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Theory of Machine (Part-I)

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CLASS TEST 2019-2020

MECHANICAL ENGINEERING

Date of Test : 09/06/2019

ANSWER KEY ➤ Theory of Machine (Part-I)

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

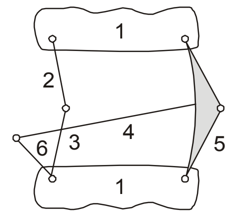
DETAILED EXPLANATIONS

4. (b)

In comparison to the slider crank, the scotch yoke has the advantage of smaller size and fewer moving parts, but can experience rapid wear in the slot.

So, statement R and S are wrong.

5. (c)



Number of links, $n = 6$

Number of lower pairs, $l = 7$

Number of higher pairs, $h = 0$

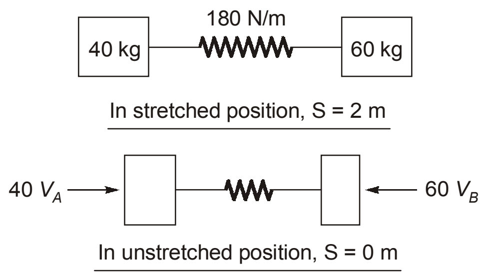
DOF $F = 3(n-1) - 2(l) - h$

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

$= 3 \times 5 - 2 \times 7$

$= 15 - 14 = 1$

6. (b)



V_A and V_B are velocity

From linear momentum conservation:

$$(\Sigma mv)_{initial} = (\Sigma mv)_{final}$$

If released from rest,

$$0 + 0 = 40V_A - 60V_B$$

$$4V_A = 6V_B$$

$$V_A = \frac{3}{2}V_B$$

From energy conservation:

$$k_1 + u_1 = k_2 + u_2$$

$$0 + \frac{1}{2}\times 180 \times 2^2 = \frac{1}{2}40V_A^2 + \frac{1}{2}60(-V_B)^2$$

$$18 \times 4 = 4V_A^2 + 6V_B^2$$

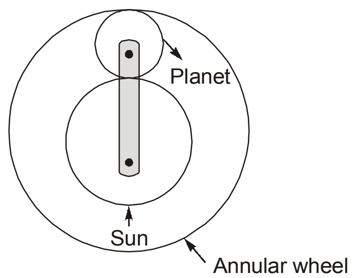
$$72 = 4 \times \frac{9}{4}V_B^2 + 6V_B^2$$

$$V_B^2 = \frac{72}{15}$$

$$\Rightarrow \quad V_B = 2.19 \text{ m/s}$$

$$V_A = \frac{3}{2} \times 2.19 = 3.29 \text{ m/s}$$

9. (d)



From the geometry,

$$r_S + 2r_P = r_A$$

$$\frac{mT_S}{2} + \frac{2mT_P}{2} = \frac{mT_A}{2}$$

$$T_S + 2T_P = T_A$$

$$T_S = 100 - 2 \times 20$$

$$T_S = 100 - 40 = 60$$

10. (c)

Static deflection, $\delta_{st} = 5 \times 10^{-3}$ m

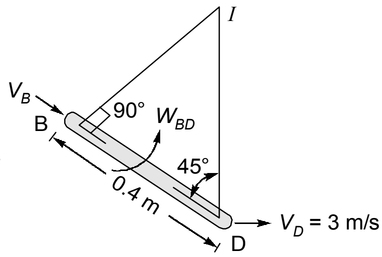
Natural frequency, $\omega_n = \sqrt{\dfrac{g}{\delta_{st}}} = \sqrt{\dfrac{9.81}{5\times10^{-3}}} = 44.2945$ rad/s

$$f = \frac{\omega_n}{2\pi} = 7.04968 \text{ Hz} \approx 7.05 \text{ Hz}$$

11. (c)

As D moves to the right, it causes AB to rotate clockwise about point A. Hence, V_B is directed perpendicular to AB. The instantaneous centre of zero velocity of BD is located at the intersection of the line segment drawn perpendicular to V_B and V_D.

