CLASS TEST

S.No. : 01SP_ME_ABC_210322

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THEORY OF MACHINES

MECHANICAL ENGINEERING

Date of Test : 21/03/2022

ANSWER KEY

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

DETAILED EXPLANATIONS

1. (c)
Because shortest link is coupler.

2. (b)
Path of contact in involute profile is a straight line, which is common normal to the involute profiles of mating gears.

3. (c)
A governor in said to be sensitive if the displacement of the sleeve is high for a given fractional change of speed.

4. (d)

5. (c)
We know that minimum number of teeth required on pinion,

$$t = \frac{2A\omega}{G\sqrt{1+\frac{1}{a}\left(\frac{1}{G}+2\right)\sin^2\phi}-1}$$

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

$$= \frac{2}{0.133} = 15.04 \simeq 15$$

6. (b)

7. (a)
Given, $N_1 = 1000$

$$\text{Coefficient of steadiness} = \frac{N_1+N_2}{2(N_1-N_2)}$$

$N_1 \rightarrow$ maximum speed
$N_2 \rightarrow$ minimum speed

$$50 = \frac{1000+N_2}{2(1000-N_2)}$$

$\Rightarrow$ $N_2 = 980.19$
maximum fluctuation of speed $= N_1 - N_2 = 19.80$ rpm

8. (d)
Let energy at A be E unit

$$E_A = E$$
$$E_B = E + 50$$
$$E_C = E + 50 - 20 = E + 30$$
$$E_D = E + 30 + 10 = E + 40$$
$$E_E = E + 40 - 30 = E + 10$$
$$E_{max.} = E + 50$$
$$E_{min.} = E + 10$$

$$\Delta E(\text{max. fluctuation of energy}) = E_{max.} - E_{min.}$$
$$= (E + 50) - (E)$$
$$= 50 \text{ J}$$

9. (c)

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

$$\therefore \quad \frac{1}{40} = \frac{1}{\left(\frac{\omega}{\omega_n}\right)^2 - 1}$$

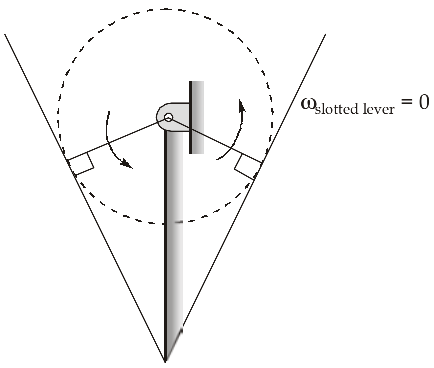
$$\Rightarrow \quad \left(\frac{\omega}{\omega_n}\right)^2 = 41$$

$$\therefore \quad \frac{\omega}{\omega_n} = 6.403$$

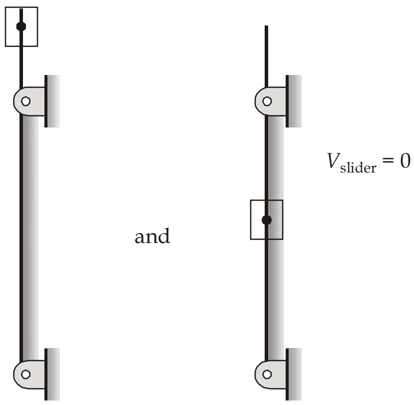
10. (d)

Coriolis component of acceleration will only be zero if either angular velocity of slotted lever is zero or the velocity of slider is zero. The possible 4 conditions are

- Two at the extremes of slotted lever.



- Two when the driving crank and slotted lever are vertical because at that position, velocity of slider will be zero.



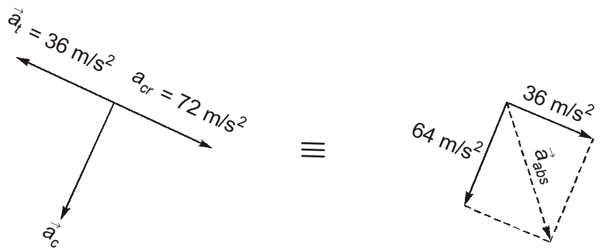
11. (b)

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.

