CLASS TEST

S.No. : 01JPME_TOM_14102023

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MECHANICAL ENGINEERING

THEORY OF MACHINES

Duration : 1:00 hr. **Maximum Marks : 50**

Read the following instructions carefully

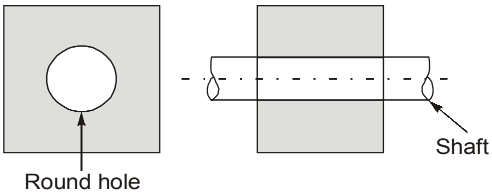
1. This question paper contains **30** objective questions. **Q.1-10** carry one mark each and **Q.11-30** carry two marks each.
2. Answer all the questions.
3. Questions must be answered on Objective Response Sheet (**ORS**) by darkening the appropriate bubble (marked **A**, **B**, **C**, **D**) using HB pencil against the question number. Each question has only one correct answer. In case you wish to change an answer, erase the old answer completely using a good soft eraser.
4. There will be **NEGATIVE** marking. For each wrong answer **1/3rd** of the full marks of the question will be deducted. More than one answer marked against a question will be deemed as an incorrect response and will be negatively marked.
5. Write your name & Roll No. at the specified locations on the right half of the **ORS**.
6. No charts or tables will be provided in the examination hall.
7. Choose the **Closest** numerical answer among the choices given.
8. 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 that questions.
9. If a question is left blank, i.e., no answer is given by the candidate, there will be **no penalty** for that question.

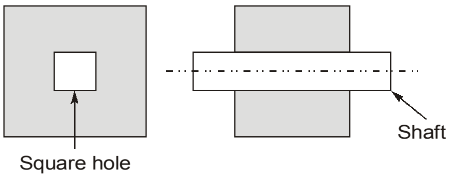
DO NOT OPEN THIS TEST BOOKLET UNTIL YOU ARE ASKED TO DO SO

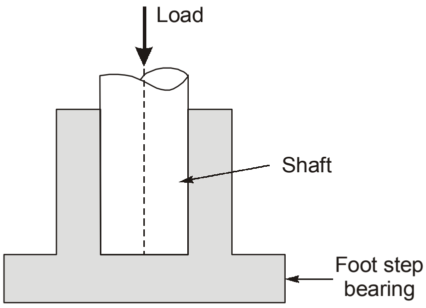
Q.No. 1 to Q.No. 10 carry 1 mark each

Q.1 Which of the following is an example of incompletely constrained motion?

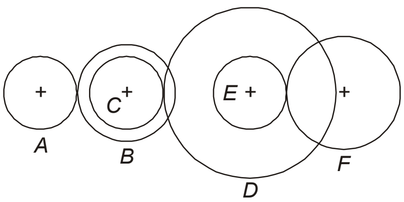
(a)


(b)


(c)


(d)


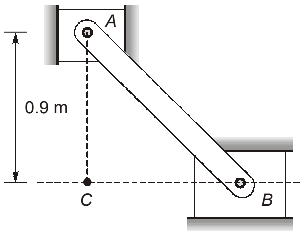
Q.2 A gear train is shown below. The motor is connected to gear *A* and runs at 975 rpm. *F* is the output gear. The speed of *F* is



Gear	A	B	C	D	E	F
Teeth	20	50	25	75	26	65

(a) 40 rpm (b) 52 rpm
(c) 50 rpm (d) 62 rpm

Q.3 The ends *A* and *B* of a 1.5 m link *AB* are constrained to move in the directions as shown in the figure. At a given instant when *A* is 0.9 m above *C* it was moving at 3 m/s upwards. The velocity of *B* at this instant will be



(a) 1.75 m/s (b) 3.50 m/s
(c) 2.25 m/s (d) 4.72 m/s

Q.4 In a spring mass vibrating system, the natural frequency of vibration is reduced to half the value when a second spring is added to the first spring in series. If the stiffness of first spring is 9 N/m then stiffness of the second spring will be
(a) 2 N/m (b) 3 N/m
(c) 4 N/m (d) 7 N/m

Q.5 Offset in radial cam is provided for
(a) decreasing pressure angle during upward movement of follower
(b) decreasing pressure angle during downward movement of follower
(c) increasing pressure angle during upward movement of follower
(d) increasing pressure angle during downward movement of follower

Q.6 The rotor of the turbine of a yacht makes 1200 rpm clockwise when viewed from the stern. The rotor has mass 750 kg and radius of gyration 250 mm. The gyroscopic couple (in kNm) transferred to the hull when the yacht pitches at angular velocity of 1 rad/s is
(a) 2.50 (b) 3.49
(c) 4.89 (d) 5.88

