CLASS TEST

S.No. : 01SKME_JKLMNOP_25925

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THEORY OF MACHINES

MECHANICAL ENGINEERING

Date of Test : 25/09/2025

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (b)

$$\text{Mass, } m = 10 \text{ kg}$$
$$\text{Damping coefficient, } c = 100 \text{ kg/s}$$
$$\text{Spring constant, } k_1 = 4000 \text{ N/m}$$
$$k_2 = 200 \text{ N/m}$$
$$k_3 = 1000 \text{ N/m}$$

$$\text{Equivalent spring constant, } k_e = k_1 + \frac{k_2 k_3}{k_2 + k_3} = 4000 + \frac{200 \times 1000}{1200} = 4166.67 \text{ N/m}$$

$$\omega_n = \sqrt{\frac{k_e}{m}} = \sqrt{\frac{4166.67}{10}} = 20.412 \text{ rad/s}$$

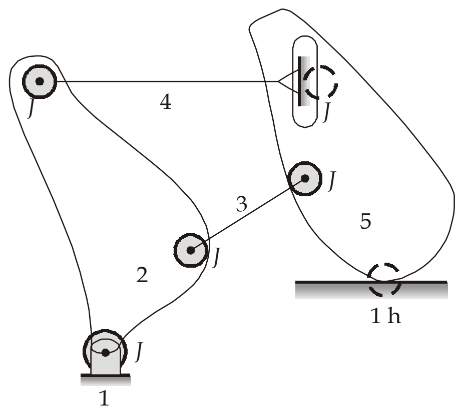
$$\text{Damping factor, } \xi = \frac{c}{2m\omega_n} = \frac{100}{2 \times 10 \times 20.412} = 0.245$$

$\xi < 1$, so our vibration system is underdamped.

2. (c)

As per given information

$$\text{Number of links, } L = 5$$
$$\text{Number of lower pair, } J = 5$$
$$\text{Number of higher pair, } h = 1$$
$$\text{Degree of freedom} = 3(L - 1) - 2J - h$$
$$= 3(5 - 1) - 2 \times 5 - 1$$
$$= 12 - 10 - 1 = 1$$



3. (d)

$$\omega_{AB} = 1 \text{ rad/s}, L_{CD} = 1.8\, L_{AB}$$

$$\frac{L_{CD}}{L_{AB}} = 1.8$$

$$V_C = V_C \text{ (Link BC in pure translation)}$$

$$\omega_{AB} L_{AB} = \omega_{CD} L_{CD}$$

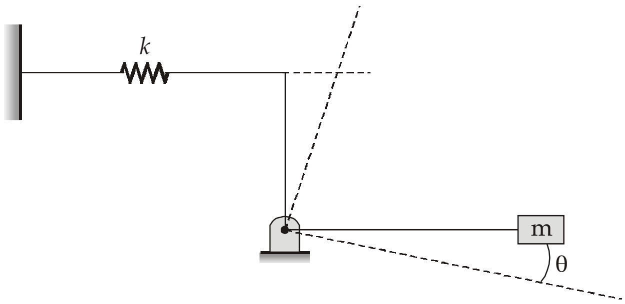
$$\frac{\omega_{AB}}{\omega_{CD}} = \frac{L_{CD}}{L_{AB}}$$

$$\omega_{CD} = \omega_{AB} \times \frac{L_{AB}}{L_{CD}} = 1 \times \frac{1}{1.8} = 0.555 \text{ rad/s}$$

4. (a)

Restoring torque $ka^2(\theta)$

From D - alenbert's principle,



$$I\ddot{\theta} + ka^2\theta = 0$$

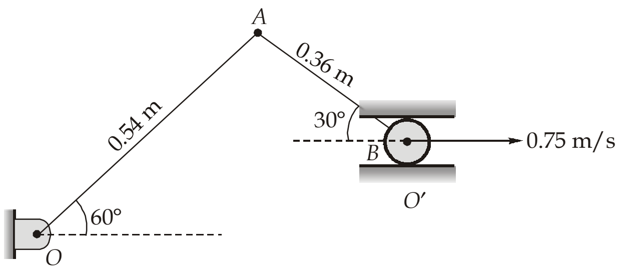
$$mb^2\ddot{\theta} + ka^2\theta = 0$$

$$\ddot{\theta} + \left(\frac{ka^2}{mb^2}\right)\theta = 0$$

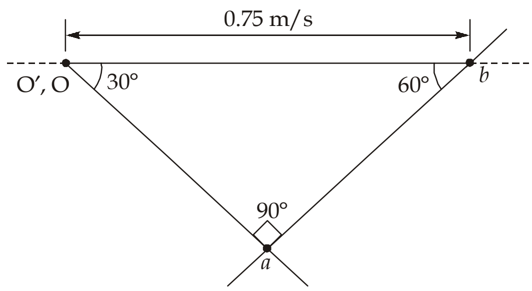
$$\omega_n = \frac{a}{b}\sqrt{\frac{k}{m}}$$

