6.	Water hyacinth	46

4. (d)

$$\text{Amplitude, } R = 10 \text{ m}, r = 3 \text{ m}, A = 3 \text{ km}^2, \eta = 0.65$$

$$\begin{aligned} \text{Average power potential available} &= 0.225 \times A(R^2 - r^2) \text{ Watts} \\ &= 0.225 \times 3 \times 10^6 (10^2 - 3^2) \\ &= 0.225 \times 3 \times 10^6 \times 13 \times 7 \\ &= 61.425 \text{ MW} \\ \text{Average power generated} &= 61.425 \times 0.65 \\ &= 39.93 \text{ MW} \simeq 40 \text{ MW} \end{aligned}$$

5. (b)

Characteristics of various fuel cells

S.No.	Fuel cell	Op. Temp.	Fuel	Efficiency
1.	PEMFC	40-60°	H_2	48-58%
2.	AFC	90°	H_2	64%
3.	PAFC	150-200°C	H_2	42%
4.	MCFC	600-700°C	H_2 and CO	50%
5.	SOFC	600-1000°C	H_2 and CO	60-65%

6. (a)

S.No.	Rotor type	Tip speed ratio	RPM	Torque
1.	Propeller (1-3 blades)(Lift)	6-20	High	Low
2.	Sailwing (Lift)	4	Moderate	Moderate
3.	Chalk multiblade (Lift)	3-4	Moderate	Moderate
4.	American multiblade (Drag)	1	Low	High
5.	Dutch type (Drag)	2-3	Low	High
6.	Savonious (Drag)	1	Low	High
7.	Darrieus (Lift)	5-6	High	Low
8.	Musgrove and Evan (Lift)	3-4	Moderate	Moderate

7. (c)

- **Zenith angle :** It is the vertical angle between the Sun's rays and the line perpendicular to the horizontal plane through the point.
- **Surface azimuth angle :** It is the angle in the horizontal plane, between the line due south and the horizontal projection of the normal to the inclined plane surface (collector).
- **Declination angle :** It is the angle subtended by a line joining the centres of the earth and the Sun with its projection on the Earth's equatorial plane.

8. (a)

$$\text{Concentration ratio} = \frac{W - D_0}{\pi D_0} = \frac{2.5 - 6.5 \times 10^{-2}}{\pi \times 6.5 \times 10^{-2}}$$

$$\simeq 11.93$$

9. (b)

$$\text{Concentration ratio} = \frac{1}{\sin\phi_{max}}$$

$$\phi_{max} = \frac{\text{Angle of acceptance}}{2} = \frac{20°}{2} = 10°$$

$$\therefore \quad c = \frac{1}{\sin 10°} = \frac{1}{0.174} = 5.75$$

$$W = 5.75 \times 20 = 115 \text{ cm}$$

$$\frac{H}{W} = \frac{1}{2}(1+c)\cos 10°$$

$$\frac{H}{W} = \frac{1}{2}(1+5.75)\times 0.985 = 3.324$$

$$H = 3.324 \times 115$$

$$H = 382.30 \text{ cm}$$

10. (d)

We know that,

$$\frac{A_{conc.}}{w \times L} = 1 + c$$

$$A_{conc} = (1+5.75)\times\frac{115}{100}\times 2$$

$$A_{conc} = 15.53 \text{ m}^2$$

11. (a)

$$\rho = \frac{P}{RT} = \frac{101.325}{0.287\times 283} = 1.247 \text{ kg/m}^3$$

Also,

$$P = \frac{1}{2}\rho A V^3$$

$$1500 = \frac{1}{2}\times 1.247\times A\times\left(\frac{24\times 1000}{3600}\right)^3$$

$\Rightarrow$

$$A \simeq 8.12 \text{ m}^2$$

12. (c)

Photons of quantum energy cannot contribute in photoelectric production. This energy is converted into thermal energy about 33% and is lost.

13. (b)

The main advantages with water as storage media are

1. It is abundant and inexpensive.
2. It is easy to handle, non-toxic and non-combustible.
3. Its flow can take place by thermo-siphon action.
4. It has high density, high specific heat, good thermal conductivity and low viscosity.
5. Can be used both as storage medium as well as working medium (thus eliminating the need for a heat exchanger, e.g., in a space-heating system)
6. Charging and discharging of heat can occur simultaneously.
7. Control of water system is flexible.

