CLASS TEST

S.No. : 02 SP_ME_D+E_230722

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THEORY OF MACHINES

MECHANICAL ENGINEERING

Date of Test : 23/07/2022

ANSWER KEY

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

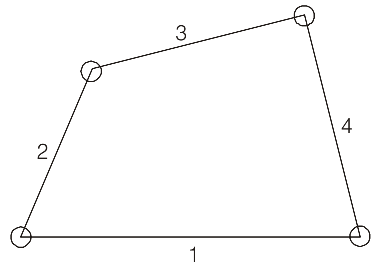
DETAILED EXPLANATIONS

1. (c)

$$n = 4$$
$$j = 3$$
$$h = 1$$
$$\text{DOF} = 3(n-1) - 2j - h$$
$$= 3(4-1) - (2 \times 3) - 1 = 9 - 6 - 1 = 2$$

2. (a)

Here all turning pairs



3. (a)

4. (b)

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

∴ (b) is incompletely constrained.

5. (b)

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

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

6. (a)

Given: $V = 150$ mm/s

$N = 60$ rpm

Coriolis acceleration $= 2\,\omega V$

$$= 2 \times \frac{2\pi \times 60}{60} \times 150 = 600\,\pi \text{ mm/s}^2$$

7. (a)

$$\omega_n = \sqrt{\frac{g}{\Delta}} = \sqrt{\frac{9.81}{0.2 \times 10^{-2}}} = 70 \text{ rad/s}$$

8. (a)

No. of instantaneous centres $= \frac{n(n-1)}{2} = \frac{(n-1)(n-2)}{2}$ (We have to replace n with n–1)

9. (b)

$$\zeta = \frac{c}{2\sqrt{sm}}$$

at critical damping, $\zeta = 1$ and $c = c_c$

$\therefore \quad c_c = 2\sqrt{sm} = 2\sqrt{5\times 20} = 2\sqrt{100} = 20\ \text{Ns/m}$

10. (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 crank rocker.

11. (b)

Given: $m = 400$ kg

$r = 2$ m

Energy stored, $\Delta E = \frac{1}{2} I\left(\omega_2^2 - \omega_1^2\right)$

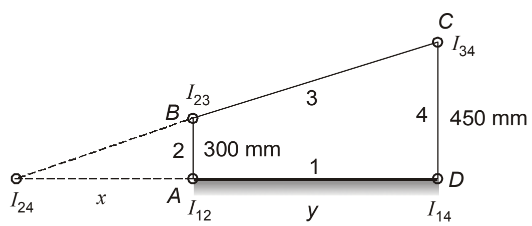
$$= \frac{1}{2}\times 400 \times 2^2 \times \left\{\left(\frac{2\pi\times 460}{60}\right)^2 - \left(\frac{2\pi \times 420}{60}\right)^2\right\}\text{J} \qquad (I = mr^2)$$

$$= \frac{400\times 2}{1000}\times\left(\frac{2\pi}{60}\right)^2\left[460^2 - (420)^2\right]\text{kJ} = 308.81\ \text{kJ}$$

12. (b)

$\therefore \quad \omega_2(I_{12}\,I_{24}) = \omega_4(I_{24}\,I_{14})$

$$\frac{20}{3}(x) = \omega_4(x+y)$$



$\therefore \quad \frac{x}{x+y} = \frac{3\omega_4}{20}$

Also $\quad \frac{300}{x} = \frac{300}{450}$

$\therefore \quad \frac{x}{x+y} = \frac{300}{450}$

$\therefore \quad \frac{3\omega_4}{20} = \frac{300}{450}$

$\therefore \quad \omega_4 = \frac{300}{450}\times\frac{20}{3}$

$V_c = r\omega_4 \qquad (CD = r = 450\ \text{mm})$

$$= \frac{450}{1000}\times\frac{300}{450}\times\frac{20}{3} = 2\ \text{m/s}$$

13. (a)