5. (b)

From given information



By applying velocity polygon analysis,



From ΔOab $\quad V_{ba} = ob\sin 30°$

$$V_{BA} = 0.75\sin 30° \text{ m/s}$$

$$= 0.375 \text{ m/s}$$

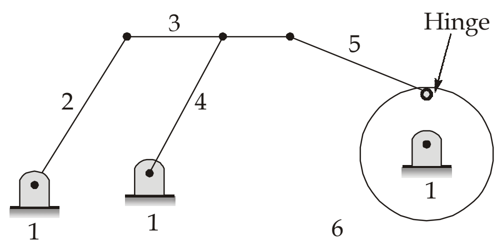
$$\omega_{AB} = \frac{V_{BA}}{AB} = \frac{0.375 \text{ m/s}}{0.36 \text{ m}} = 1.0416 \text{ rad/s}$$

6. (b)

Number of links, $n = 6$

Number of lower pair, $j = 7$

Number of higher pair, $h = 0$



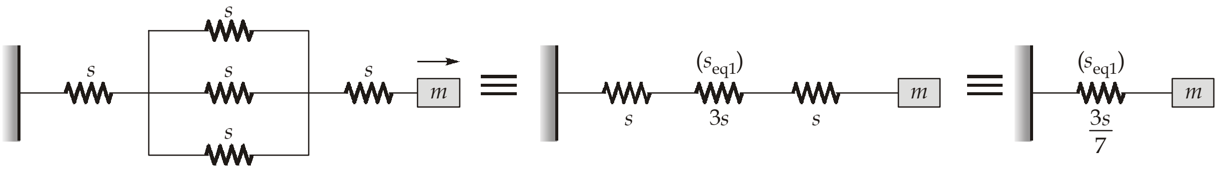
Degree of freedom, $F = 3(n-1) - 2j - h$

$$= 3(6-1) - 2 \times 7 - 0$$

$$= 15 - 14 = 1$$

7. **(a)**

For parallel, $s_{eq} = s_1 + s_2 + s_3$ and for series $\frac{1}{s_{eq}} = \frac{1}{s_1} + \frac{1}{s_2} + \frac{1}{s_3}$



$$s_{eq1} = s + s + s = 3s$$

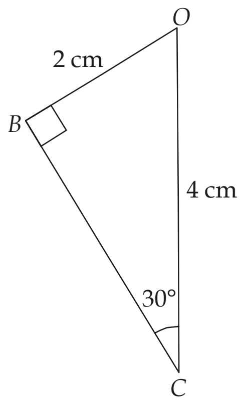
$$\frac{1}{s_{eq2}} = \frac{1}{s} + \frac{1}{3s} + \frac{1}{s} = \frac{1}{s}\left[2 + \frac{1}{3}\right] = \frac{1}{s} \times \frac{7}{3}$$

$$s_{eq2} = \frac{3s}{7}$$

Natural frequency, $\omega_n = \sqrt{\frac{s_{eq2}}{m}} = \sqrt{\frac{3s}{7m}} = \sqrt{\frac{3 \times 7}{7 \times 3}} = 1$ [Given: $\frac{s}{m} = \frac{7}{3}$]

8. **(a)**

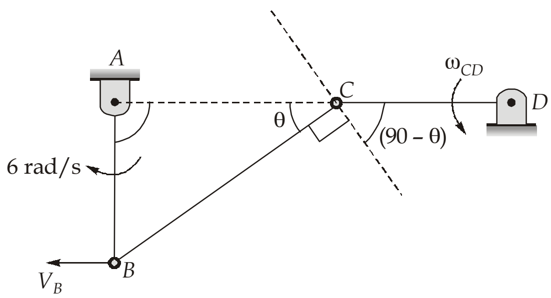
Drawing configuration at θ = 30°



At this position ∠OBC will be 90°, velocity of B perpendicular to CD will be zero hence $\omega_{CD} = 0$. So, Coriolis acceleration will be zero.