The main disadvantages with water as storage media are

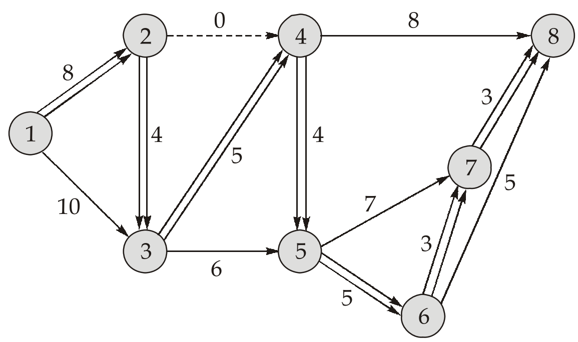
1. Limited temperature range (0°C to 100°C).
2. Corrosive medium.
5. Low surface tension (i.e., leaks easily)

14. (c)

$$\text{Number of orders/year, } N = \sqrt{\frac{C_h\times D}{2\times C_0}} = \sqrt{\frac{2.69\times 9000}{2\times 100}}$$

$$= \sqrt{121.05} \simeq 11 \text{ orders/years}$$

15. (a)



16. (b)

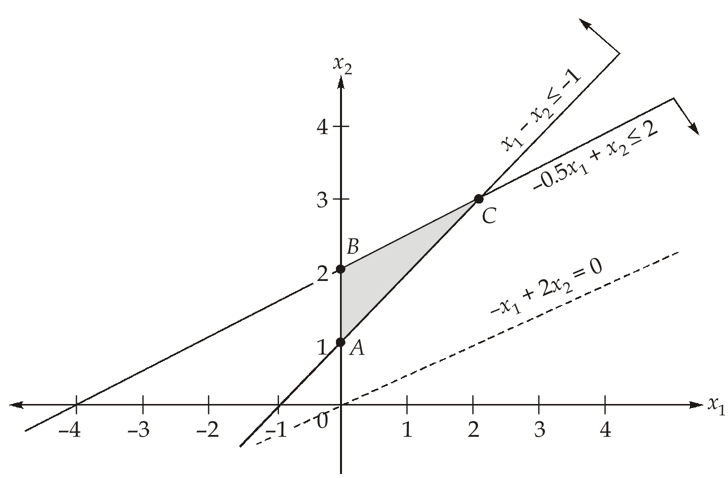
- **SOS analysis :** This analysis is based on the nature of the items.
- **HML analysis :** In this analysis, items are classified on the basis of unit cost rather than their usage value.
- **FNSD analysis :** This analysis divide items into four categories in the descending of their consumption rate.

17. (c)

RHS of the first constraint is negative. Multiplying both sides of the constraint by –1, it takes the form.

$$-x_1 + x_2 \geq 1$$

The solution space satisfying the constraints and meeting the non-negativity restrictions is shown shaded in figure below.



Values of the objective function at the vertices of the closed region ABC are

Extreme point (Vertex)	Coordinates	Value of Z
A	(0, 1)	2
B	(0, 2)	4
C	(2, 3)	4

Thus both points B and C give the same maximum value of $Z = 4$. It follows that every point between B and C on the line BC also gives the same value of Z. The problem, therefore, has multiple optimal solutions and $Z_{max} = 4$.

18. (b)

For the application of optimality test in case of transportation model, the number of allocations should be equal to (m + n – 1), where, m is the number of rows and 'n' is the number of columns.

19. (b)

Reliability of aircraft flying without crash = 1 – (1 – 0.6)(1 – 0.6)

$$= 1 - 0.4 \times 0.4 = 1 - 0.16$$
$$= 0.84$$

20. (b)

- **Alarm level :** The state developed in the equipment due to early stage of occurrence of the failure and is noticed by same predetermined symptoms of the failure.
- **Breakdown level :** The ultimate and final failure stage of the equipment at which stoppage of production or catastrophe even with a possible damage can occur.
- **Lead time :** The duration between the points of start of failure to breakdown in process of deterioration of the equipment.

21. (b)

Predictive maintenance is done to know the health or condition of a machine.

It leads to lower maintenance costs, less repair down time, improved operator safety, etc.

