S.No. : 06 GH_ME_F_190919

Theory of Machine

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CLASS TEST 2019-2020

MECHANICAL ENGINEERING

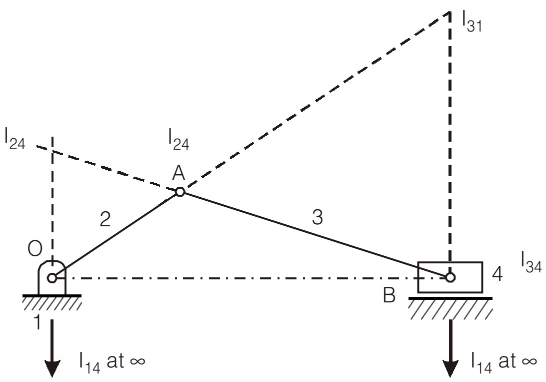
Date of Test : 19/09/2019

ANSWER KEY ➤ Theory of Machine

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

Detailed Explanations

2. (a)



5. (c)

$$\frac{\frac{2h\omega}{\psi}}{\frac{\pi h\omega}{2\psi}} = \frac{4}{\pi}$$

7. (c)

Number of links = 6

$\therefore$No. of instantaneous centre $= {}^6C_2 = \dfrac{6\times5}{2\times1} = 15$

9. (c)

A and C are correct statements.

10. (d)

$$T_{min} = \frac{2a_g}{\sqrt{1+\frac{1}{G}\left(\frac{1}{G}+2\right)\sin^2\varphi}-1}$$

$$= \frac{2\times1}{\sqrt{1+\frac{1}{1.125}\left(\frac{1}{1.125}+2\right)\sin^2 14.5^\circ}-1}$$

$$= 25.8 \approx 26$$

$\therefore$ $$G = \frac{T_{min}}{t_{min}}$$

$\Rightarrow$ $$t_{min} = 23.11 \approx 24$$

$$\frac{N_g}{N_p} = \frac{16}{18} = 0.888 \quad \text{...(i)}$$

$$\frac{N_{g_1}}{N_{p_1}} = \frac{24}{26} = 0.923$$

$$\frac{N_{g_2}}{N_{p_2}} = \frac{24}{27} = 0.888 \quad \text{...(iii)}$$

12. (d)

$$\omega = \frac{2\pi \times 240}{60} = 25.13 \text{ rad/s}$$

$$a_{\text{uniform (during ascent)}} = \frac{4h\omega^2}{\psi_a^2} = \frac{4 \times 30 \times (25.13)^2}{\left(70 \times \frac{\pi}{180}\right)^2}$$

$$= 50{,}771 \text{ mm/s}^2 = 50.77 \text{ m/s}^2$$

$$a_{\text{uniform (during decent)}} = \frac{4h\omega^2}{\psi_d^2} = \frac{4 \times 30 \times (25.13)^2}{\left(80 \times \frac{\pi}{180}\right)^2}$$

$$= 38{,}871.5 \text{ mm/s}^2 = 38.871 \text{ m/s}^2$$

$\therefore$ Difference $= 50.77 - 38.871$

$= 11.89 \approx 11.9 \text{ m/s}^2$

13. (d)

$$\sigma = \rho V^2$$

$$7 \times 10^6 = 7200 \times V^2$$

$$\Rightarrow \quad V = 31.2 = \frac{\pi DN}{60}$$

$$\Rightarrow \quad D = \frac{60 \times 31.2}{\pi \times 800} = 0.744 \text{ m} = 744 \text{ mm}$$

For flywheel, $m = \rho \times V$

$= \rho \times (\pi D \times A)$

$604 = 7200 \times \pi \times 0.744 \times (5t \times t)$ $\quad (\because A = b \times t)$