9. **(c)**

AB = 100 mm = 0.1 m, BC = 220 mm = 0.220 m, CD = 150 mm = 0.150 m

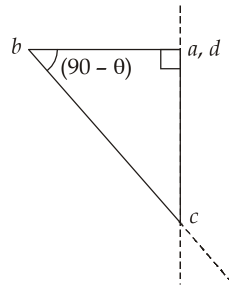


$$\sin\theta = \frac{AB}{BC} = \frac{100}{220}$$

$$\theta = \sin^{-1}(0.4545) = 27.035°$$

$$V_B = (AB) \times \omega_{AB} = 0.1 \times 6 = 0.6 \text{ m/s}$$

Making velocity triangle for above configuration.



$$\tan(90-\theta) = \frac{dc}{ab}$$

$$dc = \tan(90-27.035)° \times 0.6$$

$$= \tan(67.96)° \times 0.6 = 1.175$$

$$\therefore \quad V_C = 1.175 \text{ m/s}$$

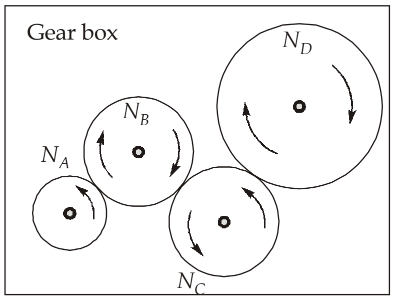
$$= \omega_{CD} \times (CD)$$

$$\omega_{CD} = \frac{1.175}{0.150} = 7.83 \text{ rad/s}$$

10. (c)

$$\frac{T_{input}}{T_{output}} = \frac{\omega_{output}}{\omega_{input}}$$

$$T_{output} = T_A \times \frac{N_A}{N_D} = \frac{80 \times 100}{20} = 400 \text{ Nm}$$



Assuming, CCW = +ve

T_A = +80 N-m

T_D = –400 N-m

Now, $\Sigma T = 0$

$$T_A + T_D + T_{GB} = 0$$

$$80 - 400 + T_{GB} = 0$$

$$T_{GB} = 320 \text{ Nm}$$

11. (d)

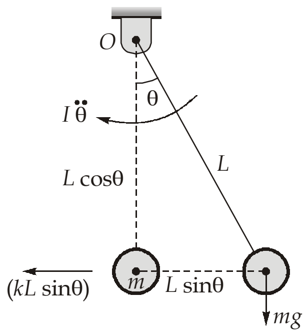
As per given configuration,

There are two forces acting on the system.

By taking the moments about point 'O',

$\Sigma M_o = 0$

$$I\ddot{\theta} + mg(L\sin\theta) + kL\sin\theta \times L\cos\theta = 0$$



For small θ, $\sin\theta = \theta; \cos\theta = 1$

$$I\ddot{\theta} + mg(L\theta) + kL^2\theta = 0$$

$$\ddot{\theta} + \frac{mgL + kL^2}{mL^2}\theta = 0 \quad \text{... (i)}$$

$$\ddot{\theta} + \omega_n^2\theta = 0 \quad \text{... (ii)}$$ By comparing

Equation (i) and (ii)

$$\text{Natural frequency, } \omega_n = \sqrt{\frac{(mgL + kL^2)}{mL^2}}$$

12. (a)

As per given data,

Teeth of right hand helical pinion, t_p = 36 teeth

Helix angle of pinion, $\psi_P = 20°$

Teeth of right hand helical gear, $T_G = 48$ teeth

Helix angle of gear, $\psi_G = ?$

As per given, both gear are of same hand,

$$\psi_P + \psi_G = 45°$$
$$\psi_G = 45° - \psi_P$$
$$= 45° - 20° = 25°$$

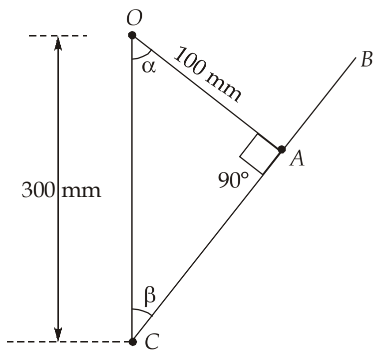
As we know, $(m_n)_G = m \cos \psi_G$

Module in the normal plane,

$$m = \frac{(m_n)_G}{\cos\psi_G} = \frac{2.5}{\cos 25°} = 2.758 \text{ mm}$$

13. (d)