22. (d)

$$\text{MTBF} = 100 \text{ hours, MTTR} = 120 \text{ min} = 2 \text{ hours}$$

$$\text{Availability} = \frac{\text{MTBF}}{(\text{MTBF} + \text{MTTR})}$$

$$= \frac{100}{100+2} = \frac{100}{102}$$

$$\text{Availability} = 0.98$$

23. (c)

- **Liquid penetrant testing :** To locate surface cracks, porosity, laps, leaks in weld bonds grinding cracks.
- **Magnetic particle testing :** To detect surface or shallow substance flaws, cracks, porosity. non-metallic inclusions and weld defects.
- **Ultrasonic testing :** To find internal defects, cracks, etc.

24. (c)

Following notations and conventions are generally used in robotics:

1. Vectors and matrices are written in upper case-bold-italic. Unit vectors are lower case-bold-italic, as an exception. Lower case italic is used for scalars. Vectors are taken as column vectors.

Components of a vector or matrix are scalars with single subscript for vector components and double subscripts for matrix components. For example, components of a vector are a_i or b_z and elements of a matrix are a_{ij}.

2. Coordinate frames are enclosed in curved parenthesis { }, for example coordinate frame with axes XYZ is $\{x\ y\ z\}$ or coordinate frame 1 is {1} and square parenthesis [ ] are used for elements of vectors and matrices.
3. The association of a vector to a coordinate frame is indicated by a leading superscript. For example, ${}^0P$ is a position vector P in frame {0}.
4. A trailing subscript on a vector is used, wherever necessary to indicate what the vector represents. For example, P_{tool}, represents the tool position vector and v_i represents velocity vector for link i.
5. Matrices used for transformation from one coordinate frame to another, have a leading superscript and a trailing subscript. For example, ${}^0T_1$ denotes the coordinate transformation matrix, which transforms coordinates from frame {1} to frame {0}.
6. Trailing superscripts on matrices are used for inverse or transpose of a matrix, for example, R^{-1} or R^T and on vectors for transpose of a vector, for example, if P is a column vector P^T is a row vector.

25. (b)

Because each joint has only one degree of freedom.

26. (b)

The 30° rotation of P about z-axis of frame {1} is

$$R_z(30°) = \begin{bmatrix} \cos 30° & -\sin 30° & 0 \\ \sin 30° & \cos 30° & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 0.866 & -0.5 & 0 \\ 0.5 & 0.866 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

For the rotation of vectors, $'Q = R_z(30°)\ 'P$

$$'Q = \begin{bmatrix} 0.866 & -0.5 & 0 \\ 0.5 & 0.866 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 4.0 \\ 3.0 \\ 2.0 \end{bmatrix}$$

$$'Q = \begin{bmatrix} 3.464 - 1.5 + 0 \\ 2 + 2.598 + 0 \\ 0 + 0 + 2.0 \end{bmatrix} = \begin{bmatrix} 1.964 \\ 4.598 \\ 2.0 \end{bmatrix}$$

$\therefore$ Coordinate of the new point $Q = [1.964 \quad 4.598 \quad 2.0]^T$

27. (b)

- **Reachable workspace :** The region that can be reached by the origin of the end effector frame with at least one orientation is called reachable workspace.
- **Joint space :** The set of all (n × 1) joint displacement vectors generates the joint vector space or joint space.
- **Cartesian space :** The configuration of the end effector is represented by three position components as displacements along three orthogonal axes of base frame and three rotations about the base frame axes. These six components can be represented by a six dimensional space called configuration space or cartesian space.

28. (a)

Defuzzification is the conversion of a fuzzy output value to an equivalent crisp value for actual use. As the fuzzy rules are evaluated and corresponding values are calculated, the result will be a number related to the corresponding membership values for different output fuzzy sets. As an example, suppose that the output power setting for an air conditioning system is fuzzified into OFF, LOW, MEDIUM, and HIGH. The result of rule base evaluation may be, say, a 25% membership in LOW and a 75% membership in MEDIUM. Defuzzification is the process of converting these values into a single number that can be sent to the air conditioning control system.

29. (a)

Inverse kinematics equations are more important since the robot controller will calculate the joint values using these equations and it will run the robot to the desired position and orientation.