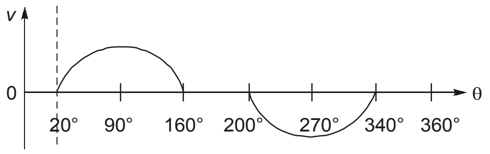
Q.7 The engine of an aeroplane rotates in clockwise direction when seen from the tail end and the aeroplane takes a turn to the left. The effect of gyroscopic couple on the aeroplane will be:
(a) to raise the nose and dip the tail
(b) to dip the nose and raise the tail
(c) to dip the nose and tail
(d) to dip the nose and tail

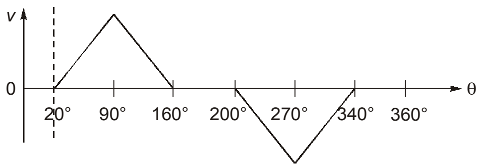
Q.8 The mass moment of inertia of a flywheel is 2500 kg-m^2 and the starting torque is 1500 Nm. The kinetic energy of the flywheel after 10 sec of start will be:
(a) 18 kNm (b) 25 kNm
(c) 36 kNm (d) 45 kNm

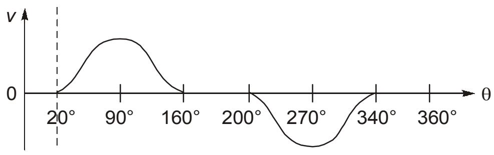
Q.9 The sleeve and each rotating mass of a porter governor weigh 200 N and 50 N, respectively. If the friction at the sleeve is 10 N, then coefficient of detention would be

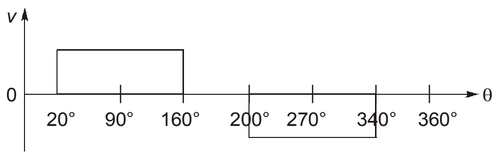
(a) 0.20 (b) 0.40
(c) 0.04 (d) 0.05

Q.10 Which of the following graph shows the velocity, v and θ diagram for cycloidal motion of a follower?

(a)


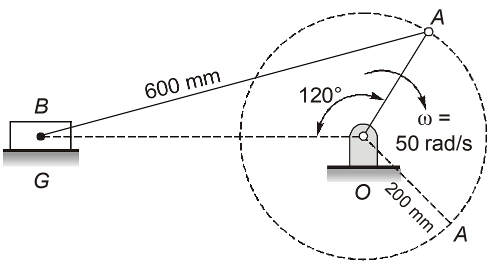
(b)


(c)


(d)


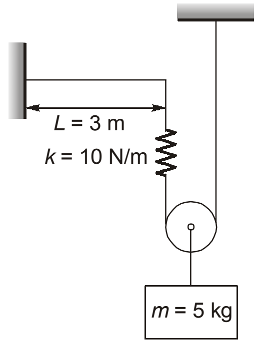
Q. No. 11 to Q. No. 30 carry 2 marks each

Q.11 For the given slider crank mechanism shown in figure below, the crank rotates at a constant angular velocity of 50 rad/s. At the instant shown, the velocity of slider will be



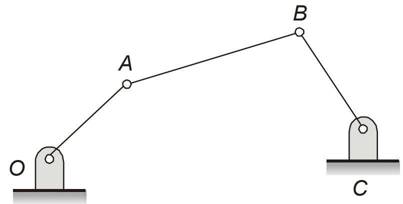
(a) 6.25 m/s (b) 7.21 m/s
(c) 8.72 m/s (d) 5.75 m/s

Q.12 The natural frequency of vibration of the following system shown in the figure will be
[Take $g = 10$ m/s^2, $EI = 200$ N.m^2 for the beam]



(a) 1.25 rad/s (b) 2.35 rad/s
(c) 3.75 rad/s (d) 4.57 rad/s

Q.13 Consider a four bar mechanism shown in the figure, with links OA = 3 cm, AB = 5 cm, BC = 6 cm, OC = 70 mm. The mechanism is

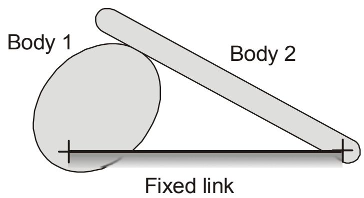


(a) Double crank mechanism
(b) Double rocker mechanism
(c) Crank rocker mechanism
(d) Single slider mechanism

Q.14 A disc cam is to give SHM to a knife edge follower during out-stroke of 40 mm. The angle of ascent is 120° and the minimum radius of cam is 40 mm. The cam shaft revolves at 200 rpm. Then the maximum velocity during ascent is