From the geometry,

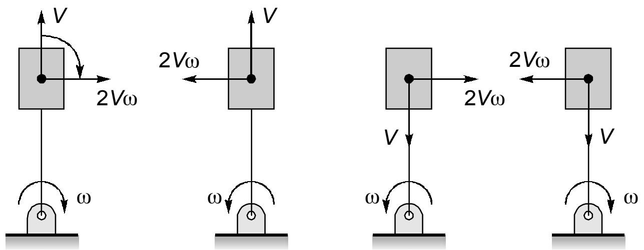


$$ID = \frac{BD}{\cos 45°} = \frac{0.4}{\cos 45°} = 0.5657 \text{ m}$$

Since the magnitude of V_D is known, the angular velocity of link BD is

$$\omega_{BD} = \frac{V_D}{ID} = \frac{3}{0.5657} = 5.30 \text{ rad/s}$$

12. (b)



15. (d)

$$\text{VR} = \frac{N_2}{N_1} = \frac{1}{3} = \frac{T_1}{T_2} \Rightarrow T_2 = 3T_1$$

Centre distance, $C = \dfrac{d_1 + d_2}{2} = \dfrac{m(T_1 + T_2)}{2} = \dfrac{6(4T_1)}{2} = 12T_1$

$$204 = 12T_1 \text{ or } T_1 = 17$$

$$T_1 = 3 \times 17 = 51$$

$$d_2 = mT_2 = 6 \times 51 = 306 \text{ mm}$$

Base circle diameter $= \dfrac{d_2}{2}\cos\phi = \dfrac{306}{2}\cos 20° = 143.77 \text{ mm} \approx 144 \text{ mm}$

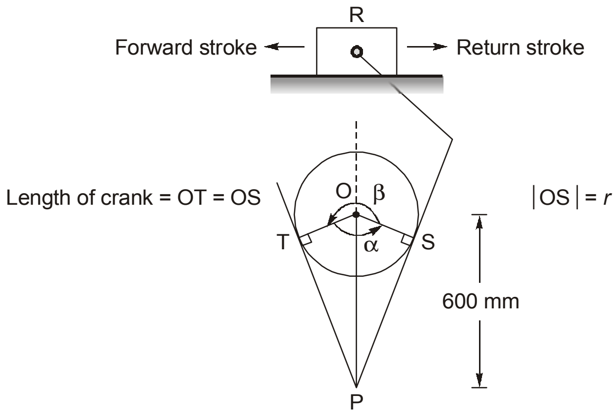
16. (a)

$$T = \frac{2A_w}{\sqrt{1 + \frac{1}{G}\left(\frac{1}{G} + 2\right)\sin^2\phi} - 1} = \frac{2\times1.1}{\sqrt{1 + \frac{1}{4}\left(\frac{1}{4} + 2\right)\sin^2 20°} - 1}$$

$$= 67.952 \approx 68 \text{ (whole number)} = T_G$$

$$t = \frac{T_G}{4} = \frac{68}{4} \Rightarrow T_P = 17$$

17. (c)



$$\text{Quick-return ratio} = \frac{\text{Time of return stroke}}{\text{Time of cutting stroke}}$$

$$\frac{1}{2} = \frac{\alpha}{\beta} = \frac{\alpha}{360-\alpha}$$

$$360 - \alpha = 2\alpha$$

$$\alpha = 120°$$

$$\text{Angle } \angle OTP = \frac{\alpha}{2} = \frac{120°}{2} = 60°$$

From triangle ΔTOP,

$$\cos\frac{\alpha}{2} = \frac{OT}{OP} = \frac{r}{600}$$

$$r = 600 \cos 60°$$

$$r = 300 \text{ mm}$$

18. (b)

$$\text{Power, } P = \frac{2\pi NT}{60000}$$

$$T = \frac{60\times10^3\times380}{2\pi\times1500} = 2419.15 \text{ N.m}$$

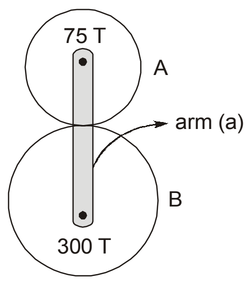
$$\text{Tangential force, } F = \frac{2419.15\times10^3}{\frac{510}{2}} = 9486.88 \text{ N}$$

$$\text{Normal pressure on the tooth} = \frac{F}{\cos\phi} = \frac{9486.88}{\cos 20°} = 10095.7 \text{ N}$$

$$\text{Width of pinion} = \frac{F_n}{\text{Limiting normal pressure}} = \frac{10095.7}{1000} = 10.1 \text{ mm}$$