30. (c)

Advantages:

1. Small size and a small weight.
2. High output impedance.
3. Can measure acceleration from a fraction of g to thousands of g.
4. High sensitivity.
5. High frequency response (10 Hz to 50 kHz)

Disadvantages:

1. Unsuitable for applications where the input frequency is lower than 10 Hz.
2. Subject to hysteresis errors.
3. Sensitive to temperature changes.

31. (a)

Features of the PIC16F84 microcontroller

- 8-bit wide data bus CMOS microcontroller;
- 18-pin DIP, SOIC;
- 1792 bytes of flash EEPROM program memory subdivided into 14-bit words (0h-3Fh);
- 68 bytes of RAM data memory;
- 64 bytes of non-volatile EEPROM data memory;
- 1024 (1 kB) instructions capability;
- 4 MHz clock speed (maximum 10 MHz);

- 15 special function hardware registers;
- 36 general purpose registers (SRAM);
- 13 I/O pins.

32. (b)

$$Q = \frac{V_{max} - V_{min}}{2^n - 1} = \frac{5-(-5)}{2^8 - 1}$$

$$= \frac{10}{256-1} = \frac{10}{255}$$

$$= 0.039 \text{ V}$$

33. (a)

We know that,
$$V_{out} = -V_R \sum_{i=1}^{N} \frac{b_i}{2^i}$$

$$V_{out} = -V_R\left[\frac{1}{2}+\frac{0}{4}+\frac{0}{8}+\frac{1}{16}+\frac{1}{32}+\frac{0}{64}+\frac{0}{128}+\frac{1}{256}\right]$$

$$V_{out} = -V_R\left[\frac{1}{2}+\frac{1}{16}+\frac{1}{32}+\frac{1}{256}\right]$$

$$V_{out} = -\frac{153}{256}V_R$$

34. (d)

The most common type unipolar stepper motor, has six wires and four coils (actually two coils divided by center wires on each coil). The outer wires for each coil will have a definite resistance that is double the resistance between the inner wire and either of the two outer wires.

35. (b)

36. (a)

We know that,
$$V = K_H \times \frac{B \times I}{t}$$

$$= \frac{3.55\times10^{-4}\times0.48\times0.015}{10^{-3}}$$

$$= 2.56 \times 10^{-3} \text{ Volt}$$

37. (b)

PLC is an inexpensive, flexible, reliable replacement of hard wired relay panels. The PLCs find least applications in the control and operation of automated manufacturing process equipment and machinery, packaging and filling equipment, chemical mixing. conveyer system and distillation etc. Most automated factories employ PLCs in plant control application such as the automations of production and assembly process.

Section B : Theory of Machines-1

38. (d)

39. (b)

Using tabular method to determine speed of gear B

Arm	Gear A (30)	Gear B (40)
0	x	$\frac{-x \times 30}{40}$
y	$y+x$	$y-\frac{3x}{4}$

Let y be speed of arm,

Speed of gear A, $y + x = 0$ (Since gear A is fixed)

Speed of arm, $y = 100$ (CCW)

$\therefore$ $x = -100$ (CW)

$$\text{Speed of the gear } B = y-\frac{3x}{4}$$

$$= 100-\frac{3(-100)}{4}=175 \text{ rpm}$$

40. (c)

41. (c)

Given : $\psi_1 = 25°$, $m_n = 12$ mm, $\psi_2 = 60 - 25° = 35°$

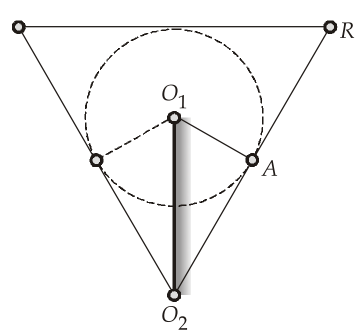
$$VR = \frac{1}{2}=\frac{N_2}{N_1}=\frac{T_1}{T_2}$$

$$T_2 = \frac{T_1}{VR}=\frac{16}{1/2}=32$$

$$C = \frac{m_n}{2}\left[\frac{T_1}{\cos\psi_1}+\frac{T_2}{\cos\psi_2}\right] = \frac{12}{2}\left[\frac{16}{\cos 25}+\frac{32}{\cos 35}\right]$$