	Arm	Gear A	Gear B
Arm fixed, gear A rotates by x rev.	0	x	$-\frac{T_A}{T_B}x$
All arrangement rotated by y rev.	y	$x+y$	$y-\frac{T_A}{T_B}x$

$$y = 150 \quad \text{(Anticlockwise} \rightarrow \text{+ve sign)}$$

$$x + y = 0 \quad \text{(Gear } A \text{ is fixed)}$$

$$x = -y$$

$\Rightarrow$ $$x = -150$$

Speed of gear B, $$N_B = y - \frac{36}{45}x = 150 + 150 \times \frac{36}{45}$$

$$= 270 \text{ rpm}$$

14. (d)

Writing equilibrium equation

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

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

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

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

$$\omega_n = \sqrt{\frac{kL^2}{4} \times \frac{12}{mL^2}} = \sqrt{\frac{3k}{m}} = \sqrt{\frac{3 \times 900}{3}} = 30 \text{ rad/s}$$

15. (c)

$$\omega = \frac{1000 \text{ rpm} \times 2\pi}{60} = 104.67 \text{ rad/sec}$$

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

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

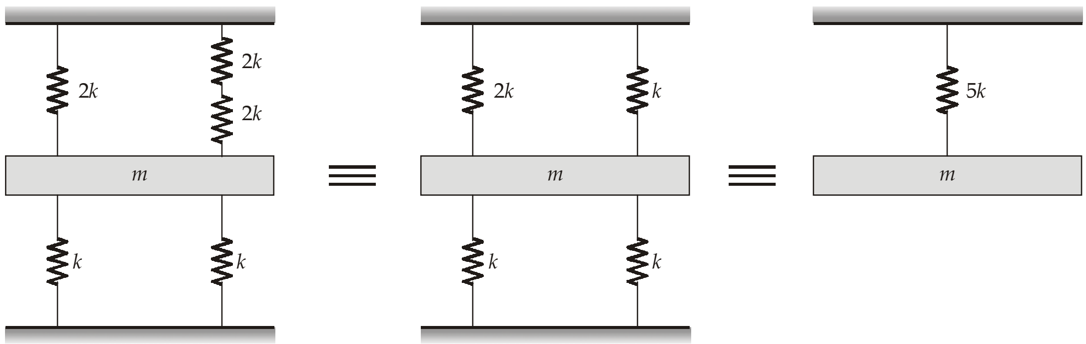
$$\omega_n = \frac{\omega}{\sqrt{11}} = 31.56 \text{ rad/sec}$$

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

$$4\text{k} = m\omega_n^2 = 40 \times 31.56^2 = 9959.19 \times 4 \text{ N/m}$$

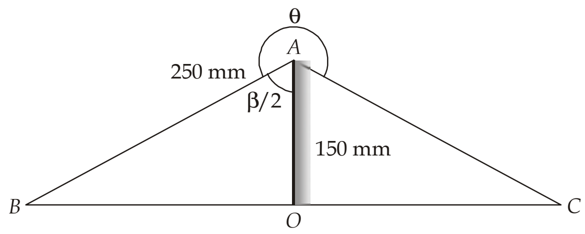
or $$k = 9959.19 \text{ N/m}$$

16. (d)



$$\omega_n = \sqrt{\frac{k_{eq}}{m}} = \sqrt{\frac{5k}{m}}$$

17. (b)



$$\frac{\text{Time of cutting}}{\text{Time of return}} = \frac{\theta}{\beta}$$

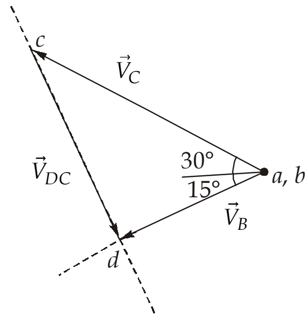
$$\cos\frac{\beta}{2} = \frac{150}{250} \qquad \beta = 106.26°$$

$$\theta = 360° - 106.26°$$
$$\theta = 253.74°$$
$$\text{Ratio} = \frac{253.74}{106.26} = 2.38$$

18. (b)