19. (d)

Sl.	Action	N_a	N_A	N_B
1.	Arm fixed, A + 1 rev.	0	1	$-\frac{T_A}{T_B}$
2.	Arm fixed, A + x rev.	0	x	$-x\frac{T_A}{T_B}$
3.	Add y	y	$x + y$	$y - x\frac{T_A}{T_B}$



$$\text{As gear B is fixed here, } N_B = 0,\ y - x\left(\frac{75}{300}\right) = 0$$

$$y = \frac{x}{4} \text{ or } x = 4y$$

$$N_{arm} = +1 \quad \text{(Assume CW direction)}$$

$$y = 1,\ x = 4$$

Number of turns by pinion A = $x + y = 5$

20. (b)

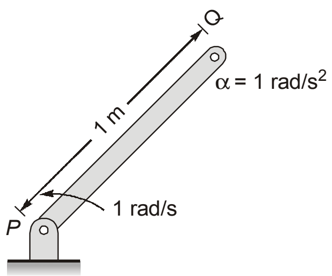
$$\omega = \frac{2\pi N}{60} = \frac{2\pi \times 90}{60} = 9.425 \text{ rad/s}$$

$$a_{cor} = 2\,\omega_2\, v$$

$$= 2 \times 9.425 \times 8.5 = 160.225 \text{ m/s}^2$$

22. (d)

$$a_t = \sqrt{(r\omega^2)^2 + (r\alpha)}$$



$$= \sqrt{(1)^2 + (1)^2}$$

$$a_t = \sqrt{2} = 1.41 \text{ m/s}^2$$

$$= 1.41 \text{ m/s}^2$$

23. (c)

$$\omega = \frac{2\pi N}{60} = \frac{2\pi \times 700}{60} = 73.3 \text{ rad/s}$$

Torque, $$T = \frac{P}{\omega} = \frac{3500}{73.3} = 47.75 \text{ N.m}$$

Tangential force, $$F = \frac{T}{\left(\frac{d}{2}\right)} = \frac{47.75 \times 10^3}{50} = 954.979 \approx 955$$

$$\text{Total force} = \frac{F}{\cos 20^\circ} = \frac{955}{\cos 20^\circ} = 1016.29 \text{ N}$$

24. (b)

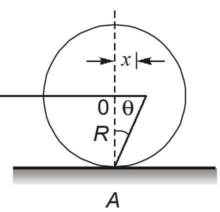
Taking moments about the instantaneous centre A, considering small oscillations of disc

$$I_A \ddot{\theta} + (kx)R = 0$$

$$(I_0 + mR^2)\ddot{\theta} + k(R\theta)R = 0$$

$$\left(\frac{1}{2}mR^2 + mR^2\right)\ddot{\theta} + kR^2\,\theta = 0$$

$$\left(\frac{3}{2}mR^2\right)\ddot{\theta} + (kR^2)\theta = 0$$



$$\ddot{\theta} + \left(\frac{2k}{3m}\right)\theta = 0$$

So,
$$f = \frac{1}{2\pi}\sqrt{\frac{2k}{3m}} = \frac{1}{2\pi}\sqrt{\frac{2k \times 9.81}{3 \times 89}} \qquad \left(\because m = \frac{|\alpha|}{g}\right)$$

$$\left(1 \times \frac{(2\pi)^2 \times 3 \times 89}{19.62}\right) = k \quad \Rightarrow \quad k = 537 \text{ N/m}$$

25. (a)

