THEORY OF MACHINES, VIBRATIONS AND DESIGNS TEST 2

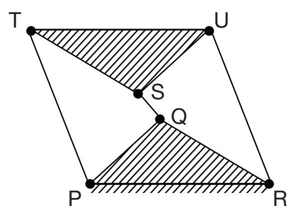
Number of Questions 35 **Time:60 min.**

Directions for questions 1 to 35: Select the correct alternative from the given choices.

1. The critical speed of a rotating shaft depends upon
(A) mass
(B) stiffness
(C) mass and stiffness
(D) mass, stiffness and eccentricity

2. If a mass of 6 kg oscillates on a spring having a mass 3 kg and stiffness 11200 N/m, then the natural frequency of the system in rad/sec will be
(A) 43.2 (B) 40
(C) 35.3 (D) 58

3. A linkage is shown below in the figure. Link *PQR* is fixed. *PQR* and *STU* are ternary links where as *PT*, *QS* and *UR* are binary links. The degree of freedom of the linkage will be



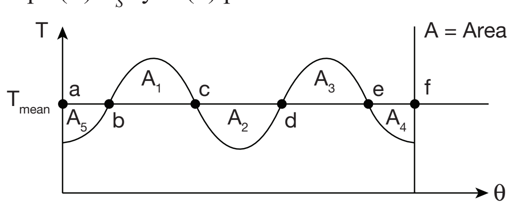
(A) 1 (B) 2
(C) 3 (D) 0

4. In a multiple disc clutch, if there are 8 discs on the driving shaft and 7 discs on driven shaft, the number of pair of contact surfaces will be equal to
(A) 30 (B) 13
(C) 15 (D) 14

5. Mitre gears are
(A) gears having different modules.
(B) right angled bevel gears having the same number of teeth.
(C) spur gears of equal diameter and pitch.
(D) helical gears having same pitch.

6. In vibration isolation system, if $\dfrac{\omega}{\omega_n} < \sqrt{2}$ then transmissibility will be
(A) >1 (B) <1
(C) =1 (D) zero

7. A torque(T) V_S cycle(θ) plot is shown below



If A_3 = +10 units, A_4 = – 6 units, Energy (*E*) at *d* = 96 units, then the energy at f will be
(A) 106 units (B) 96 units
(C) 100 units (D) 92 units

8. The centre distance between two involute teeth gears of radii r and R and pressure angle (ϕ) is given by
(A) $(R + r)\sin\phi$ (B) $\dfrac{(R+r)}{\cos\varphi}$
(C) $(R + r)\cos\phi$ (D) $\dfrac{(R+r)}{\sin\varphi}$

9. Which one of the following loading is considered for design of axles?
(A) Combined bending moment and torsion.
(B) Combined bending moment, twisting moment and axial thrust.
(C) Bending moment only.
(D) Combined bending moment and axial thrust.

10 A journal bearing of diameter 5 cm and length 50 cm carriers a load of 250 kN. The average bearing pressure in (kN/cm^2) will be
(A) 12.73 (B) 10
(C) 1 (D) 100

11. Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I	List-II
P. Spherical roller bearing	1. Light loads
Q. Needle roller bearing	2. Carrying both radial and thrust load
R. Tapered roller bearing	3. Self-aligning property
S. Ball bearing	4. Heavy loads with oscillatory motion

	P	*Q*	*R*	*S*
(A)	3	4	2	1
(B)	3	2	4	1
(C)	1	4	2	3
(D)	1	2	4	3

12. A single-plate clutch transmits 20 kW at 1000 rpm. The maximum pressure intensity between the plates is 100 kPa. The outer diameter and inner diameter of the plate are 0.2 m and 0.18 m respectively. Both the sides of the plate are effective. The axial force to engage the clutch in kN will be
(A) 2.5 (B) 5
(C) 2.2 (D) 4.5

13. A machine weighs 26 kg and is supported on springs and dashpots. The total stiffness of the spring is 16 N/mm and damping is 0.2 N/mm/sec. The system is initially at rest and a velocity is imparted to the mass. The damped frequency (radian/sec) will be

(A) 24.08 (B) 24.5
(C) 25.8 (D) 25.5

14. Which of the following are examples of forced closed kinematic pairs?
1. Door closing mechanism.
2. Cam and roller mechanism.
3. Slider-crank mechanism.