(a) 0.28 m/s (b) 0.39 m/s
(c) 0.87 m/s (d) 0.63 m/s

Q.15 The mobility of planar mechanism shown below is

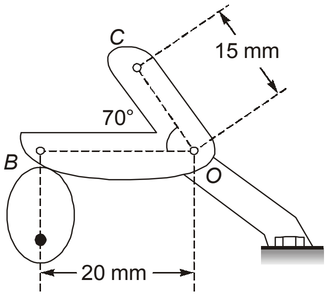


(a) 0 (b) 1
(c) 2 (d) –1

Q.16 Four masses m_1, m_2, m_3 and m_4 of 200 kg, 300 kg, 240 kg, and 260 kg respectively, are rotating in corresponding radius of rotation 0.2 m, 0.15 m, 0.25 m and 0.3 m respectively. The angles between successive masses are 45°, 75° and 135°. What will be the magnitude of balancing mass required at the radius of 0.2 m?

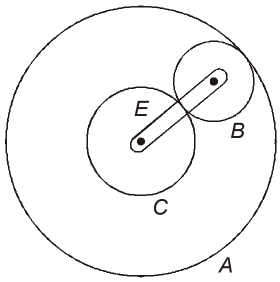
(a) 116 kg (b) 110 kg
(c) 90 kg (d) 42 kg

Q.17 The figure illustrate the cam mechanism used to drive exhaust port of an IC engine. For this instant, the cam forces point *B* upwards at 30 mm/s. The velocity (in mm/s)with which point *C* moves will be



(a) 15 (b) 16.5
(c) 22.5 (d) 30

Q.18 An epicyclic gear train is shown in figure below:

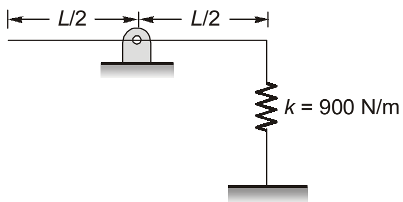


Gear	*A*	*C*
Teeth	72	32

Gear *B* meshes with both *A* and *C* and is carried by arm *E* which rotates at 18 rpm about centre of *A*. If the gear *A* is fixed, what will be the speed of gear *B*?

(a) 18 rpm (b) 40.5 rpm
(c) 46.8 rpm (d) 50 rpm

Q.19 A uniform rod of mass 3 kg and length 1 m is hinged at its centre and laterally supported at one end by a spring of stiffness 900 N/m. The natural frequency is



(a) 60 rad/s (b) 120 rad/s
(c) 80 rad/s (d) 30 rad/s

Q.20 An exhaust fan, rotating at 1000 rpm is to be supported by four springs. If only 10% of the unbalanced force is to be transmitted to the base and mass of the fan is 40 kg, the value of stiffness of each spring is nearly

(a) 1872 N/m (b) 11609 N/m
(c) 9969 N/m (d) 8569 N/m

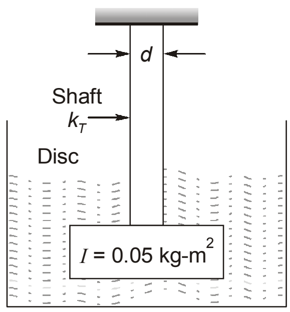
Q.21 Two involute gears in a mesh have a velocity ratio of 3. The arc of approach is not to be less than the circular pitch when the pinion is the driver. The pressure angle of the involute teeth is 20°. The least number of teeth on each gear is

(a) 17, 51 (b) 18, 54
(c) 19, 57 (d) 20, 60

Q.22 In a spring controlled governor the curve of controlling force is a straight line. When balls are 35 cm apart the controlling force is 1100 N and when 20 cm apart, it is 550 N. To make the governor isochronous, the required initial tension on the spring would be

(a) 172.5 N (b) 183.3 N
(c) 192.7 N (d) 162.5 N

Q.23 The torsional pendulum with a disc of moment of inertia as 0.05 kg-m^2 immersed in a viscous fluid as shown in diagram. During vibrations of pendulum, the observed amplitudes on the same side of neutral axis for successive cycles are reduced to 50% of initial value. The damping factor will be

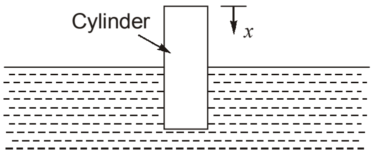


(a) 0.278 (b) 0.317
(c) 0.018 (d) 0.109

Q.24 A single cylinder reciprocating engine has crank rotating at speed of 480 rpm. The stroke length is 600 mm and the mass of reciprocating parts is 100 kg. If two-third of the reciprocating parts and all the revolving parts are to be balanced, the residual unbalanced force when the crank has rotated 60° from inner dead centre is