The general solution is

$$x = A \sin \omega t + B \cos \omega t$$

$$v = \frac{dx}{dt} = A\omega \cos \omega t - B\omega \sin \omega t$$

$$\omega = 2\pi f = 2\pi \times 6 = 37.7 \text{ rad/s}$$

Putting in initial conditions, we have

$$x(t = 0) = B = 0.1 \text{ m} \Rightarrow B = 0.1 \text{ m}$$

$$v(t = 0) = A\omega = 5 \text{ m/s} \Rightarrow A = \frac{5}{37.7} = 0.133 \text{ m}$$

$$\text{Amplitude of motion} = \sqrt{A^2 + B^2} = \sqrt{(0.133)^2 + (0.1)^2} = 0.166 \text{ m} = 166 \text{ mm}$$

26. (b)

$$m = 50 \text{ kg}, \ \omega = \frac{2\pi \times 1200}{60} = 125.664 \text{ rad/s}, \ \zeta = 0.07$$

Transmissibility,
$$\text{TR} = \frac{F_T}{F_O} = \left\{\frac{1 + (2\zeta r)^2}{(1 - r^2)^2 + (2\zeta r)^2}\right\}^{1/2}$$

For 75% isolation, TR = 0.25 (75% of vibration isolated and only 25% transmitted)

$$(0.25)^2 = \frac{1 + (2 \times 0.07r)^2}{(1 - r^2)^2 + (2 \times 0.07r)^2}$$

By rearranging, we get

$$0.0625\gamma^4 - 0.143375\gamma^2 - 0.9375 = 0$$

Solution of this equation is given by

$$r^2 = 5.186255 \text{ (only +ve value taken)}$$

or
$$r = \sqrt{5.186255} = \frac{\omega}{\omega_n} = 2.773$$

$$\omega_n = \frac{\omega}{2.2773} = \frac{125.664}{2.2773} = 55.1803 \text{ rad/s}$$

Maximum stiffness,
$$k = m\omega_n^2$$
$$= 50 \times (55.1803)^2$$
$$= 152243.1865 \text{ N/m}$$
$$= 152.243 \text{ kN/m}$$

27. (c)

In many practical situations, it is possible to reduce but not eliminate the dynamic forces that cause vibrations. Several methods can be used to control vibrations. Among them, the following are important:

1. Controlling the natural frequencies of the system and avoiding resonance under external excitations.
2. Preventing excessive response of the system, even at resonance, by introducing a damping or energy-dissipating mechanism.
3. Reducing the transmission of the excitation forces from one part of the machine to another by the use of vibration isolators.
4. Reducing the response of the system by the addition of an auxiliary mass neutralizer or vibration absorber.

28. (a)

As the shaft is held in long bearings, it may be assumed to be fixed at the ends.

$$\Delta = \frac{mgl^3}{192EI}$$

$$\Delta = \frac{16\times 9.81\times(1.2)^3}{192\times 200\times 10^9\times\frac{\pi}{64}(0.014)^4} = 0.0375 \text{ m}$$

$$f_n = \frac{1}{2\pi}\sqrt{\frac{g}{\Delta}} = \frac{1}{2\pi}\sqrt{\frac{9.81}{0.0375}} = 8.143 \text{ Hz}$$

Critical speed $= 8.143$ rps $= 8.143 \times 60 = 489$ rpm

29. (b)

$$k_1 = \frac{k}{3}+\frac{k}{3}+\frac{k}{3} = k \qquad \text{(for parallel springs)} \qquad \left(k_2 = \frac{k}{4}\right)$$

$$k_{eq} = \frac{k_1 k_2}{k_1 + k_2} = \frac{k\times\frac{k}{4}}{k+\frac{k}{4}} = \frac{k}{5}$$

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

30. (b)

$$m = 12.5 \text{ kg}, \; k = 1000 \text{ N/m}, \; c = 18 \text{ Ns/m}$$

Critical damping $C_c = 2\sqrt{km}$

$$= 2\sqrt{12.5\times 1000} = 223.6 \text{ Ns/m}$$

$$\in = \frac{C}{C_c} = \frac{18}{223.6} = 0.0805$$

Logarithmic decrement, $\delta = \frac{2\pi\in}{\sqrt{1-\in^2}} = \frac{2\pi\times 0.0805}{\sqrt{1-(0.0805)^2}} = 0.50744$

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