$$\simeq 340 \text{ mm}$$

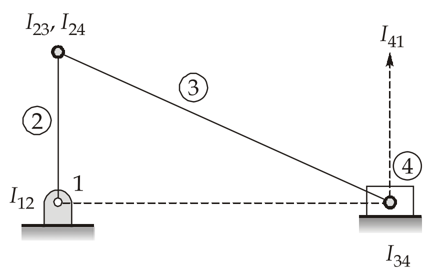
42. (b)



$$\text{Stroke} = \frac{2 \times (O_1A) \times (O_2R)}{O_1O_2}$$

$$= \frac{2 \times 50 \times 400}{200} = 200 \text{ mm}$$

43. (b)



$$V_{slider} = \omega_2 (I_{24} I_{21})$$

$$= 40 \times 0.15 = 6 \text{ m/s}$$

44. (d)

45. (b)

$$\text{Workdone per second} = 50000 \text{ W}$$

For a double-acting engine, the number of working strokes per minute = 2 × 200 rpm

$$\text{Indicated work per stroke} = \frac{\text{Workdone per second}}{\text{Number of working strokes per second}}$$

$$= \frac{50000}{400/60} = 7500$$

$$\text{Fluctuation of energy} = 7500 \times 0.3 = 2250 \text{ N.m}$$

$$k = \frac{\omega_1 - \omega_2}{\omega} = \frac{1.01\omega - 0.99\omega}{\omega} = 0.02$$

$$k = \frac{e}{I\omega^2}$$

$$0.02 = \frac{2250}{m \times (0.5)^2 \times (20.933)^2}$$

$$m = 1026.95 \simeq 1027 \text{ kg}$$

46. (a)

k_1, k_2 and k_3 are in parallel

$$k_{parallel} = k_1 + k_2 + k_3$$

$$\omega_n = \sqrt{\frac{k_{eq}}{m}} = \sqrt{\frac{k_1 + k_2 + k_3}{m}}$$

47. (b)

48. (a)

Vibration range of frequencies

$$\omega_1 = \frac{2\pi \times 1600}{60} = 167.55 \text{ rad/sec}$$

80% isolation means,

$$\text{Transmissibility ratio} = 1 - 0.8 = 0.2 \text{ TR}$$

$$-0.2 = \frac{1}{1-\left(\frac{\omega}{\omega_n}\right)^2}$$

$$1-\left(\frac{\omega}{\omega_n}\right)^2 = -5$$

$$\sqrt{6} = \left(\frac{\omega}{\omega_n}\right)$$

$$\Rightarrow \quad \omega_n = \frac{167.55}{\sqrt{6}}$$

$$= 68.4 \text{ rad/s}$$

49. (d)

$$f(t) = 100 \cos(10t) \text{ N},$$

$$f_0 = 100,\ \omega = 10 \text{ rad/s},\ k = 6000 \text{ N/m}$$

$$x = 20 \times 10^{-3}$$

$$x = \frac{f_0}{(k - m\omega^2)}$$

$$k - m\omega^2 = \frac{100}{20 \times 10^{-3}} = 5000$$

$$6000 - 5000 = m\omega^2$$

$$m = \frac{1000}{(10)^2} = 10 \text{ kg}$$

50. (b)

Minimum number of teeth on pinion to avoid interference,

$$T = \frac{2A_w}{\sqrt{1+\frac{1}{G}\left(\frac{1}{G}+2\right)\sin^2\phi} - 1} = \frac{2 \times 1}{\sqrt{1+\frac{1}{3}\left(\frac{1}{3}+2\right)\sin^2 20^\circ} - 1}$$

$$T = 44.9 \simeq 45$$

Taking the higher whole number divisible by V.R. 45

$$t = \frac{45}{3} = 15$$

51. (a)

$$\omega = \frac{2\pi N}{60} = \frac{2\pi \times 120}{60} = 12.57 \text{ rad/s}$$

$$f_{max} = \frac{h}{2}\left(\frac{\pi\omega}{\phi_a}\right)^2$$

$$= \frac{30}{2}\left(\frac{\pi \times 12.57}{150 \times \frac{\pi}{180}}\right)^2 = 3413 \text{ mm/s}^2 = 3.413 \text{ m/s}^2$$

52. (a)

53. (c)

The kinetic energy of the barrel must be equal to the potential energy of the spring.