(a) 38.44 kN (b) 29.60 kN
(c) 52.68 kN (d) 45.54 kN

Q.25 A cylinder of diameter 10 mm and mass 2 kg floats vertically in a liquid of mass density 900 kg/m^3 as shown in figure. It is depressed slightly and released. If specific gravity of liquid is 1.2, the period of oscillation will be approximately,



(a) 11 sec (b) 8 sec
(c) 14 sec (d) 5 sec

Q.26 A machine is coupled to a power source. The machine requires constant torque but torque supplied by the power source is (1000 + 300 sin θ) N-m. Mass moment of inertia of the flywheel is 200 kg-m^2. What is the maximum angular acceleration of the flywheel and at what position does it occur?

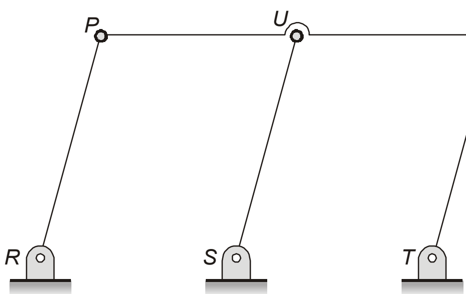
(a) $\frac{3}{2}$rad/sec^2, $\theta = 0°$

(b) $\frac{3}{2}$rad/sec^2, $\theta = 90°$

(c) $\frac{1}{3}$rad/sec^2, $\theta = 180°$

(d) $\frac{1}{3}$rad/sec^2, $\theta = 90°$

Q.27 PQ is a single link in a double-parallelogram mechanism as shown below. The correct statement pertaining to this mechanism is



(a) It is a structure with zero DOF
(b) It is a five link and four turning pair mechanism
(c) It violates Grashof's law
(d) It is a Gruebler paradox

Q.28 When the primary direct crank of a reciprocating engine positioned at 60° clockwise, the secondary reverse crank for balancing will be at:

(a) 60° clockwise
(b) 120° clockwise
(c) 60° anticlockwise
(d) 120° anticlockwise

Q.29 Consider the following statements about the properties of involute profile :

1. The shape of involute profile is dependent only on the dimensions of base circle.
2. The angular velocity ratio when two involutes are in mesh, is directly proportional to the size of the base circles.
3. Basic rack for involute tooth profile has straight line form.
4. Involute is the only tooth form that is not sensitive to centre distance of their base circles.

Which of the above statements are correct?

(a) 1, 3 and 4 (b) 1, 2 and 3
(c) 2, 3 and 4 (d) 1, 2 and 4

Q.30 **Statment (I):** Helical gears are used for transmitting motion and power between intersecting shafts, where as straight bevel gears are used for transmitting motion and power between two shafts intersecting each other at 90°.

Statment (II): In helical gears teeth are inclined to the axis of the shaft and are in the form of a helix, whereas in bevel gears, teeth are tapered both in thickness and height from one end to the other.

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is NOT the correct explanation of Statement (I).
(c) Statement (I) is true but Statement (II) is false.
(d) Statement (I) is false but Statement (II) is true.

■■■■

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THEORY OF MACHINES

MECHANICAL ENGINEERING

Date of Test : 14/10/2023

ANSWER KEY

1.	(b)	7.	(a)	13.	(c)	19.	(d)	25.	(a)
2.	(b)	8.	(d)	14.	(d)	20.	(c)	26.	(b)
3.	(c)	9.	(c)	15.	(b)	21.	(b)	27.	(d)
4.	(b)	10.	(c)	16.	(a)	22.	(b)	28.	(d)
5.	(a)	11.	(b)	17.	(c)	23.	(d)	29.	(a)
6.	(d)	12.	(b)	18.	(c)	24.	(d)	30.	(d)

DETAILED EXPLANATIONS

1. (b)

'*a*' is completely constrained. (c) is also completely constrained and (d) is successfully constrained. Only (b) has two possible motion, sliding and rotating.

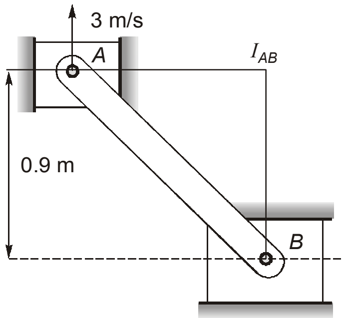
$\therefore$ (b) is incompletely constrained.