$\Rightarrow \quad t = 84.7 \text{ mm} \approx 85 \text{ mm}$

14. (b)

$$\text{Max. arc of approach} = \frac{r.\sin\phi}{\cos\phi} = r\tan\phi$$

$$r\tan\phi = p_c = \pi m = \pi\frac{2r}{t}$$

$$\Rightarrow \quad t = \frac{2\pi}{\tan 14.5°} = 24.3 \approx 25$$

$\therefore \quad T = G.t = 100$

Now,

$$T = \frac{2a_w}{\sqrt{1 + \frac{1}{G}\left(\frac{1}{G} + 2\right)\sin^2\phi} - 1}$$

$$100 = \frac{2a_w}{\sqrt{1 + \frac{1}{4}\left(\frac{1}{4} + 2\right)\sin^2 14.5°} - 1}$$

$$\Rightarrow \quad a_w = 0.87 \text{ m} = 0.87 \times \frac{p_c}{\pi} = 0.278 p_c$$

15. (b)

$$F = pA - F_I + mg$$

$$= 200\times10^3\times\frac{\pi}{4}(0.8)^2 - 250\times0.3\times\left(\frac{2\times\pi\times300}{60}\right)^2\left(\cos40^\circ+\frac{\cos80^\circ}{4}\right) + 250\times9.81$$

$$= 100531 - 59917.6 + 250\times9.81$$

$$= 43065.5\text{ N}$$

$$F_t = F_c\sin(\theta+\beta) = \frac{F}{\cos\beta}\sin(\theta+\beta)$$

$$\beta = \sin^{-1}\left(\frac{\sin\theta}{n}\right) = \sin^{-1}\left(\frac{\sin40^\circ}{4}\right) = 9.247^\circ$$

$$= \frac{43065.5}{\cos9.247}\times\sin(40^\circ+9.247^\circ) = 33053\text{ N}$$

$$T = F_t\times r = 33053\times0.3$$

$$= 9916\text{ N-m} = 9.916\text{ kN-m}$$

16. (d)

$$\omega = \frac{2\pi\times240}{60} = 25.13\text{ rad/s}$$

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17. (b)

From the velocity triangle, if ω_{ab} is in CW direction, then ω_{bc} is in ACW direction

$\therefore$ velocity of rubbing at pin B $= r_b(\omega_{ab}+\omega_{bc})$

$= 20\times10^{-3}(12+8)$

$= 0.4$ m/s

18. (a)

(a) $j_1 = \dfrac{3l-5}{2}$

$l = 5 \Rightarrow j_1 = 5$

(b) $j_1 = \dfrac{3l - 5}{2}$

$l = 7 \Rightarrow j_1 = 8$

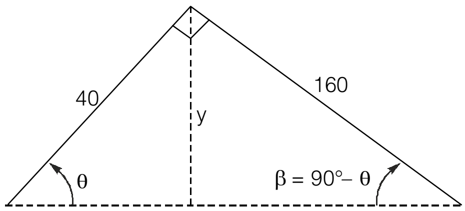
(c) $2j_1 = 3l - 4$

if $l = 4 \Rightarrow j_1 = 4 \Rightarrow$ No excess turning pair

(d) $2j_1 = 3l - 4$

if $l = 6 \Rightarrow j_1 = 7 \Rightarrow$ one excess turning pair

19. (b)



$$\sin\theta = \frac{y}{40}, \ \sin(90° - \theta) = \frac{y}{160}$$

$$\Rightarrow \quad 40 \sin\theta = 160 \cos\theta$$

$$\Rightarrow \quad \tan\theta = 4$$

$$\Rightarrow \quad \theta = \tan^{-1}(4) = 75.96°$$

$$\Rightarrow \quad \beta = 90° - \theta = 14.04°$$

Now, $T = F_t \times r = F_c \sin(\theta + \beta) \times r$

$$= \frac{F}{\cos\beta}\sin(\theta+\beta)\times r$$

$$F = \Delta P \times A - mr\omega^2\left(\cos\theta + \frac{\cos 2\theta}{n}\right)$$