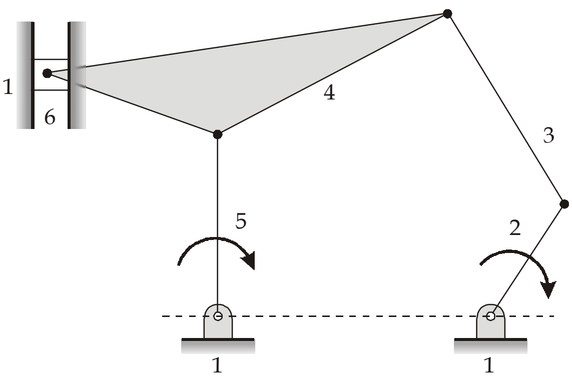
As per configuration,



$$\cos\alpha = \frac{OA}{OC} = \frac{100}{300}$$
$$\alpha = 70.528°$$

$$\text{Quick return ratio} = \frac{\text{Angle turned by crank during forward stroke}}{\text{Angle turned by crank during return stroke}}$$
$$= \frac{360° - 2\alpha}{2\alpha} = \frac{360° - 2\times 70.528°}{2\times 70.528°} = 1.55$$

14. (a)



Given:

$l = 6, j = 7, h = 0$

$$\text{DOF} = 3(l-1) - 2j - h - Fr$$
$$= 3(6-1) - 2 \times 7 - 0 - 0 = 15 - 14$$
$$\text{DOF} = 1$$

15. **(b)**

As per given information

$$\text{Arc of contact} = \frac{\text{Path of contact}}{\cos\phi}$$

$$\text{Path of contact} = \text{Arc of contact} \times \cos\phi$$

$$2\left(\sqrt{(R_a)^2 - (R\cos\phi)^2} - R\sin\phi\right) = 2 \times 2.54 \times \cos 20° \quad \text{... (i)}$$

$$\text{Circular pitch} = 2.54 = \frac{\pi \times D}{T} = \frac{\pi \times 2R}{30}$$

$$R = 12.127 \text{ cm}$$

From equation (i)

$$(R_a)^2 - (12.127 \cos 20°)^2 = (2.54 \cos 20° + 12.127 \sin 20°)^2$$
$$R_a^2 = (12.127 \cos 20°)^2 + 42.702$$
$$R + \text{Addendum} = 13.136 \text{ cm}$$
$$\text{Addendum} = (13.136 - 12.127) \text{ cm}$$
$$= 1.009 \text{ cm}$$

16. **(b)**

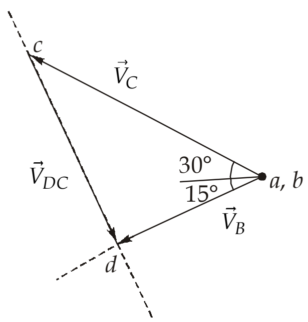
Drawing velocity diagram,

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 = $|\vec{V}_{CD}| = |\vec{V}_{DC}| = |\vec{V}_C| \sin 45°$

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



17. **(a)**

Using Energy Method:

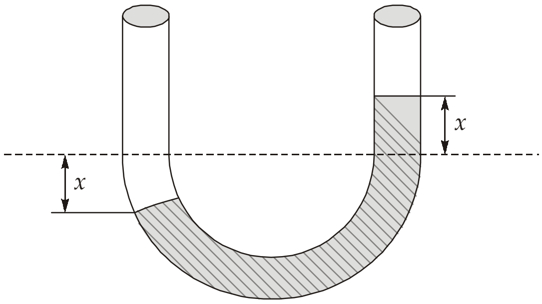
The liquid column is displaced from equilibrium position by a distance x. if ρ and A are the density of liquid and cross-section area respectively, then the mass of the liquid column is $\rho A l$,

$$\text{KE} = \frac{1}{2}m\dot{x}^2 = \frac{1}{2}(\rho A l)\dot{x}^2$$

$$\text{PE} = mgx = \rho A x g x = \rho A g x^2$$

Total energy of system is constant,

$$\frac{1}{2}\rho A l \dot{x}^2 + \rho A g x^2 = C$$



Differenciating w.r.t. time,

$$\rho A l x \ddot{x} + 2\rho A g x \dot{x} = 0$$

$$l\ddot{x} + 2gx = 0$$

So,

$$\omega_n = \sqrt{\frac{2g}{l}} \text{ rad/ s}$$

$$f_n = \frac{1}{2\pi}\sqrt{\frac{2 \times 10}{0.16}} = 1.779 \text{ Hz}$$

18. (c)