2. (b)

$$\frac{N_F}{N_A} = \frac{T_{\text{input}}}{T_{\text{output}}} = \frac{T_E}{T_F} \times \frac{T_C}{T_D} \times \frac{T_A}{T_B} = \frac{26 \times 25 \times 20}{65 \times 75 \times 50}$$

$$N_F = 0.0533\, N_A = 0.0533 \times 975 = 52 \text{ rpm}$$

3. (c)



$$I_{AB} \cdot B = 0.9 \text{ m}$$

$$AB = 1.5 \text{ m}$$

$$I_{AB} \cdot A = \sqrt{(AB)^2 - (I_{AB} \cdot B)^2} = \sqrt{(1.5)^2 - (0.9)^2} = \sqrt{2.25 - 0.81} = 1.2 \text{ m}$$

$$\therefore \quad \frac{V_B}{V_A} = \frac{I_{AB} \cdot B}{I_{AB} \cdot A} = \frac{0.9}{1.2}$$

$$V_B = V_A \times \frac{0.9}{1.2} = 3 \times \frac{9}{12} = 2.25 \text{ m/s}$$

4. (b)

$$\omega_n = \sqrt{\frac{k}{m}}$$

where, ω_n = natural frequency; k = stiffness of spring; m = mass

For first spring, $$\omega_1 = \sqrt{\frac{k_1}{m}}$$

For second spring, $$\omega_2 = \frac{1}{2}\sqrt{\frac{k_1}{m}} \qquad \left[\text{given}, \omega_2 = \frac{\omega_1}{2}\right]$$

$$\sqrt{\frac{k_{eq}}{m}} = \frac{1}{2}\sqrt{\frac{k_1}{m}}$$

$$k_{eq} = \frac{k_1}{4}$$

Springs are connected in series, then stiffness,

$$\frac{1}{k_{eq}} = \frac{1}{k_1} + \frac{1}{k_2}$$

$$k_{eq} = \frac{k_1 k_2}{k_1 + k_2} = \frac{k_1}{4}$$

$$4k_2 = k_1 + k_2$$

$$\therefore \quad 3k_2 = k_1$$

Stiffness of second spring, $k_2 = \frac{k_1}{3} = \frac{9}{3} = 3$ N/m

5. (a)

The vertical component ($F\cos\alpha$) lifts the follower whereas the horizontal component ($F\sin\alpha$) exerts lateral pressure on the bearing. In order to reduce the lateral pressure or $F\sin\alpha$, α has to be decreased which means making the surface more convex and longer.

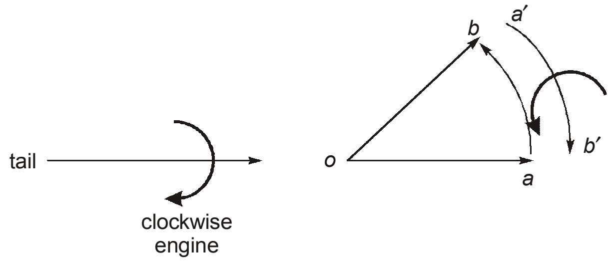
6. (d)

Angular velocity of rotor is given by,

$$\omega = \frac{2\pi \times 1200}{60} = 125.6 \text{ rad/s}$$

$\therefore$ Gyroscopic couple, $c = I\omega\omega_p = 750 \times 0.25^2 \times 125.6 \times 1 = 5887.5 \text{ Nm} = 5.88 \text{ kNm}$

7. (a)



ab = angular momentum vector

$a'\ b'$ = reactive vector which when seen from right side causes a couple in vertical plane in counter clockwise direction and thus trying to raise the nose and dip the tail.

8. (d)

As torque, $T = I\alpha$

$\Rightarrow \quad 1500 = 2500 \times \alpha$

$\Rightarrow \quad \alpha = 0.6$

After 10 sec. speed, $\omega_2 = \omega_1 + \alpha t = 0 + 0.6 \times 10 = 6$ rad/s

$\Rightarrow \quad \text{KE} = \frac{1}{2}I\omega^2 = \frac{1}{2} \times 2500 \times 6^2 = 45$ kNm

9. (c)

$$\text{Coefficient of detention} = \frac{f}{(M+m)g} = \frac{10}{200+50} = \frac{10}{250} = 0.04$$

10. (c)

In cycloidal motion, there are no abrupt changes in the velocity and the acceleration at any stage of the motion. Thus, it is the most ideal programme for high-speed follower motion.