Select the correct answer using the codes given below:
(A) 1 only (B) 1 and 2
(C) 2 and 3 (D) 1, 2 and 3

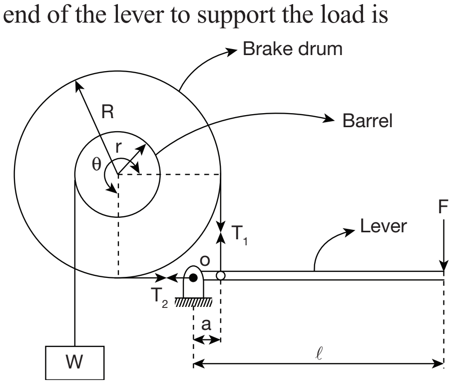
15. In a slider-crank mechanism, when does the connecting rod have zero angular velocity?
(A) When crank angle = 45°
(B) When crank angle = 0°
(C) When crank angle = 90°
(D) Never

16. An inverted slider-crank mechanism is shown in the figure. The crank *PQ* is 400 mm long and rotates 24 rad/sec. It was found that rod *RS* is rotating with velocity of 4 m/s. The sliding velocity of the slider on link TS in m/s will be
(A) 8.7 (B) 9.6
(C) 4 (D) 10.4

17. The number of teeth of a spur gear is 50 and it rotates at 250 rpm. If it has a module of 2.5 mm, then its circular pitch (in mm) and the pitch line velocity (in mm/sec) respectively will be
(A) 6.28 and 3272.5 (B) 6.28 and 1636.2
(C) 7.85 and 1636.2 (D) 7.85 and 3272.5

18. A machine is coupled to a two-stroke engine which produces a torque of (1200 + 200 Sin3θ) N-m, where ‘θ’ is the crank angle. The mean engine speed is 400 rpm. Determine the power of the engine (in kW).
(A) 75.4 (B) 25.13
(C) 58.64 (D) 50.26

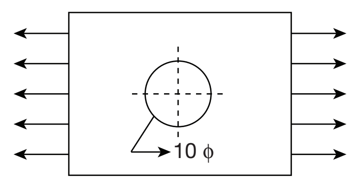
19. A crane is required to support a weight 2 kN on the rope round its barrel of 500 mm diameter. The brake drum diameter is 800 mm, the angle of contact of the band is 270° and the coefficient of friction is 0.25. If the value of $a = 200$ mm and $\ell = 800$ mm, then the force required (*N*) at the end of the lever to support the load is



(A) 138.9 (B) 451.4
(C) 277.8 (D) 902.8

20. A shaft supported freely at the ends has a mass of 150 kg placed 300 mm from one end. If the length of the shaft is 800 mm, Young’s modulus (*E*) = 200 GPa and shaft diameter is 40 mm then the frequency of the natural transverse vibration in Hz will be
(A) 133.65 (B) 19.3
(C) 112.76 (D) 21.3

21. A plate made of steel 20C8 is hot rolled and normalized condition is shown in figure. If fatigue stress concentration factor is given as 2, then the value of notch sensitivity factor will be



(A) 0.5 (B) 0.25
(C) 2 (D) 0.3

22. A ball bearing is operating on a work cycle consisting of 3 parts – a radial load of 2000 N at 1200 rpm for one quarter cycle, a radial load of 4000 N at 1000 rpm for one half cycle, and radial load of 2500 N at 1400 rpm for one quarter cycle. If the expected life of the bearing is 12000 hours then the dynamic load carrying capacity (in N)of the bearing will be
(A) 44791 (B) 38620
(C) 30619 (D) 41640

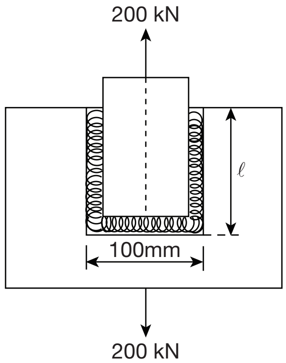
23. A cone clutch with asbestos friction lining transmits 40 kW power at 600 rpm. The coefficient of friction is 0.25 and the permissible intensity of pressure is 107 kPa. The outer diameter is fixed as 400 mm from space limitations and inner diameter is 350 mm. Assuming uniform wear theory, the semicone angle will be
(A) 13.5° (B) 10.5°
(C) 11.5° (D) 12.5°

24. Match List-I (Items in joints) with List-II (Type of failure) and select the correct answer using the codes given below the lists:

	List-I		List-II
P.	Rivets in lap joints.	1.	Double transverse shear.
Q.	Cotters in cotter joint.	2.	Torsional shear.
R	Bolts in bolted joints of engine cylinder cover plate.	3.	Single transverse shear.
S.	Bolts holding two flanges in a flange coupling.	4.	Tension.