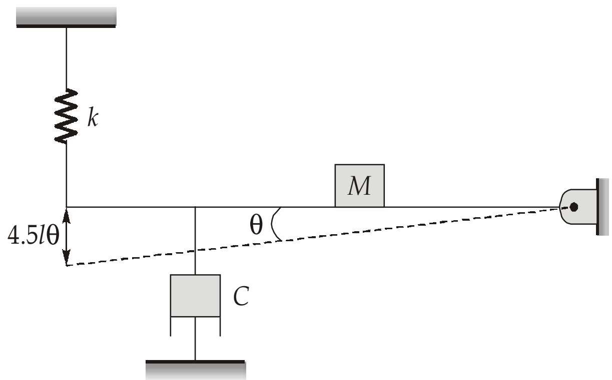
$$\psi = \text{Helix angle}$$
$$\lambda = \text{Lead angle}$$
$$\lambda + \psi = 90°$$
$$\text{Lead angle, } \lambda = 20°$$

$$\text{Gear ratio} = \frac{T_G}{T_W} = \frac{15}{1} = \frac{\text{Number of teeth on worm gear}}{\text{Number of start thread on worm}}$$

$$T_W = \text{Triple start thread worm} = 3$$
$$T_G = 15 \times T_W = 15 \times 3 = 45$$

19. (a)

For very small deflection



$$\text{Spring torque} = k(4.5l)^2\theta = 20.25\, k\theta l^2$$

$$\text{dashpot torque} = c(3.5l)^2\dot{\theta} = 12.25\, c\dot{\theta} l^2$$

$$\text{Inertia torque} = m(2l)^2\ddot{\theta} = 4m\ddot{\theta} l^2$$

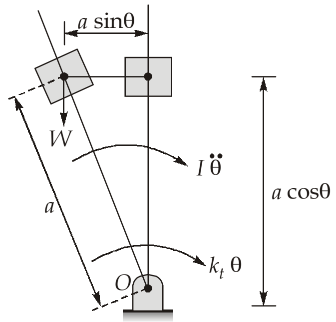
from De Alembert's principle,

$$4m\ddot{\theta}l^2 + 12.25c\dot{\theta}l^2 + 20.25k\theta l^2 = 0$$

$$m\ddot{\theta} + 3.0625c\dot{\theta} + 5.0625k\theta = 0$$

20. (b)

From the torque equation about 'O'



$$I\ddot{\theta} + k_t\theta - W \cdot a\sin\theta = 0$$

For small displacement

$$I\ddot{\theta} + k_t\theta - W \cdot a\theta = 0$$

$$\frac{W}{g}a^2\ddot{\theta} + (k_t - W \cdot a)\theta = 0$$

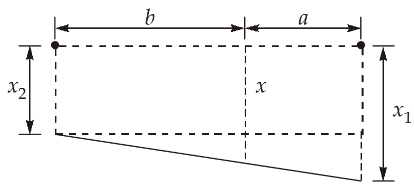
$$\ddot{\theta} + \frac{(k_t - W \cdot a)\theta}{\frac{W}{g}a^2} = 0$$

$$\omega_n = \sqrt{\frac{g}{a^2 \cdot W}(k_t - W \cdot a)} = \sqrt{\frac{g}{a}\left[\frac{k_t}{W \cdot a} - 1\right]}$$

21. (a)

As per given configuration,

After application of force, spring '2' deflect 'x_2' and spring '1' deflect 'x_1'.