11. (b)

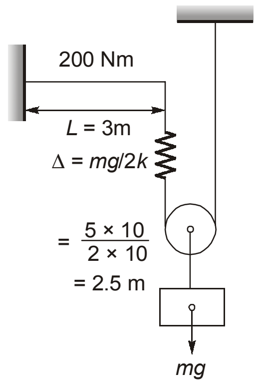
Given: Length of crank, $r = 200$ mm, Length of connecting rod, $l = 600$ mm, $\omega = 50$ rad/s, $\theta = 120°$

$$\text{Velocity of slider, } V_b = r\omega\left[\sin\theta + \frac{\sin 2\theta}{2n}\right] \qquad \left(\text{as we know, } n = \frac{l}{r}\right)$$

$$= 0.2 \times 50 \times \left[\sin 120 + \frac{\sin 240}{2 \times \frac{600}{200}}\right] = 0.2 \times 50 \times \left[\frac{\sqrt{3}}{2} - \frac{\sqrt{3}}{4 \times 3}\right]$$

$$= 0.2 \times 50 \times \sqrt{3} \times \left[\frac{1}{2} - \frac{1}{4 \times 3}\right] = 0.2 \times 50 \times \sqrt{3} \times \left[\frac{1}{2} - \frac{1}{12}\right] = 7.21 \text{ m/s}$$

12. (b)



$$\text{Deflection of cantilever} = \frac{PL^3}{3EI} = \frac{5 \times 10 \times 3^3}{2 \times 3 \times 200} = \frac{9}{2 \times 4} m = 1.125 \text{ m}$$

$$\text{Total deflection of mass} \quad \Delta = (2.5 + 1.125)/2 = 1.8125 \text{ m}$$

$$\omega_n = \sqrt{\frac{g}{\Delta}} = \sqrt{\frac{10}{1.8125}} = 2.348 \text{ rad/s} \simeq 2.35 \text{ rad/s}$$

13. (c)

$$s + l = 3 + 7 = 10 \text{ cm}$$
$$p + q = 5 + 6 = 11 \text{ cm}$$
$$s + l < p + q$$

Since Grashof's law is satisfied and link adjacent to shortest is fixed hence it is crank rocker mechanism.

14. (d)

Given: $h = 40$ mm, $N = 200$ rpm, $\phi = 120°$

$$\text{Angular velocity, } \omega = \frac{2\pi N}{60} = \frac{2\pi \times 200}{60} = 20.94 \text{ rad/s}$$

$\because$ Maximum velocity during ascent,

$$V_{max} = \left(\frac{\pi h}{2}\right)\left(\frac{\omega}{\phi}\right) = \left(\frac{\pi \times 40 \times 10^{-3}}{2}\right)\left(\frac{20.94 \times 180}{120 \times \pi}\right)$$
$$= 0.628 \text{ m/s} \simeq 0.63 \text{ m/s}$$

15. (b)

Number of links, $n = 3$

Number of joints with single degree of freedom, $j_1 = 2$

Number of joints with double degree of freedom, $j_2 = 1$

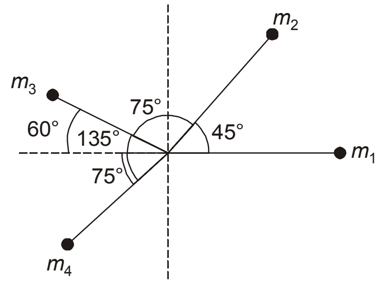
$\therefore$ Number of degrees of freedom of the mechanism, m

$$m = 3(n-1) - 2j_1 - j_2$$
$$= 3(3-1) - 2 \times 2 - 1 = 6 - 4 - 1 = 1$$

16. (a)

Given data

$$m_1 = 200 \text{ kg};\ m_2 = 300 \text{ kg};\ m_3 = 240 \text{ kg and } m_4 = 260 \text{ kg}$$

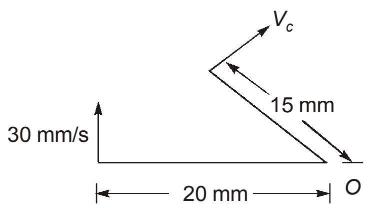


$$\Sigma H = m_1r_1 + m_2r_2\cos 45° - m_3r_3\cos 60° - m_4r_4\cos 75°$$
$$= 200 \times 0.2 + 300 \times 0.15\cos 45° - 240 \times 0.25\cos 60° - 260 \times 0.3\cos 75°$$
$$= 40 + 31.8 - 30 - 20.19$$
$$= 21.61 \text{ kgm}$$
$$\Sigma V = 0 + 300 \times 0.15\sin 45° + 240 \times 0.25 \times \sin 60° - 260 \times 0.3\sin 75° = 8.44 \text{ kgm}$$
$$F = \sqrt{\Sigma V^2 + \Sigma H^2} = 23.1 \text{ kgm}$$

$$\therefore \quad \text{Balancing mass} = \frac{23.2}{0.2}\text{kg} = 116 \text{ kg}$$