	P	Q	R	S
(A)	3	1	4	2
(B)	3	2	4	1
(C)	4	1	3	2
(D)	4	2	3	1

25. Two plates are joined together by means of single transverse and double parallel fillet weld as shown in the given figure. The size of the weld is 6 mm and allowable shear load per mm of weld is 350 N. If length for starting and stopping of the weld run is 15 mm then determine the length of each parallel fillet weld in (mm)



(A) 235.7 (B) 250.7
(C) 265.9 (D) 273.3

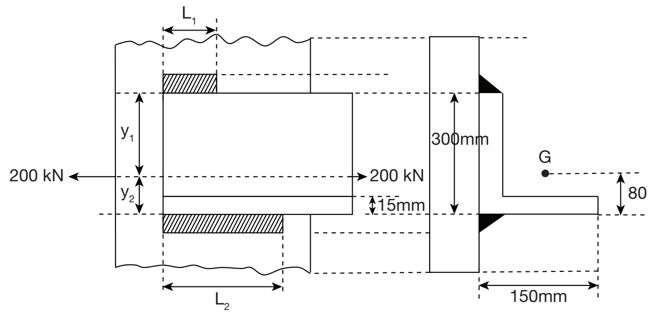
26. Two 20° gears have a module pitch of 5 mm. The number of teeth on gear 1 is 50 and on gear 2 is 30. If gear 2 rotates at 800 rpm, the velocity of sliding when the contact is at the tip of the tooth of gear 2 will be
(Take addendum = 1 module and gear 2 as pinion)
(A) 1.64 m/s (B) 0.95 m/s
(C) 1.98 m/s (D) 2.46 m/s

27. A rotor has a mass of 15 kg and is mounted midway on a horizontal shaft supported at the ends by two bearings. The shaft rotates at 3000 rpm. If the center of mass of the rotor is 0.15 mm away from the geometric center of the rotor due to a certain manufacturing defect and the natural frequency is given as 115 rad/sec then the dynamic force transmitted to the bearing (in N) will be
(A) 45.34 (B) 28.39
(C) 52.35 (D) 34.36

28. *PQRS* is a mechanism with link lengths *PQ* = 200, *QR* = 300, *RS* = 400 and *SP* = 350. Which one of the following link should be fixed for the resulting mechanism to be a double crank mechanism? (All lengths are in mm)
(A) *QR* (B) *RS*
(C) *PQ* (D) *SP*

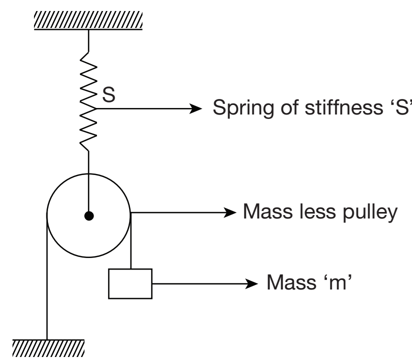
29. If the annular wheel of an epicyclic gear train has 100 teeth and the planet wheel has 25 teeth, the number of teeth on the sun wheel is
(A) 100 (B) 25
(C) 75 (D) 50

30. An ISA 300 × 150 × 15 angle is welded to a steel plate by means of fillet welds as shown in figure. Determine the length of weld at the top (in mm). (Assume permissible shear stress for the weld as 80 N/mm)



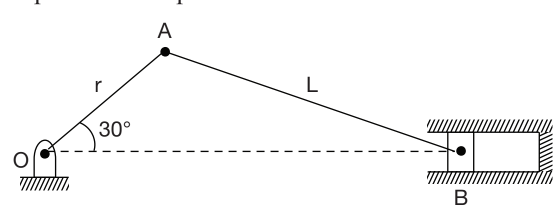
(A) 59.341 (B) 62.864
(C) 69.368 (D) 72.646

31. Determine the natural frequency of the given system shown below.



(A) $\sqrt{\dfrac{gS}{4mg}}$ (B) $\sqrt{\dfrac{gS}{2mg}}$
(C) $\sqrt{\dfrac{gS}{mg}}$ (D) $\sqrt{\dfrac{gS}{6mg}}$

Common Data Question 32 and 33:
A single slider crank mechanism is shown below. Crank rotates at speed of 400 rpm.