Drawing velocity diagram,

From geometry, $\angle dca = \angle cad = 45°$

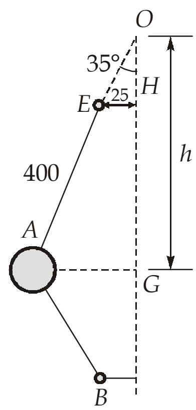


$$|\vec{V}_C| = \omega_2 AC = 4 \times 15 \text{ cm/s}$$
$$= 60 \text{ cm/s} = 0.6 \text{ m/s}$$

Velocity of slider wrt link 4 $= |\vec{V}_{CD}| = |\vec{V}_{DC}| = |\vec{V}_C| \sin 45°$

$$= \frac{0.6}{\sqrt{2}} = 0.424 \text{ m/s}$$

19. (c)



$$h = GO = GH + HO = AE\cos\theta + EH\cot\theta$$
$$h = 400\cos 35° + 25\cot 35° = 363.4 \text{ mm}$$
$$h' = 400\cos 30° + 25\cot 30° = 389.7 \text{ mm}$$

Now, $h = \frac{g}{\omega^2}$ and $h' = \frac{g}{\omega'^2}$

$$\frac{\omega'}{\omega} = \sqrt{\frac{h}{h'}} = \sqrt{\frac{363.4}{389.7}} = 0.966$$

Decrease in speed $= (1 - 0.966) \times 100 = 3.44\%$

20. (a)

As per given data, $I = 1.5$ kg-m^2

The angular velocity of spin of the disc,

$$\omega = \frac{2\pi \times 500}{60} = \frac{100\pi}{6} \text{ rad/s}$$

The angular velocity of precession ,

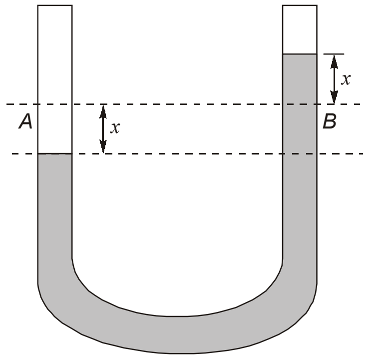
$$\omega_p = \frac{2\pi}{5} \text{ rad/s}$$

Gyroscopic couple, $T = I\omega\omega_p$

$$= 1.5 \times \frac{100\pi}{6} \times \frac{2\pi}{5} = 10\pi^2 = \frac{20\pi^2}{2} \text{ kg-m}^2/\text{s}^2$$

21. (c)

Let the liquid is displaced by x and the cross-section area of tube be A.



The column of liquid of length $2x$ on the right side exerts a restoring force on the remaining liquid.

Total mass of liquid, $m = AL\rho$

So, $m\ddot{x} = -2xA\rho g$

$\Rightarrow \quad \rho AL\ddot{x} + 2xA\rho g = 0$

$\Rightarrow \quad \ddot{x} + \frac{2g}{L}x = 0$

$\therefore \quad \omega = \sqrt{\frac{2g}{L}}$

22. (d)

23. (c)

Given: $C = 40$ N/m/s, $C_c = 420$ N/m/s

So, $\xi = \frac{C}{C_c} = \frac{40}{420} = 0.095$

Now, logarithmic decrement (δ)

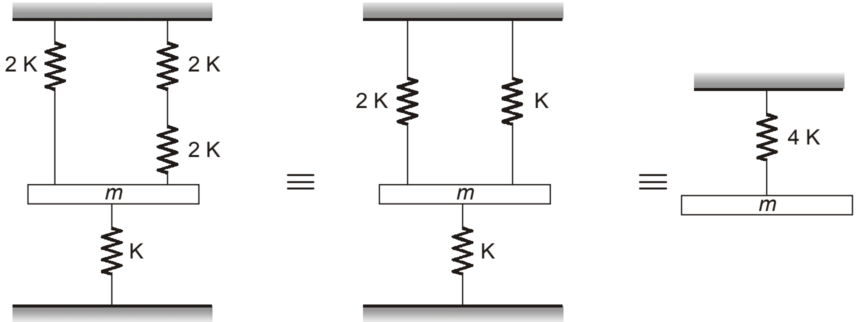
$$\delta = \frac{2\pi\xi}{\sqrt{1-\xi^2}} = \frac{2\pi \times 0.095}{\sqrt{1-0.095^2}} = 0.6$$