17. (c)

Angular velocity of rocker,



$$\omega = \frac{V_B}{OB}$$
$$\omega = \frac{30}{20} = 1.5 \text{ rad/s}$$
$$\text{Velocity of } C = V_c = \omega \cdot OC$$
$$= 1.5 \times 15 = 22.5 \text{ mm/s}$$

18. (c)

$$\text{From geometry, } \frac{d_A}{2} = \frac{d_c}{2} + d_B$$

As the module is the same for gears to mesh with each other, we have,

$$\frac{T_A}{2} = \frac{T_C}{2} + T_B$$
$$\frac{72}{2} - \frac{32}{2} = T_B$$
$$\Rightarrow \quad T_B = 20$$

	Gear *A*	Arm *E*	Gear *B*	Gear *C*
Whole system	x	x	x	x
Arm is fixed & gear *c* rotates by *y*	$x - y\frac{T_C}{T_A}$	O	$x - y\frac{T_C}{T_B}$	$x + y$

$$\text{from question,} \quad x - y\frac{T_C}{T_A} = 0 \qquad \text{(Gear } A \text{ fixed)}$$

$$y = \frac{72}{32}x = \frac{9x}{4}$$

and $$x = 18 \text{ rpm}$$

$\Rightarrow$ $$y = 40.5 \text{ rpm}$$

$\therefore$ $$N_B = x - y\frac{T_C}{T_B} = 18 - 40.5 \times \frac{32}{20} = -46.8 \text{ rpm}$$

Negative indicates direction of B is opposite to that of the arm.

19. (d)

Writing equilibrium equation

$$I\ddot{\theta} + kx\left(\frac{L}{2}\right) = 0$$

$$I\ddot{\theta} + \frac{kL}{2}\left(\theta \times \frac{L}{2}\right) = 0$$

$$I\ddot{\theta} + \frac{kL^2}{4}\theta = 0$$

$$\frac{mL^2}{12}\ddot{\theta} + \frac{kL^2}{4}\theta = 0$$

$$\omega_n = \sqrt{\frac{kL^2}{4} \times \frac{12}{mL^2}} = \sqrt{\frac{3k}{m}} = \sqrt{\frac{3 \times 900}{3}}$$

$$\omega_n = 30 \text{ rad/s}$$

20. (c)

$$\omega = \frac{1000 \text{ rpm} \times 2\pi}{60} = 104.72 \text{ rad/sec}$$

$$\text{Transmissibility ratio} = 0.1$$

$$T_j = 0.1 = \left\{\frac{1 + \left[2\xi\left(\frac{\omega}{\omega_n}\right)\right]^2}{\left[1 - \left(\frac{\omega}{\omega_n}\right)^2\right]^2 + \left(2\xi\frac{\omega}{\omega_n}\right)^2}\right\}^{1/2}$$

Here, $$\xi = 0$$

$\therefore$ $$T_j = \frac{1}{\left|1 - \left(\frac{\omega}{\omega_n}\right)^2\right|} = 0.1$$

$$\left|1 - \left(\frac{\omega}{\omega_n}\right)^2\right| = 10$$

$$1 - \left(\frac{\omega}{\omega_n}\right)^2 = -10$$

or $$1 - \left(\frac{\omega}{\omega_n}\right)^2 = +10 \qquad \text{(Rejected)}$$

$$\left(\frac{\omega}{\omega_n}\right)^2 = 11$$

$$\omega_n = \frac{\omega}{\sqrt{11}} = 31.57 \text{ rad/sec}$$

$$\omega_n = \sqrt{\frac{4k}{m}}$$

$$4k = m\omega_n^2 = 40 \times 31.57^2 = 9959.19 \times 4 \text{ N/m}$$

or $$k = 9969.3 \text{ N/m}$$

21. (b)

$$\phi = 20°$$

$$VR = 3$$

$$\text{Arc of approach} = \text{Circular pitch} = \pi m$$

$$\text{Path of approach} = \pi m \cos 20 = 2.952 m$$

Maximum length of path of approach

$$= r\sin\phi = \frac{mt}{2}\sin\phi = 0.171\,mt$$

$\therefore$ $$0.171\,mt = 2.952\,m$$

$$t = 17.2631 \simeq 18$$

$$T = 3 \times 18 = 54$$

22. (b)

The controlling force curve of a spring controlled governor is a straight line and thus can be expressed as

$$F = ar + b$$

where b will be positive for unstable and negative for stable overnor and zero for isochronous governor