Given that r = 100 mm and L = 400 mm.

32. Determine the approximate velocity of piston in m/s.
(A) 4.1 (B) 6.3
(C) 3.0 (D) 2.6

33. Determine the approximate acceleration of piston in m/s^2
(A) 173.9 (B) 124.6
(C) 139.4 (D) 166.7

Linked Data Question 34 and 35:
A uniform rigid rod of mass, $m = 2$ kg and length, $\ell = 2$ m is hinged at its centre and laterally supported at one end by a spring of spring constant $(K) = 400$ N/m.

34. The equivalent spring stiffness in the vibration equation is given by
(A) 400 N-m (B) 200 N-m
(C) 200 N-m (D) 400 N-m

35. The natural frequency of oscillation of the rod about the hinge point is
(A) 32.5 rad/sec (B) 24.4 rad/sec
(C) 19.6 rad/sec (D) 12.25 rad/sec

Answer Keys

1. C	**2.** B	**3.** D	**4.** D	**5.** B	**6.** A	**7.** C	**8.** B	**9.** C	**10.** C
11. A	**12.** D	**13.** B	**14.** B	**15.** C	**16.** A	**17.** C	**18.** D	**19.** B	**20.** D
21. A	**22.** C	**23.** D	**24.** A	**25.** B	**26.** A	**27.** D	**28.** C	**29.** D	**30.** B
31. A	**32.** C	**33.** A	**34.** D	**35.** B					

Hints and Explanations

1. Critical speed $= \omega = \sqrt{\dfrac{k}{m}}$ Choice (C)

2. $\omega_n = \sqrt{\dfrac{k}{m+\dfrac{m_s}{3}}} = \sqrt{\dfrac{11200}{6+\dfrac{3}{3}}}$

$\omega_n = 40$ rad/sec Choice (B)

3. D.O.F $= 3(L-1) - 2J - h$ (kutzbach's equation)
$\Rightarrow$ D.O.F $= 3(5-1) - 2(6) = 0$
L = Number of links = 5
J = Number of binary joints = 6
h = Number of higher pair = 0 Choice (D)

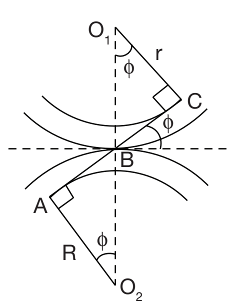
4. $n = D_1 + D_2 - 1 = 8 + 7 - 1$
$\Rightarrow$ $n = 14$ Choice (D)

6. At $\dfrac{\omega}{\omega_n} < \sqrt{2};\ \in > 1$

$\dfrac{\omega}{\omega_n} = 0;\ \in = 1$ *and* $\dfrac{\omega}{\omega_n} > \sqrt{2};\ \in < 1$ Choice (A)

7. $E_f = E_d + A_3 - A_4 \Rightarrow E_f = 96 + 10 - 6 = 100$ units
Choice (C)

8.



ϕ = constant
$\text{Sin}(90 - \phi) = r/O_1B$

$\Rightarrow$ $O_1B = \dfrac{r}{\cos\varphi}$

Similarly, $O_2B = \dfrac{R}{\cos\varphi}$

Center distance $= O_1B + O_2B$

$= \dfrac{(r+R)}{\cos\varphi}$ Choice (B)

9. Axle is use to support the wheel only and has no role in transmitting power. Hence axle is subjected to bending moment only. Choice (C)

10. Average Pressure $(P) = \dfrac{\text{Load }(W)}{\text{Projected area }(A)}$

$\Rightarrow P = \dfrac{W}{LD} = \dfrac{250}{5\times 50} = 1\dfrac{\text{kN}}{\text{cm}^2}$ Choice (C)