From similar triangle property,

$$x = \frac{bx_1}{(a+b)} + \frac{ax_2}{(a+b)} \quad \text{... (i)}$$

If F_1 is the force acting on spring '1' and F_2 is the force acting on spring '2',

$$F = F_1 + F_2$$

$$F_2 \times b = F_1 \times a$$

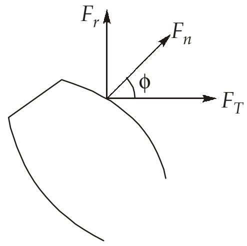
$$F_1 = \frac{bF}{a+b} \Rightarrow x_1 = \frac{F_1}{k_1} = \frac{bF}{k_1(a+b)} \quad \text{... (ii)}$$

$$F_2 = \frac{aF}{a+b} \Rightarrow x_2 = \frac{F_2}{k_2} = \frac{aF}{k_2(a+b)} \quad \text{... (iii)}$$

From (i), (ii) and (iii) $\quad x = \frac{F}{(a+b)^2}\left[\frac{k_2b^2 + k_1a^2}{k_1k_2}\right]$

$$\Rightarrow \quad k_e = \frac{F}{x} = \frac{k_1k_2(a+b)^2}{k_2b^2 + k_1a^2}$$

22. (c)



As per given information

$$F_r = \frac{1}{3}F_n$$

As we know, $\quad F_r = F_n \sin\phi$

$$\sin\phi = \frac{1}{3}$$

$$\phi = \sin^{-1}\left(\frac{1}{3}\right) = 19.47°$$

$$A \times m = 0.8m$$

$$A = 0.8$$

When pinion gears with rack, $A_R = 0.8$

$$t_{\min} = \frac{2A_R}{\sin^2\phi} = \frac{2 \times 0.8}{(\sin 19.47°)^2}$$

$$t_{\min} = 14.40 \approx 15$$

23. (a)

As per given information,

Longitudinal vibration,

$$\delta_{\text{static}} = \frac{MgL}{AE} = \frac{300 \times 9.81 \times 0.9}{\frac{\pi}{4}(0.1)^2 \times 200 \times 10^9} = 1.686 \times 10^{-6} \text{ m}$$

$$\omega_n = \sqrt{\frac{g}{\delta_{\text{static}}}} = \sqrt{\frac{9.81}{1.686 \times 10^{-6}}} = 2412.004 \text{ rad/s}$$

For transverse vibration,

$$\delta_{\text{static}} = \frac{WL^3}{3EI} = \frac{300 \times 9.81 \times 0.9^3}{3 \times 200 \times 10^9 \times \frac{\pi}{64}(0.1)^4}$$

$$= 7.28 \times 10^{-4} \text{ m}$$

$$\omega_n = \sqrt{\frac{g}{\delta_{\text{static}}}} = \sqrt{\frac{9.81}{7.28 \times 10^{-4}}} = 116.047 \text{ rad/s}$$

Therefore, $(\text{Freqency})_{\text{longitudinal}} > (\text{Freqency})_{\text{transverse}}$ is correct.

24. (a)

Given data:

Mass of vehicle, m = 300 kg

Velocity of vehicle, V = 108 km/hr

$$= \frac{108 \times 1000}{3600} \text{ m/s} = 30 \text{ m/s}$$

Wavelength, λ = 6.9 m

Time taken to cover one wavelength distance, $t = \dfrac{\lambda}{V}$

$$t = \frac{6.9}{30} = 0.23 s$$

Frequency for one revolution, $\omega = \dfrac{2\pi}{t} = \dfrac{2\pi}{0.23} = 27.318 \text{ rad/s}$

We know that,

Natural frequency for spring mass sytem, $\omega_n = \sqrt{\dfrac{k}{m}}$.

For resonance to occur, $\omega = \omega_n$

$$27.318 = \sqrt{\frac{k}{m}}$$

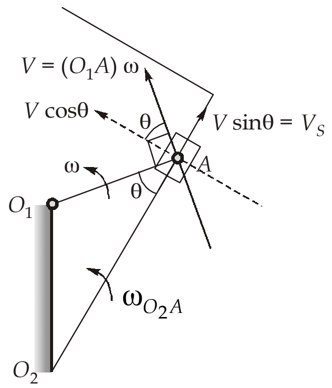
$$(27.318)^2 = \frac{k}{300}$$

$$k = 223885.166 \text{ N/m}$$

$$= 0.224 \text{ MN/m}$$

25. **(b)**

Given: $\omega = 1.85$ rad/s^2, $O_1O_2 = 500$ mm, $O_1A = 400$ mm, $O_2A = 800$ mm