$$\frac{1}{2}m\dot{x}^2 = \frac{1}{2}kx^2$$

$$\Rightarrow \qquad \frac{1}{2}mV^2 = \frac{1}{2}kD^2$$

$$mV^2 = kD^2$$

$$c_c = 2\sqrt{mk}$$

$$= 2\sqrt{m\left(\frac{mV^2}{D^2}\right)} = \frac{2mV}{D}$$

54. (d)

Given : Speed of engine = 500 rpm;

$$2r = 100 \text{ mm} \quad \Rightarrow \quad r = 50 \text{ mm}$$

$$m_{reci} = 30 \text{ kg}; \ m_{\text{revolving part}} = 10 \text{ kg}$$

The balancing mass (m_b) is given by

$$m_b \times r_b = (m_{Rot}\, r_{Rot} + c\, m_{reci} \cdot r)$$

$$m_b \times 150 = (10 \times 50) + \left(\frac{2}{3} \times 30 \times 50\right)$$

$$m_b = 10 \text{ kg}$$

55. (a)

56. (c)

A hooke's joint (universal joint) is indeed used to connect two non-parallel and intersecting shafts, so the assertion is true. However, the speed of the driven shaft in a hook's joint is not constant; it varies due to angular misalignment, reaching minimum and maximum values during rotation.

Section C : SOM and Engg Mechanics-2

57. (d)

For same weight,

$$D^2 = D_0^2(1-k^2) \qquad \therefore \qquad \frac{D_0}{D} = \frac{1}{\sqrt{1-k^2}}$$

$$T \propto Z_p$$

$$\Rightarrow \qquad \frac{T_H}{T_S} = \frac{D_0^3(1-k^4)}{D^3} = \frac{(1+k^2)(1-k^2)}{(1-k^2)^{3/2}}$$

$$= \frac{1+k^2}{\sqrt{1-k^2}} > 1$$

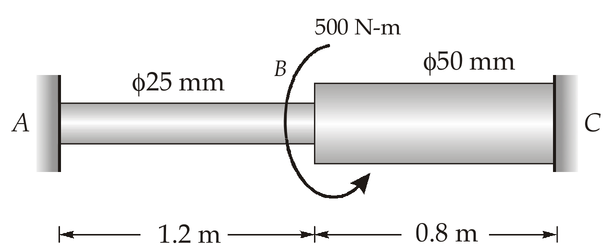
58. (b)

$$\frac{T}{J} = \frac{\tau}{r}$$

$$\tau = \frac{T\cdot r}{J} = \frac{314\times10^3\times20}{\frac{\pi}{32}\times50^4}$$

$$= 10.24 \text{ MPa}$$

59. (c)



Compatibility equation,

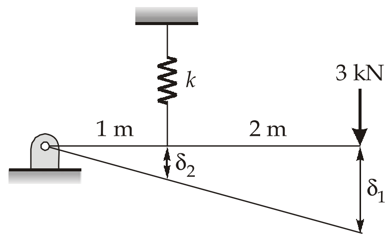
$$\left(\frac{TL}{JG}\right)_{AB} + \left(\frac{TL}{GJ}\right)_{BC} = 0$$

$$\frac{T_A\times1.2}{(25)^4} + \frac{(T_A-500)\times0.8}{(50)^4} = 0$$

$$\frac{T_A\times1.2}{(25)^4} = \frac{T_C\times0.8}{(50)^4}$$

$$\frac{T_C}{T_A} = \left(\frac{50}{25}\right)^4 \times \frac{1.2}{0.8} = 16 \times \frac{3}{2} = 24$$

60. (b)



$$\frac{\delta_2}{1} = \frac{\delta_1}{3} \qquad \text{...(i)}$$

$$\Sigma M_{\text{Hinge}} = 0$$

$$F_{\text{spring}} \times 1 = 3 \times 3$$

$$k \cdot \delta_2 = 9$$

$$\delta_2 = \frac{9}{1} = 9 \text{ mm}$$

From equation (i), $\delta_1 = 3\delta_2 = 27$ mm

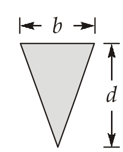
61. (d)

Normal stress is indeed maximum at the outermost fibres, but shear stress does not exist in pure bending.