11. Choice (A)

12. In case of power transmission, through a clutch, it is safer to use the uniform wear theory.
$\text{F} = 2\pi\, P\, R_i\left(R_o - \text{R}_\text{i}\right)\times n$
$\Rightarrow$ $F = 2\pi \times 100 \times 10^3 \times 0.18(0.2 - 0.18) \times 2$
$\Rightarrow$ $F = 4.524$ kN Choice (D)

13. $\omega_n = \sqrt{\dfrac{S}{m}} = \sqrt{\dfrac{16\times 1000}{26}} = 24.807\text{ rad/sec}$

$C = 2m\omega_n\xi$
$\Rightarrow$ $200 = 2 \times 26 \times 24.807 \times \xi$
$\Rightarrow$ $\xi = 0.155$

$\omega_d = \sqrt{1-\xi^2} \times \omega_n$

$\Rightarrow \omega_d = \sqrt{1-0.155^2} \times 24.807$

$\Rightarrow$ $\omega_d = 24.51$ rad/sec Choice (B)

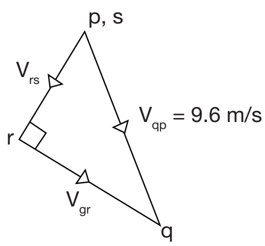
14. In option 1 and 2, external force is applied to connect the two elements of a pair and hence known as force-closed pair. Choice (B)

15. Angular velocity of connecting rod, $\omega_c = \dfrac{\omega\cos\theta}{\sqrt{n^2 - \text{Sin}^2\theta}}$

At $\theta = 90^o$; $\text{Cos}\theta = 0$

$\therefore\quad \omega_c = 0$ Choice (C)

16. **Velocity Diagram**



Given:- $V_{rs} = 4$ m/s

V_{qr} = sliding velocity

$V_{qp}^2 = V_{rs}^2 + V_{qr}^2$

$\Rightarrow\quad 9.6^2 = 4^2 + V_{qr}^2$

$\Rightarrow\quad V_{qr} = 8.727$ m/s Choice (A)

17. Circular pitch = $\pi\, m = \pi \times 2.5 = 7.854$ mm

Pitch line velocity, $V_p = \omega r$

$$V_p = \frac{2\pi N}{60} \times \frac{d}{2}$$

$$\Rightarrow V_p = \frac{2\pi \times 250}{60} \times \frac{mT}{2}$$

$$\Rightarrow V_p = \frac{\pi \times 250}{60} \times 2.5 \times 50$$

$\Rightarrow\quad V_p = 1636.2$ mm/sec Choice (C)

18. $$T_{mean} = \frac{1}{2\pi/3}\int_0^{2\pi/3} \left(1200 + 200\,\text{Sin}\,3\theta\right) d\theta$$

$$\Rightarrow T_{mean} = \frac{3}{2\pi}\left[1200\theta - \frac{200}{3}\text{Cos}\,3\theta\right]_0^{2\pi/3}$$

$\Rightarrow\quad T_{mean} = 1200$ N-m

Power = $T_{mean} \times \omega$

$= 1200 \times \dfrac{2\times\pi\times 400}{60} = 50.266$ kW Choice (D)

19. $\dfrac{T_1}{T_2} = e^{\mu\theta} \Rightarrow \dfrac{T_1}{T_2} = e^{0.25\times 270\times\frac{\pi}{180}}$

$\Rightarrow\quad T_1 = 3.25\, T_2$ (1)

For equilibrium, $(T_1 - T_2)R = W \times r$

$(T_1 - T_2) = \dfrac{2\times 1000\times 0.5}{0.8}$

$T_1 - T_2 = 1250$ (2)

From equation (1) and (2) we get

$T_1 = 1805.56$ N and $T_2 = 555.56$ N

Taking moment about o

$(F \times \ell) - (T_1 \times a) = 0$

$\Rightarrow\quad (F \times 0.8) = (1805.56 \times 0.2)$

$\Rightarrow\quad F = 451.4$ N Choice (B)