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

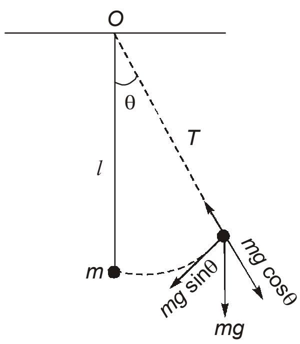
Coriolis acceleration, $\vec{a}_{cr} = 2\,V_{sliding}\,\omega$
$$= 2 \times 9 \times 4 = 72 \text{ m/s}^2$$

Direction of Coriolis acceleration $\rightarrow$ 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.



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

12. (c)



$$T = -mgl\sin\theta$$
$$T = -mgl\theta \qquad [\because \sin\theta \simeq \theta \text{ as } \theta \text{ is very small}]$$
$$T = I\alpha = -mgl\theta$$
$$I = ml^2$$
$$\alpha = \frac{-g\theta}{l} \qquad \text{...(i)}$$

and we know $\alpha = \ddot{\theta} = -\omega_n^2\theta$ ...(ii)

Comparing (i) and (ii)

$$\omega_n = \sqrt{\frac{g}{l}}$$

So, $\omega_n \propto \sqrt{g}$

$$g_{Moon} = \frac{g_{Earth}}{6}$$

$$(\omega_n)_{Moon} = \sqrt{\frac{g_{Moon}}{l}}$$

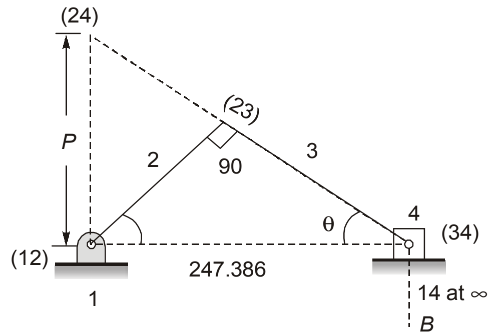
$$(\omega_n)_{Moon} = \frac{1}{\sqrt{6}}\sqrt{\frac{g_{Earth}}{l}} = \frac{1}{\sqrt{6}}(\omega_n)_{Earth}$$

$$(\omega_n)_{Moon} = 0.4082[\omega_n]_{Earth}$$

13. (b)

In a locomotive, the ratio of the connecting rod length to the crank radius is kept very large in order to minimize the effect of secondary forces.

14. (c)



$$AB = \sqrt{60^2 + 240^2}$$

$$AB = 247.386 \text{ mm}$$

$$AB = .247 \text{ m}$$

$$\tan\theta = \frac{60}{240} = \frac{P}{247.386}$$

$$P = 61.8465 \text{ mm}$$

$$P = 0.06184 \text{ m}$$

By Keneddy's theorem,

$$\omega_2 (I_{24} I_{12}) = V_4 = \omega_2 (I_{24} I_{14})$$

$$\Rightarrow \quad V_4 = 10\,(0.06184)$$

$$V_4 = 0.618 \text{ m/s}$$

15. (b)

$$X_{max} = \frac{Fo}{\sqrt{(k - m\omega^2)^2 + (c\omega)^2}}$$

$$0.04 = \frac{10}{\sqrt{(6250 - 10 \times 25^2)^2 + (C \times 25)^2}}$$

$$\Rightarrow \quad 0.04 = \frac{10}{C \times 25}$$

$$C = 10 \text{ Ns/m}$$

16. (b)

arm	A	B/C	D	E
O	1	$\frac{-40}{30}$	$\frac{-40x}{30} \times \left(\frac{-70}{40}\right)$	$\frac{-7}{3} \times \frac{40}{60}$
O	x	$\frac{-40x}{30}$	$\frac{7x}{3}$	$\frac{-14x}{9}$
y	$y + x$	$y - \frac{40x}{30}$	$y + \frac{7x}{3}$	$y\ \frac{-14x}{9}$