62. (b)

Bending stress, $\sigma \propto y_{max}$

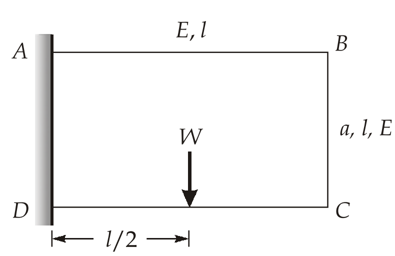
$$\frac{\sigma_T}{\sigma_C} = \frac{\frac{1}{3}d}{\frac{2}{3}d} = \frac{1}{2}$$



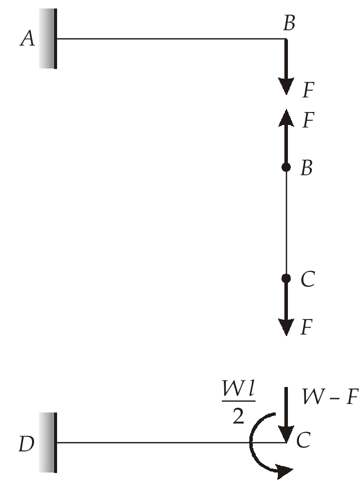
63. (d)

The assumption that plane sections remains plane after twisting is valid only for circular shafts (solid/hollow). For non-circular shafts warping occurs, and plane section do not remain plane.

64. (d)



FBD



From compatibility equation,

$$\delta_B = \delta_C$$

$$\frac{Fl^3}{3EI} = \frac{(W-F)l^3}{3EI} - \frac{\left(\frac{Wl}{2}\right)l^2}{2EI}$$

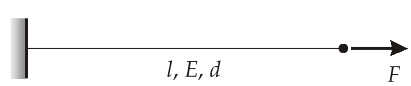
$$F = W - F - \frac{W}{4} \times 3$$

$$2F = \frac{W}{4}$$

$$F = \frac{W}{8}$$

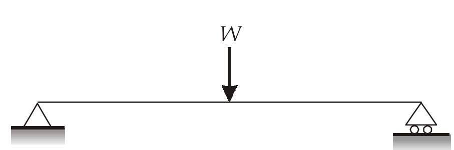
65. (c)

Case I : as axial member



$$\delta = \frac{4FL}{\pi d^2 E}$$

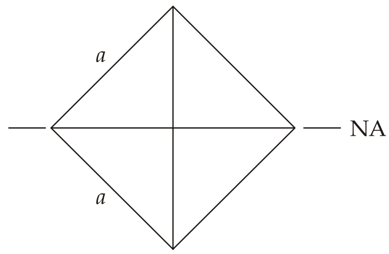
Case II : as beam



$$\frac{y}{\delta} = \frac{\left(\frac{64Wl^3}{48E\pi d^4}\right)}{\left(\frac{4Fl}{\pi d^2 E}\right)} = \frac{Wl^2}{3Fd^2}$$

$$\therefore \quad y = \frac{Wl^2}{3Fd^2} \cdot \delta$$

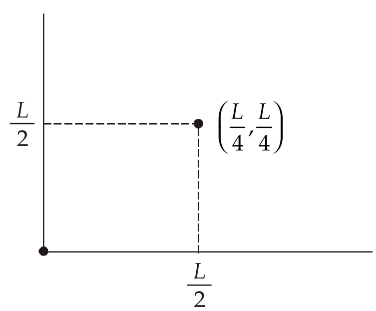
66. (c)



$$I_{NA} = \frac{a^4}{12}$$

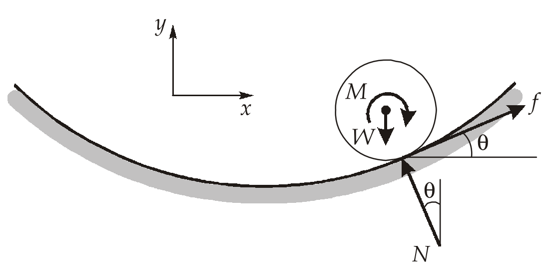
$$\text{Section modulus, } Z_{NA} = \frac{a^4/12}{\left(\frac{\sqrt{2}a}{2}\right)} = \frac{a^3}{6\sqrt{2}}$$

67. (d)