20. $I = \dfrac{\pi}{64}\times d^4 = \dfrac{\pi}{64}\times 0.04^4 = 1.256\times 10^{-7}\ \text{m}^4$

$$f_n = \frac{1}{2\pi}\sqrt{\frac{g}{\Delta}}$$

$$\Delta = \frac{mg\,a^2\,b^2}{3\,EIL} = \frac{150\times 9.81\times 0.3^2\times 0.5^2}{3\times 200\times 10^9\times 1.256\times 10^{-7}\times 0.8}$$

$\Rightarrow\quad \Delta = 5.492 \times 10^{-4}$ m

$f_n = \dfrac{1}{2\pi}\sqrt{\dfrac{9.81}{5.492\times 10^{-4}}} = 21.3$ Hz Choice (D)

21. $k_f = 1 + q(k_t - 1)$

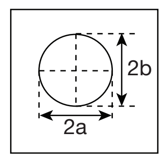
$$\Rightarrow q = \frac{(k_f - 1)}{(k_t - 1)}$$

k_f = fatigue stress concentration factor

k_t = geometric stress concentration factor

q = notch sensitivity

k_t for circle



$$k_t = 1 + \frac{2\text{b}}{\text{a}} = 1 + \frac{d}{d/2}$$

$\Rightarrow\quad k_t = 3$

$\therefore q = \dfrac{(2-1)}{(3-1)}$

$\Rightarrow\quad q = 0.5$ Choice (A)

22. Dynamic load carrying capacity, $C = P(L_{10})^{1/3}$

Now, equivalent load for complete work cycle (P)

$N_1 = \dfrac{1200}{4} = 300\,\text{rev}$

$N_2 = \dfrac{1000}{2} = 500\,\text{rev}$

$N_3 = \dfrac{1400}{4} = 350\,\text{rev}$, $n = 300 + 500 + 350 = 1150$ rpm

$$P = \sqrt[3]{\left[\frac{N_1P_1^3 + N_2P_2^3 + N_3P_3^3}{N_1 + N_2 + N_3}\right]}$$

$$\Rightarrow P = \sqrt[3]{\left[\frac{300(2000)^3 + 500(4000)^3 + 350(2500)^3}{(300+500+350)}\right]}$$

$\Rightarrow\quad P = 3260.7$ N

$L_{10} = \dfrac{60\times n\times 12000}{10^6} = \dfrac{60\times 1150\times 12000}{10^6} = 828\,\text{mr}$

$\therefore\quad C = 3260.7(828)^{1/3}$

$\Rightarrow\quad C = 30619$ N Choice (C)

23. Power (p) = $\dfrac{2\pi NT}{60\times1000}$

$\Rightarrow \dfrac{40\times60\times1000}{2\times\pi\times600} = T$

$\Rightarrow T = T = 636.62$ N.m

Now, $T = \dfrac{\pi\mu p\,d}{8\sin\alpha}(D^2 - d^2)$

$\Rightarrow 636.62 = \dfrac{\pi\times0.25\times107\times10^3\times0.35}{8\times\sin(\alpha)}(0.4^2 - 0.35^2)$

Sin $\alpha = 0.21658 \Rightarrow \alpha = 12.5°$ Choice (D)

24. Choice (A)

25. (Total Length) $L = \dfrac{200\times10^3}{350} = 571.43$ mm

Now, $L = (2\times\ell) + 100$

$(2\times\ell) + 100 = 571.43$

$\Rightarrow \ell = 235.715$ mm

Adding 15 mm for starting and stopping of weld run we get

$\ell = 235.715 + 15$

$\ell = 250.715$ mm Choice (B)

26. Velocity of sliding = $(\omega_p + \omega_g)$ × Path of recess

Path of recess = $\sqrt{r_a^2 - (r\cos\varphi)^2} - r\mathrm{Sin}\theta$

$r_a = \dfrac{mt}{2} + 5 = \dfrac{5\times30}{2} + 5 = 80$ mm

$r = \dfrac{mt}{2} = 75$ mm

Path of recess = $\sqrt{80^2 - (75\times\mathrm{Cos}20)^2} - (75\times\mathrm{Sin}20)$

= 12.2 mm

$\therefore$ Velocity of sliding $= 2\pi\,(N_p + N_g)\times 12.2$

$N_g = N_p \times \dfrac{t}{T} = 800\times\dfrac{30}{50} = 480$ rpm

$\therefore$ Velocity of sliding $= 2\pi\left(\dfrac{800 + 480}{60}\right)\times 12.2$