Arm a rotates at 210 rpm clockwise,

$$y = 210$$

Gear D is fixed, thus $y + \frac{7x}{3} = 0$

or $\quad 210 + \frac{7x}{3}$ or $x = -90$

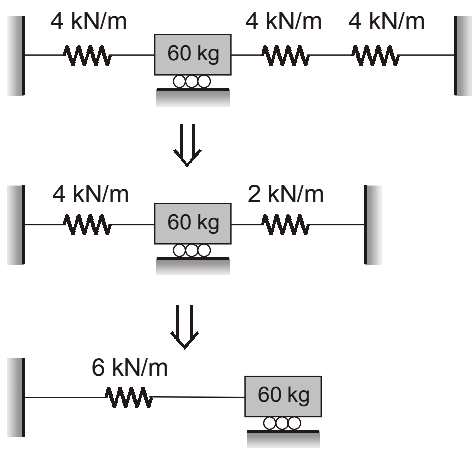
$$\text{Speed of } A = y + x$$

$$210 - 90 = 120 \text{ rpm (clockwise)}$$

$$\text{Speed of } E = y - \frac{14x}{9} = y - \frac{2\ x}{7}$$

$$= 350 \text{ rpm (clockwise)}$$

17. (a)



$$\omega_n = \sqrt{\frac{s}{m}} = \sqrt{\frac{6\times10^3}{60}}$$

$$\sqrt{100} = 10 \text{ rad/s}$$

18. (d)

Average cutting velocity $=$ L.N$(1 + M)$

$M \rightarrow$ Quick return ratio

$L \rightarrow$ Stroke length

$= 30 \times 250\,(1 + 0.6)$

$= 12$ m/min

19. (b)

$$F_{\text{unbalanced force}} = mr\omega^2\left[\cos\theta + \frac{\cos 2\theta}{n}\right]$$

$$= \underbrace{mr\omega^2 \cos\theta}_{\text{Primary unbalanced force}} \quad \underbrace{\frac{mr\omega^2 \cos 2\theta}{n}}_{\text{Secondary unbalanced force}}$$

20. (c)

Sheared area per hole $= \pi dt$

$= \pi \times 40 \times 15 = 1885 \text{ mm}^2$

Energy required to punch a hole

$E_1 = 6 \times 1885 = 11310$ Nm

Energy required for punching work/s.

$$= \frac{\text{Energy required}}{\text{hole}} \times \frac{\text{No. of holes}}{\text{S}}$$

$$= 11310 \times \frac{30}{60} = 5655 \text{ Nm/s}$$

$\because$ Punching takes $\frac{1}{10}$ of a second, Energy supplied by the motor in $\frac{1}{10s}$

$$\Rightarrow \quad E_2 = 5655 \times \frac{1}{10} = 565.5 \text{ Nm}$$

Maximum furcation of energy of flywheel

$$\Delta E = E_1 - E_2 = 11310 - 565.5 = 10749.5 \text{ Nm}$$

Mean speed, $$N = \frac{N_1 + N_2}{2} = \frac{160 + 140}{2} = 150 \text{ rpm.}$$

Now, ΔE

$$\Rightarrow \quad 10744.5 = \frac{\pi^2}{900} \times mI^2 N(N_1 - N_2)$$

$$\Rightarrow \quad 10744.5 = \frac{\pi^2}{900} \times m \times 1^2 \times 150(160 - 140)$$

$$\Rightarrow \quad m = 327 \text{ kg}$$

21. (b)

$$r = 51.5 \text{ mm}$$
$$R = 64.2 \text{ mm}$$
$$r_a = 57.5 \text{ mm}$$
$$R_a = 71.2 \text{ mm}$$

$$CR = \frac{\text{Arc of contact}}{\text{Circular pitch}}$$

$$= \frac{\dfrac{\left\{\sqrt{R_a^{\,2} - R^2\cos^2\phi} - R\sin\phi\right\} + \left\{\sqrt{r_a^{\,2} + r^2\cos^2\phi} - r\sin\phi\right\}}{\cos\phi}}{\pi\left(2 \times \dfrac{64.2}{20}\right)}$$

$$= \frac{\dfrac{\left\{\sqrt{71.2^2 - 64.2^2\cos^2 20^\circ} - 64.2\sin 20^\circ\right\} + \left\{\sqrt{57.5^2 - 51.5^2\cos^2 20^\circ} - 51.5\sin 20^\circ\right\}}{\cos 20^\circ}}{20.169}$$

$$= \frac{15.8568 + 13.4384}{18.95} = 1.545$$

22. (b)