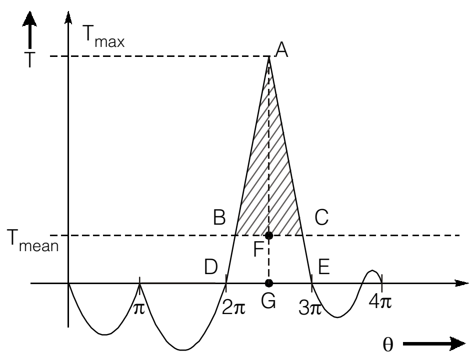
$$= 68 \times \frac{\pi}{4}(40)^2 - 125 \times 0.4 \times \left(\frac{2\times\pi\times 250}{60}\right)^2\left(\cos 75.96° + \frac{\cos 151.92}{4}\right)$$

$$= 84,694 \text{ N}$$

$$\therefore \quad T = \frac{84,694}{\cos 14.04}\sin(90°)\times 0.4$$

$$= 34.920 \text{ kN-m}$$

20. (c)



$$P = \frac{2\pi N T_{mean}}{60}$$

$$\Rightarrow \quad T_{mean} = \frac{60 \times 40 \times 10^3}{2 \times \pi \times 130} = 2938.245 \text{ N-m}$$

$$\Rightarrow \quad \text{Energy produced} = T_{mean} \times 4\pi = 36923.076 \text{ N-m}$$

Now, work done during the power stroke

$$= 1.5 \times \text{Energy produced per cycle}$$

$$= 1.5 \times 36923.076$$

$$= 55384.615 \text{ Nm}$$

Now, from similar triangles ABC, ADE;

$$\frac{AF}{AG} = \frac{BC}{DE}$$

$$\frac{1}{2} \times T_{max} \times \pi = 55384.6$$

$$\Rightarrow \quad T_{max} = 35258.93 \text{ Nm} = AG$$

Now, $\dfrac{35258.93 - 2938.245}{35258.93} = \dfrac{BC}{\pi}$

$$\Rightarrow \quad BC = 2.879 \text{ rad}$$

Now, maximum fluctuation of energy $= \dfrac{1}{2} \times AF \times BC$

$$= \frac{1}{2} \times (35258.93 - 2938.245) \times 2.879$$

$$= 46525.62 \text{ N-m}$$

21. (b)

Torsional stiffness, $k_t = \dfrac{T}{\theta} = \dfrac{GJ}{L} = \dfrac{G\left(\dfrac{\pi}{32} d^4\right)}{L}$

$$= \frac{0.8 \times 10^{11} \times \frac{\pi}{32}(0.03)^4}{0.3}$$

$$= 21205.75 \text{ N-m/rad}$$

Next, $\omega_n = \sqrt{\dfrac{k_t}{I}} = \sqrt{\dfrac{21205.75}{0.53}} = 200.027 \text{ rad/s}$

Next, frequency ratio $= \dfrac{\omega}{\omega_n} = \dfrac{314}{200.027} = 1.569$

Now, magnification factor

$$MF = \left| \frac{1}{1 - \left(\frac{\omega}{\omega_n}\right)^2} \right| = \left| \frac{1}{1 - 1.569^2} \right| = 0.683$$

Now, amplitude of twist with dynamic load,

$$\theta_d = (MF)\theta_s$$

$$\theta_s = \text{Static twist}$$

$$\therefore \quad \theta_d = 0.683 \times \left(\frac{TL}{GJ}\right)$$

$$= 0.683 \times \frac{300 \times 0.3}{0.8 \times 10^{11} \times \frac{\pi}{32}(0.03)^4}$$

$$= 9.66 \times 10^{-3} \text{ rad}$$

$$\therefore \quad \frac{\tau_{max}}{R} = \frac{G\theta_d}{L}$$

$$\Rightarrow \quad \tau_{max} = \frac{0.8 \times 10^{11} \times 9.66 \times 10^{-3} \times 15 \times 10^{-3}}{0.3}$$

$$= 38.64 \text{ MPa}$$

22. (c)