Putting values of F and r, we have

$$1100 = \frac{a \times 0.35}{2} + b$$

$$550 = \frac{0.20 \times a}{2} + b$$

[as balls are 35 cm apart radius = $\frac{35}{2}$ = 17.5 cm]

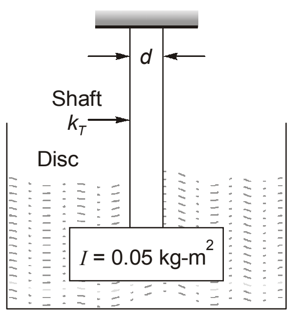
Solving

$$a = 7333.33$$

$$b = -183.33$$

For making it isochronous, the value of b should be zero. This can be done by increasing initial tension to 183.33 N.

23. (d)



Say initial displacement is θ

$\Rightarrow$ $$\delta = \ln\left(\frac{\theta}{\theta/2}\right) = \ln 2 = 0.693$$

also $$\delta = \frac{2\pi\zeta}{\sqrt{1-\zeta^2}}$$, on solving we get

$\Rightarrow$ $$\zeta = 0.109$$

24. (d)

Given $$N = 480 \text{ rpm}$$

$\Rightarrow$ $$\omega = \frac{2\pi N}{60} = 50.26 \text{ rad/s}$$

$$\text{Stroke} = l = 600 \text{ mm} \Rightarrow r = 300 \text{ mm} = 0.3 \text{ m}$$

$$m_{\text{reciprocating}} = m_1 = 100 \text{ kg}$$

$$c = \frac{2}{3}$$

$$\text{Residual unbalanced force} = m_1 r\omega^2\sqrt{(1-c)^2\cos^2\theta + c^2\sin^2\theta}$$

$$= 100 \times 0.3 \times (50.26)^2\sqrt{\left(1-\frac{2}{3}\right)^2\cos^2 60° + \left(\frac{2}{3}\right)^2\sin^2 60°} = 45.54 \text{ kN}$$

25. (a)

Let us assume 'x' as the displacement of the cylinder

$$\text{Restoring force} = \rho(Ax) \times g$$

According to Newton's law

$$m\ddot{x} = -\rho Axg$$

$$m\ddot{x} + \rho Axg = 0$$

$$\omega_n = \sqrt{\frac{\rho Ag}{m}}$$

$$T = \frac{2\pi}{\omega_n} = 2\pi\sqrt{\frac{m}{\rho Ag}} = 2\pi\sqrt{\frac{2}{900 \times \frac{\pi}{4} \times 0.01^2 \times 9.81}}$$

$$T = 10.67 \approx 11 \text{ sec}$$

26. (b)

$$T_{\text{mean}} = \frac{1}{\pi}\int_0^{\pi}(1800 + 300\sin\theta)d\theta = 1800 \text{ N-m}$$

$$\Delta T = (T - T_{\text{mean}})$$

$$\Delta T = (1800 + 300 \sin\theta) - (1800)$$

$$\Delta T = 300 \sin\theta$$

$$\Delta T_{\text{max}} = 300\ (\theta = 90°)$$

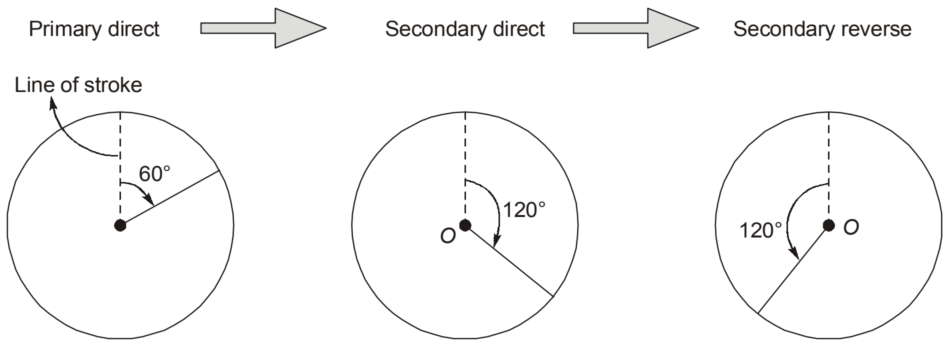
As we know $$\alpha = \frac{\Delta T}{I} = \frac{300}{200} = \frac{3}{2} \text{ rad/sec}^2$$

$$\theta = 90°$$

27. (d)

The shown mechanism has five links, but the function of the mechanism is not affected even if any one of the links PR, US or QT are removed. It is a mechanism with redundant link.

28. (d)


Primary direct
Secondary direct
Secondary reverse
Line of stroke
60°
120°
O
120°
O

■■■■