By cosine rule,

$$\cos\theta = \frac{O_1A^2 + O_2A^2 - O_1O_2^2}{2O_1A \times O_2A} = \frac{400^2 + 800^2 - 500^2}{2 \times 400 \times 800} = 0.86$$

$$\theta = \cos^{-1}(0.86) = 30.75°,$$

$$\theta = 30.75°$$

Velocity, $V = (O_1A)\omega = 0.400 \times 1.85 = 0.74$ m/s

Coriolic acceleration, $a_c = 2V_s\,\omega_{O_2A}$

where, V_s = Velocity of slider along link $O_2A = V\sin\theta$

ω_{O_2A} = Angular velocity of link $O_2A = \dfrac{V\cos\theta}{O_2A}$

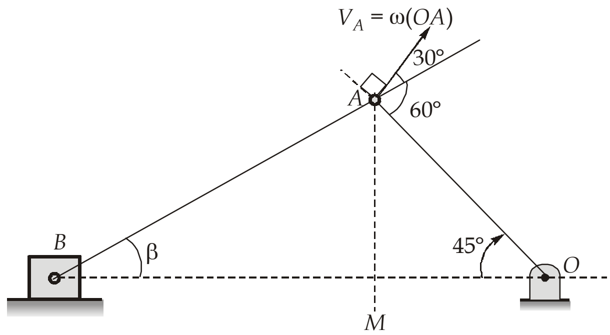
$$\therefore \quad a_c = 2V_s\,\omega_{O_2A} = 2 \times V\sin\theta \times \frac{V\cos\theta}{O_2A}$$

$$= \frac{V^2(2\sin\theta\cos\theta)}{O_2A} = \frac{V^2\sin 2\theta}{O_2A}$$

$$= \frac{0.74^2\sin(2\times 30.75)}{0.800} = 0.60155\ \text{m/s}^2$$

$\therefore \quad a_c = 601.55\ \text{mm/s}^2$

26. (d)



Given: $N = 60$ rpm, $OA = 8\sqrt{2}$ cm, $AB = 30.9$ cm

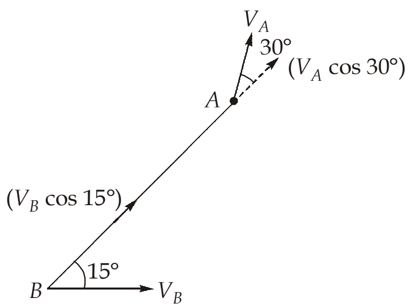
$$\omega = \frac{2\pi N}{60} = \frac{2\times\pi\times 60}{60} = 2\pi\ \text{rad/s}$$

Now, $AM = OA\sin 45° = AB\sin\beta$

$$\frac{8\sqrt{2}\sin 45°}{30.9} = \sin\beta$$

$$\beta = 15°$$

Treating connecting rod as rigid link. So, there should not be any relative velocity along the link.



$\therefore \quad V_B\cos 15° = V_A\cos 30°$

$$V_B = \frac{\omega(OA)\cos 30°}{\cos 15°} = \frac{2\pi\times 8\sqrt{2}\times\cos 30°}{\cos 15°}$$

$$V_B = 63.734\ \text{cm/s}$$

Alternate Method :

$$V_{slider} = \omega r\left(\sin\theta + \frac{\sin 2\theta}{2n}\right)$$

$$n = \frac{l}{r} = \frac{30.9}{8\sqrt{2}} = 2.73$$

$$V_{slider} = 2\pi \times 8\sqrt{2}\left(\sin 45° + \frac{\sin(2\times 45)°}{2\times 2.731}\right) = 63.28 \text{ cm/s}$$

27. (d)

Given r = 60 mm, Module, m = 5 mm

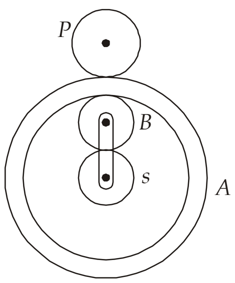
$$\text{Fractional addendum} = 0.8 \text{ module,}$$
$$\text{Addendum} = 0.8 \times 5 = 4 \text{ mm}$$
$$r_a = r + a = 60 + 4 = 64 \text{ mm}$$
$$a_r = 4 \text{ mm and } \phi = 20°$$