24. (c)

Disturbing force, $F = (1 - c)\, mr\omega^2\cos\theta$

$= (1 - 0.4) \times 6 \times 0.10 \times 15^2 \times \cos 60 = 40.5$ N

25. (b)



$$\omega_n = \sqrt{\frac{K_{eq.}}{m}} = \sqrt{\frac{4K}{m}} = 2\sqrt{\frac{K}{m}}$$

26. (b)

Absolute acceleration of B will be vector addition of centripetal acceleration, tangential acceleration due to rotation of link OA and Coriolis acceleration due to sliding motion of block B.

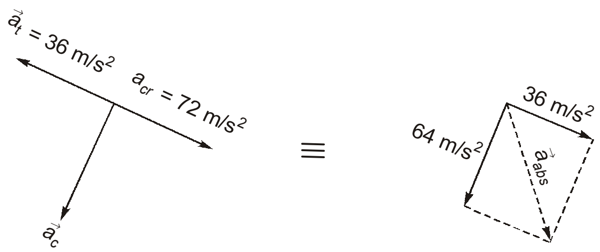
$$\vec{a}_c = \omega^2 r \text{ (towards centre)}$$
$$= 4^2 \times 4 = 64 \text{ m/s}^2$$
$$\vec{a}_t = r\alpha \text{ (tangential in direction of } \alpha)$$
$$= 4 \times 9 = 36 \text{ m/s}^2$$

Coriolis acceleration, $\vec{a}_{cr} = 2\, V_{\text{sliding}}\, \omega$

$$= 2 \times 9 \times 4 = 72 \text{ m/s}^2$$

Direction of Coriolis acceleration → Rotating direction of sliding velocity which is inwards through 90° in the direction of the angular velocity which is counter clockwise.

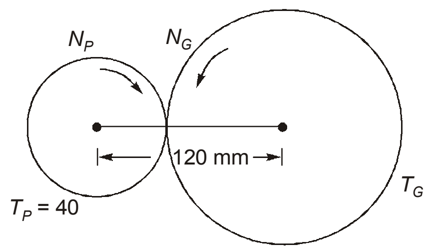
Therefore direction of Coriolis acceleration is opposite and collinear to the tangential acceleration.



$$\left|\vec{a}_{abs}\right| = \sqrt{64^2 + 36^2} = 73.43 \text{ m/s}^2$$

27. (c)

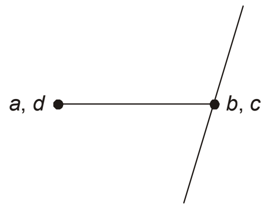
$$T_P = 40$$
$$m = 2 \text{ mm}$$
$$N_P = 800 \text{ rpm}$$
$$D_P = 80 \text{ mm}$$
$$r_P = 40 \text{ mm}$$
$$r_P + r_G = 120 \text{ mm}$$
$$r_G = 80 \text{ mm}$$



$$\Rightarrow \quad \frac{r_G}{r_P} = \frac{T_G}{T_P}$$
$$T_G = \frac{80}{40} \times 40 = 80$$
$$\Rightarrow \quad \frac{N_G}{N_P} = \frac{T_P}{T_G}$$
$$\Rightarrow \quad N_G = \frac{40}{80} \times 800 = 400 \text{ rpm}$$

28. **(b)**

29. **(d)**



Velocity diagram for this configuration of mechanism

from velocity diagram

$$V_b = V_c = (AB)W_2 = 0.2 \times 20 = 4 \text{ m/s}$$

30. **(b)**

For the Hartnell governor
spring stiffness is given by

$$k = 2\left(\frac{a}{b}\right)^2 \left(\frac{F_1 - F_2}{r_1 - r_2}\right)$$

$$k = 2\left(\frac{a}{b}\right)^2 \left(\frac{1500 - 100}{20 - 15}\right)$$

$$k = 2\left(\frac{1400}{5}\right) = 560 \text{ N/cm} \quad (\because \text{ a and b are same})$$

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