If shaft is supported in long bearing, it means both ends are fixed.

$$\therefore \quad \delta = \frac{wl^4}{192EI} = \frac{Wl^3}{192EI}$$

$$= \frac{490.5 \times (0.2)^3}{192 \times 2 \times 10^{11} \times \frac{\pi}{64}(0.005)^4} = 3.33 \times 10^{-3} \text{ m}$$

Now, critical speed, $N_{CS} = \frac{0.4985}{\sqrt{\delta}} = \frac{0.4985}{\sqrt{3.33 \times 10^{-3}}} = 8.638 \text{ rps}$

Let, $N = \text{speed of shaft} = 0.75\, N_{CS}$

From theory of simple bending,

$$\frac{M}{I} = \frac{\sigma}{y_1}$$

$$\Rightarrow \quad \frac{\frac{W_1(0.2)}{8}}{\frac{\pi}{64}(0.005)^4} = \frac{\sigma}{\frac{0.005}{2}}$$

$$\Rightarrow \quad W_1 = \frac{2 \times \pi \times 0.005^4 \times 8}{0.2 \times 64 \times 0.005}\sigma = 4.9 \times 10^{-7}\, \sigma \text{ N}$$

$\therefore$ Additional deflection due W_1

$$W \rightarrow \delta$$

$$W_1 \rightarrow y$$

$$\Rightarrow \quad y = \frac{W_1}{W} \times \delta = \frac{4.9 \times 10^{-7}}{490.5} \times 3.33 \times 10^{-3} = 3.3266 \times 10^{-12}\, \sigma$$

Now, $$y = \frac{\pm e}{\left(\frac{\omega_{CS}}{\omega}\right)^2 - 1} = \frac{\pm e}{\left(\frac{N_{CS}}{N}\right)^2 - 1}$$

$$3.3266 \times 10^{-12} \times \sigma = \pm \frac{0.25 \times 10^{-3}}{\left(\frac{N_{cs}}{0.75 N_{cs}}\right)^2 - 1}$$

$$\Rightarrow \quad \sigma = 96.64 \text{ MN/m}^2$$

23. (b)

arm	S	P	A
0	x	$-x\frac{Z_S}{Z_P}$	$-x\frac{Z_S}{Z_P} \times \frac{Z_P}{Z_A}$
+y	y + x	$y - x\frac{Z_S}{Z_P}$	$y - x\frac{Z_S}{Z_P} \times \frac{Z_P}{Z_A}$

$$r_s + 2r_p = r_A$$
$$Z_S + 2Z_P = Z_A$$
$$N_S = 5 N_{arm}$$
$$y + x = 5y$$
$$x = 4y$$
$$y - x\frac{Z_S}{Z_A} = 0$$
$$y - 4y\frac{Z_S}{Z_A} = 0$$
$$Z_A = \frac{324}{6} = 54 \qquad \left(\because m_A = \frac{d_A}{Z_A}\right)$$
$$1 = 4 \times \frac{Z_S}{54}$$
$$\Rightarrow \quad Z_S = 13.5 \approx 14$$

24. (b)

Transmissibility, $\epsilon = \frac{F_T}{F_{UN}} = \frac{150}{150} = 1$

$\therefore \quad \frac{\omega}{\omega_n} = \sqrt{2}$ as $\epsilon = 1$

$\therefore \quad \omega_n = \frac{\omega}{\sqrt{2}} = \frac{2 \times \pi \times 1000}{60 \times \sqrt{2}}$

$= 74.048$ rad/s

At 1600 rpm

$$F(t) = 150 \times \left(\frac{1600}{1000}\right)^2$$
$$= 150 \times 1.6^2 = 384 \text{ N}$$

And corresponding frequency ratio,

$$\left(\frac{\omega}{\omega_n}\right)^1 = \frac{\frac{2\times\pi\times1600}{60}}{74.048} = 2.2627$$