Path of contact for rack and pinion arrangement = $\left[\frac{a_r}{\sin\phi} + \sqrt{r_a^2 - r^2\cos^2\phi} - r\sin\phi\right]$

$$\text{Path of contact} = \frac{4}{\sin 20°} + \sqrt{64^2 - 60^2\cos^2 20°} - 60\sin 20°$$
$$= 21.458 \text{ mm}$$
$$\text{Arc of contact} = \frac{\text{Path of contact}}{\cos\phi} = \frac{21.458}{\cos 20°} = 22.835 \text{ mm}$$
$$\text{Contact ratio} = \frac{\text{Arc of contact}}{\text{Circular pitch}(P_c)} = \frac{22.835}{\pi m} \qquad \left[P_c = \frac{\pi D}{t} = \pi m\right]$$
$$= \frac{22.835}{\pi \times 5} = 1.453$$
$$\text{Contact ratio} = 1.45$$

28. (c)

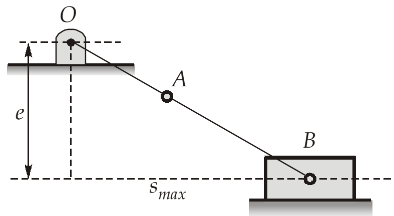
Given: $T_S = \frac{T_A}{4}$, N_S = 400 rpm, N_P = 600 rpm, N_a = –40 rpm



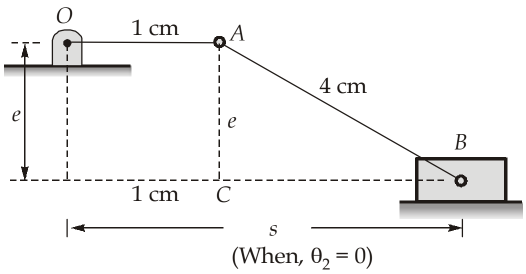
Action	arm 'a'	S	B	A	P
arm 'a' fixed + 1 rev to S	0	+1	$-\frac{T_S}{T_B}$	$-\frac{T_S}{T_B}\times\frac{T_B}{(T_{int})_A}$	$+\frac{T_S}{T_B}\times\frac{T_B}{(T_{int})_A}\times\frac{(T_{ext})_A}{T_P}$
arm 'a' fixed + x rev to S	0	x	$-\frac{T_S}{T_B}x$	$-\frac{T_S}{(T_{int})_A}x$	$+\frac{T_S}{T_P}\times\frac{(T_{ext})_A}{(T_{int})_A}x$
All given y rev	y	$y+x$	$y-\frac{T_S}{T_B}x$	$y-\frac{T_S}{(T_{int})_A}x$	$y+\frac{T_S}{T_P}\times\frac{(T_{ext})_A}{(T_{int})_A}x$

$$N_S = y + x = 400 \text{ rpm},$$
$$N_a = y = -40 \text{ rpm}$$
then, $$x = 440 \text{ rpm}$$
$$N_P = y + \frac{T_S}{T_P} \times x = 600 \text{ rpm} \qquad [(T_{ext})_A = (T_{int})_A]$$
$$-40 + \frac{T_S}{T_P} \times 440 = 600$$
$$\frac{T_S}{T_P} = \frac{640}{440} = 1.45$$

29. (a)



$$e^2 + s^2_{max} = OB^2$$
$$OB = \sqrt{3^2 + 4^2} = 5 \text{ cm}$$
$$OB = OA + AB = 5 \text{ cm}$$
∴ $$AB = 4 \text{ cm (Given } OA = 1 \text{ cm)}$$
For, $$\theta_2 = 0$$
$$AC^2 + BC^2 = AB^2$$
$$BC = \sqrt{4^2 - 3^2} = \sqrt{7}$$
$$(s)_{\theta_2=0} = 1 + \sqrt{7} = 3.64 \text{ cm}$$



30. (c)

For the given gear train speed ratio can be written as.

$$\text{Speed ratio} = \frac{\left(\begin{array}{c}\text{Product of the number of}\\ \text{teeth on driven}\end{array}\right)}{\left(\begin{array}{c}\text{Product of the number of}\\ \text{teeth on driver}\end{array}\right)}$$
$$\frac{\omega_2}{\omega_8} = \frac{T_3 \times T_5 \times T_6 \times T_8}{T_2 \times T_4 \times T_5 \times T_7}$$
$$S.R = \frac{T_3 \times T_6 \times T_8}{T_2 \times T_4 \times T_7}$$

Therefore, speed ratio is independent from gear, 5.
So idler gear is gear 5.

■■■■