23. (c)

$$T_{mean} = \frac{1}{\pi}\int_0^{\pi} T d\theta$$

$$= \frac{1}{\pi}\int_0^{\pi} (1000 + 400\sin 2\theta - 500\cos 2\theta) \times .d\theta$$

$$T_{mean} = 1000 \text{ Nm}$$

At any instant, $$\Delta T = T - T_{mean}$$

$$= (1000 + 400 \sin 2\theta - 500 \cos 2\theta) - 1000$$
$$= 400 \sin 2\theta - 500 \cos 2\theta$$

$\therefore$ ΔT is zero, when

$$400 \sin 2\theta - 500 \cos 2\theta = 0$$
$$\tan 2\theta = \frac{5}{4}$$
$$2\theta = 51.34° \quad \text{or} \quad 231.34°$$
$$e_{max} = \int_{25.67}^{115.67} (400 \sin 2\theta - 500 \cos 2\theta) \times d\theta$$
$$e_{max} = 640.312 \text{ Nm}$$
$$e_{max} = Ik_s \left[\frac{\omega_{max} + \omega_{min}}{2}\right]^2$$
$$640.312 = 500 \times .35^2 \times k \times 10\pi \times 10\pi$$
$$k = 0.01059$$
$$\therefore \quad k\% = 1.059\,\%$$

24. (a)

Energy supplied by the motor is 1s = 5000 Nm

Energy supplied by the motor is 1.5s = 7500 Nm

Energy required/hole = 10000

Energy supplied by flywheel

$$e = 1000 - 7500 = 2500$$

also,
$$e = \frac{1}{2}\left(\omega_1^2 - \omega_2^2\right)$$
$$2500 = \frac{1}{2} \times 200 \times 0.5^2 \times \left(\left(\frac{2\pi \times 350}{60}\right)^2 - \omega^2\right)$$
$$\Rightarrow \quad \omega_2 = 35.25 \text{ rad/s}$$

25. (a)

$$\frac{N_1}{N_2} = \frac{T_2}{T_1} = 2.5, \quad \frac{N_3}{N_4} = \frac{T_4}{T_3} = 4$$
$$\therefore \quad r_1 + r_2 = r_3 + r_4 = 160$$
$$\Rightarrow \quad m_1T_1 + m_2T_2 = 320$$
$$\Rightarrow \quad T_1 + T_2 = 100$$
$$T_1 = 28.57, \quad T_2 = 28$$
$$T_2 = 72$$
$$\Rightarrow \quad m_3T_3 + m_4T_4 = 320$$
$$T_3 + T_4 = 160$$
$$T_3 = 32$$
$$T_4 = 128$$
$$\text{Exact velocity ratio} = \frac{T_2T_4}{T_1T_3} = \frac{72}{28} \times \frac{128}{32} = 10.29$$

26. (b)

$$\frac{x_4}{x_9} = e^{-5\times\xi\times T_d\times\omega_n} = 0.02$$

Take *ln* of both sides

$$5\times\xi\times\frac{2\pi}{\sqrt{1-\xi^2}} = \ln\left(\frac{1}{0.02}\right)$$

$$\xi = 0.12357$$

$$MF = \frac{1}{\sqrt{\left(1-\left(\frac{\omega}{\omega_n}\right)^2\right)^2+\left(2\xi\frac{\omega}{\omega_n}\right)^2}}$$

At resonance, $\frac{\omega}{\omega_n} = 1$

$$MF = \frac{1}{2\xi} = \frac{1}{2\times 0.12357}$$

$$MF = 4.0463$$

27. (c)

$$KP = \sqrt{R_A^2 - R^2\cos^2\phi} - R\sin\phi = 12.65 \text{ mm}$$

$$PL = \sqrt{r_A^2 - r^2\cos^2\phi} - r\sin\phi = 11.49 \text{ mm}$$

$\Rightarrow$ Arc of contact $= \frac{KP+PL}{\cos\phi} = 25.69$ mm

Contact ratio $= \frac{\text{Arc of contact}}{\pi m} = 1.635$

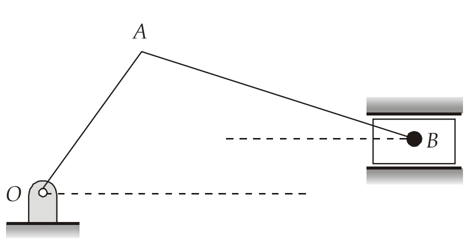
For one pair of teeth in contact, arc of contact