68. (c)

FBD



In equilibrium condition,

$\Sigma F_x = 0$

$$N\sin\theta = f\cos\theta \qquad \because \quad f = \mu N$$

$$\tan\theta = \mu = \frac{5}{12}$$

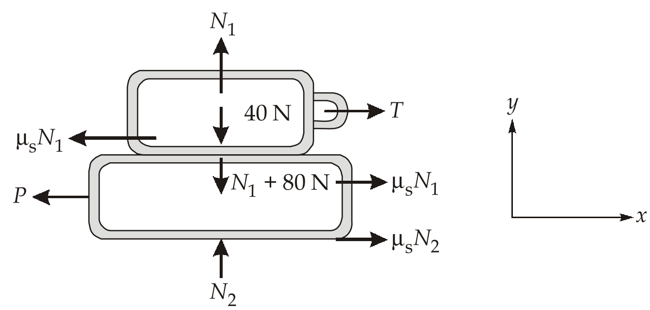
$\Sigma M_{point\ of\ contact} = 0$

$$M = W\sin\theta \cdot R$$

$$= W\frac{5}{13}R = \frac{5WR}{13}$$

69. (d)

FBD,



in equilibrium,

Upper block,

$\Sigma F_y = 0$

$$\Rightarrow \quad N_1 = 40 \text{ N}$$

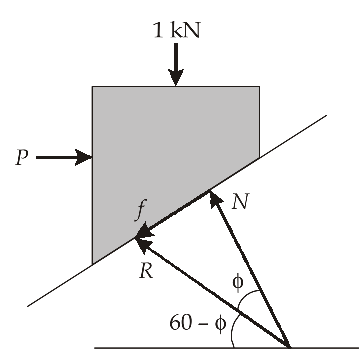
Lower block,

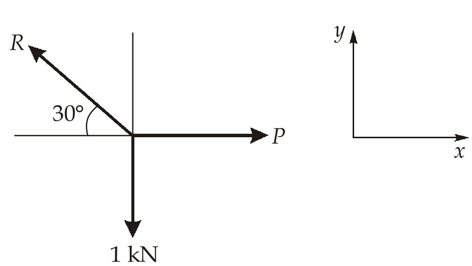
$\Sigma F_x = 0$

$$P = \mu_S N_1 + \mu_S N_2$$
$$= 0.4(40 + 120)$$
$$= 64 \text{ N}$$

70. (c)

$$\phi = \tan^{-1}\mu_s = \tan^{-1}\frac{1}{\sqrt{3}} = 30°$$





$\Sigma F_y = 0$

$$R \sin 30 = 1 \qquad \therefore \qquad R = 2 \text{ kN}$$

$\Sigma F_x = 0$

$$R \cos 30 = P$$

$$P = 2 \times \frac{\sqrt{3}}{2} = \sqrt{3} \text{ kN}$$

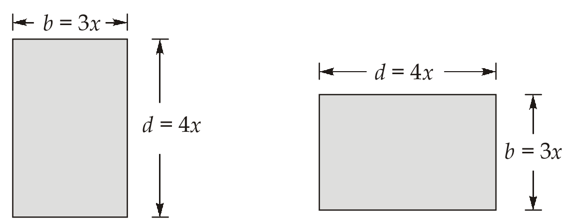
71. (b)

When a cross-section rotates about its centroidal axis, the cause of this rotation is a moment that acts perpendicular to that axis.

72. (a)

$$\sigma = \frac{M}{I_{NA}} y_{max}$$

$$\Rightarrow \qquad \sigma \propto \frac{1}{Z_{NA}}$$



$$\frac{\sigma_{initial}}{\sigma_{final}} = \frac{Z_{NA,f}}{Z_{NA,i}}$$

$$= \frac{b^2 d}{bd^2} = \frac{b}{d} = \frac{3}{4}$$

73. (c)

74. (b)

$$M_{max} = \frac{wl^2}{2}$$

$$M_{max} = \sigma_{per} \times \frac{I}{y_{max}}$$

$$w = 125 \times \frac{75 \times 10^6}{\left(\frac{300}{2}\right)} \times \frac{2}{(2000)^2} = 31.25 \text{ N/mm}$$

75. (c)

Stress in independent of material it only depends on the load and geometry of the cross-section.

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