Now, When

$$\xi = 0$$

$$\in_{(N=1600)} = \frac{1}{2.2627^2 - 1}$$

$$= \frac{1}{4.1198} = \frac{F_T}{F_{UN}}$$

$\therefore$

$$F_T = \frac{384}{4.1198} = 93.20\text{N}$$

25. (b)

$$E_a = E$$
$$E_b = E + 280$$
$$E_L = E + 280 - 600 = E - 320$$
$$E_d = E + 280 - 600 + 100 = E - 220$$
$$E_e = E + 280 - 600 + 100 - 400 = E - 620$$
$$E_f = E + 280 - 600 + 100 - 400 + 890 = E + 270$$
$$E_g = E + 280 - 600 + 100 - 400 + 890 - 270 = E$$

$\therefore$

$$\Delta E = (E+280)-(E-620) = 900\times750\times\frac{5\pi}{180}$$

$$= 58904\text{ N-m}$$

$$\Delta E = I\omega^2C_s$$

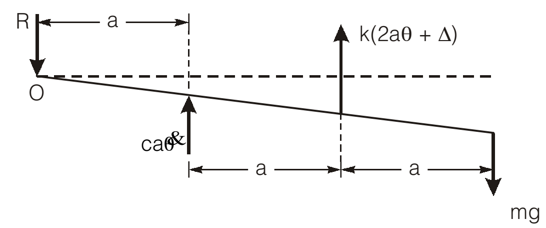
$$58904.8 = 60\times2.4^2\times\left(\frac{2\times\pi\times1500}{60}\right)^2\times C_s$$

$$\Rightarrow \quad C_s = 0.69\%$$

26. (c)

For static equilibrium

$$(k\Delta)\,2a = (mg)\,3a$$



Taking moments about 'O'

$$m(3a)^2\ddot{\theta} = mg3a - k(2a\theta+\Delta)\times2a - ca\dot{\theta}a$$

$$\Rightarrow \quad 9a^2m\ddot{\theta} + ca^2\dot{\theta} + 4a^2k\theta = 0$$

$$\theta = e^{st}$$

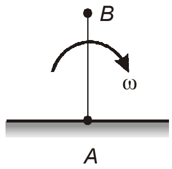
$$\therefore \quad 9\,ms^2 + cs + 4k = 0$$

$$s = \frac{-c \pm \sqrt{c^2 - 144km}}{18\,m}$$

$\therefore$ critical damping coefficient,

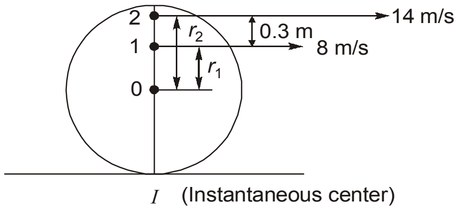
$$C_c = 12\sqrt{km} = 12\sqrt{100 \times 1} = 120$$

27. (b)



$$V_B - V_A = \omega \cdot AB$$

28. (c)



$$\therefore \quad \omega = \frac{V_1}{r_1} = \frac{V_2}{r_2}$$

$$\Rightarrow \quad \frac{8}{r_1} = \frac{14}{r_2}$$

$$r_2 - r_1 = 0.3$$

$$\Rightarrow \quad r_1 = r_2 - 0.3$$

$$\Rightarrow \quad \frac{8}{r_2 - 0.3} = \frac{14}{r_2}$$

$$8r_2 = 14r_2 - 4.2$$

$$6r_2 = 4.2$$

$$r_2 = 0.7 \text{ m} = 700 \text{ mm}$$

Radial distance of outer point from the instantaneous center is 700 + 800 = 1500 mm

29. (c)

Given: $V = 150$ mm/s

$N = 60$ rpm

$$\text{Coriolis acceleration} = 2\omega V = 2 \times \frac{2\pi \times 60}{60} \times 150 = 600\pi \text{ mm/s}^2$$

30. (a)

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

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