$$= \frac{25.69}{1.635} = 15.712 \text{ mm}$$

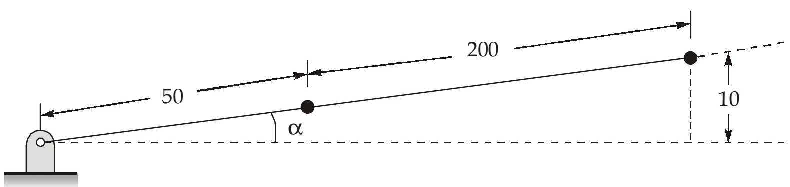
Angle turned by pinion for one pair of teeth in mesh

$$= \frac{15.712}{r}\times\frac{180}{\pi} = \frac{15.712}{50}\times\frac{180}{\pi} = 18.00°$$

28. (d)

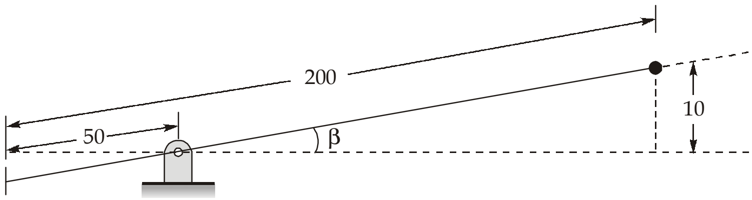


Case I: When the slider is farthest from *O*,



So, $$\alpha = \sin^{-1}\left(\frac{10}{50+200}\right) = 2.2924°$$

Case II: When the slider is closest to O,



So, $$\beta = \sin^{-1}\left(\frac{10}{200-50}\right) = 3.8225°$$

Angle covered by the crank in backward stroke, $\theta_b = 180 - \alpha + \beta$

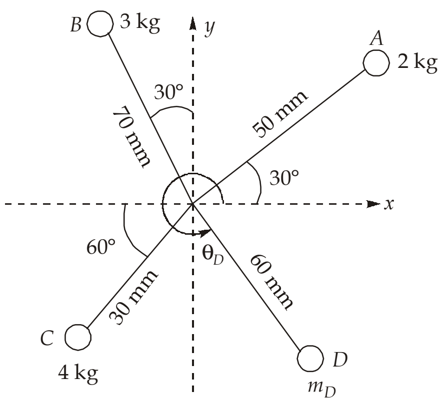
$$\theta_b = 181.5301°$$

So, angle covered by the crank in forward stroke, $\theta_f = 360 - \theta_b$

$$\theta_f = 178.4699°$$

Now, $$\frac{t_b}{t_f} = \frac{\theta_b}{\theta_f} = \frac{181.5301}{178.4699} = 1.0171$$

29. (a)



$$\Sigma F_{x\_net} = 0$$
$$\Sigma mr\cos\theta = 0$$
$$2 \times 50\cos 30° + 3 \times 70\cos 120° + 4 \times 30\cos 240° + m_D \times 60\cos\theta_D = 0$$
$$m_D\cos\theta_D = 1.3066 \quad \text{...(i)}$$
$$\Sigma F_{y\_net} = 0$$
$$\Sigma mr\sin\theta = 0$$
$$2 \times 50\sin 30° + 3 \times 70\sin 120° + 4 \times 30\sin 240° \times m_D \times 60\sin\theta_D = 0$$
$$m_D\sin\theta_D = -2.1324 \quad \text{...(ii)}$$

Using (i) and (ii)

$$m_D = 2.5 \text{ kg}$$
$$\theta_D = 301.49°$$
$$\text{Angle from } A = 301.49 - 30 = 271.49°$$

30. (d)

$$\frac{X_0}{X_N} = e^{\xi \omega_n N T_d}$$

$$\omega_n = \sqrt{\frac{k}{m}} = \sqrt{\frac{40 \times 10^3}{200}} = 14.14 \text{ rad/s}$$

$$50 = e^{0.22 \times 14.14 \times (NT_d)}$$

$\Rightarrow$ $$NT_d = 1.26 \text{ s}$$

$$\text{Total time} = 1.26 \text{ s}$$

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