$\times 10^{-3}$

= 1.64 m/s Choice (A)

27. $y = \dfrac{e}{\left(\dfrac{\omega_n}{\omega}\right)^2 - 1} = \dfrac{0.15}{\left(\dfrac{115\times60}{2\times\pi\times3000}\right)^2 - 1}$

$\Rightarrow y = 0.1732$ mm

Dynamic force on the bearing = sy

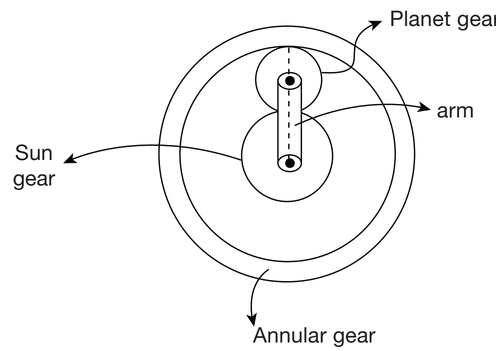
$= m\,\omega_n^2 y$

$= 15 \times 115^2 \times 0.1732 \times 10^{-3}$

= 34.36 N Choice (D)

28. For double crank mechanism always shortest link will be fixed. Therefore PQ will be fixed. Choice (C)

29.



$\dfrac{100}{2} = 25 + \dfrac{T_1}{2}$

$\Rightarrow T_s = 50$ teeth Choice (D)

30. **Total Length:** $P = 0.707\,hL\tau$

$200\times10^3 = 0.707\times(15)\times L\times 80$

$\Rightarrow L = 235.74$ mm

Now $L_1y_1 = L_2y_2$

$\Rightarrow L_1\times(300 - 80) = L_2\times 80$

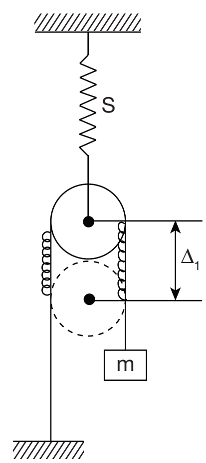
$\therefore L_1 = 0.3636\,L_2$

and $L_1 + L_2 = 235.74$

$\therefore L_1 + \dfrac{L_1}{0.3636} = 235.74 \Rightarrow L_1 = 62.864$ mm

Choice (B)

31.



$\omega_n = \sqrt{\dfrac{g}{\Delta}}$

$\Delta_1 = \dfrac{\text{Force}}{\text{Stiffness}} = \dfrac{2mg}{S}$

$\Delta = 2\Delta_1 = \dfrac{4mg}{S}$

$\therefore \omega_n = \sqrt{\dfrac{gS}{4mg}}$ Choice (A)

32. $V_{\text{approx}} = r\omega[\text{Sin}\theta + \dfrac{\text{Sin}\,2\theta}{n}]$

$$n = \frac{L}{r} = 4$$

$$\Rightarrow V_{approx} = \frac{0.1\times 2\times\pi\times 400}{60}\times\left[\text{Sin}\,30 + \frac{\text{Sin}\,60}{4}\right]$$

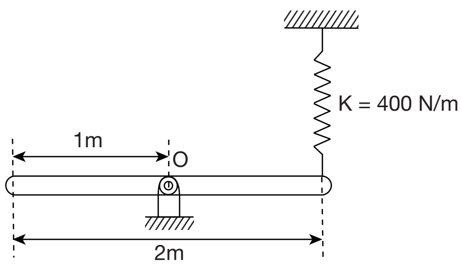
$\Rightarrow \quad V_{\text{approx}} = 3$ m/s Choice (C)

33. $a_{\text{approx}} = r\omega^2\left[\cos\theta + \dfrac{\cos 2\theta}{n}\right]$

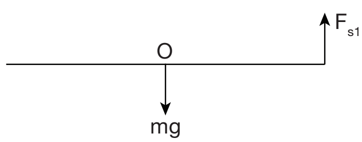
$$= 0.1\times\left[\frac{2\pi\times 400}{60}\right]^2\times\left[\text{Cos}\,30 + \frac{\text{Cos}\,60}{4}\right]$$

$a_{\text{approx}} = 173.9$ m/s^2 Choice (A)

34.

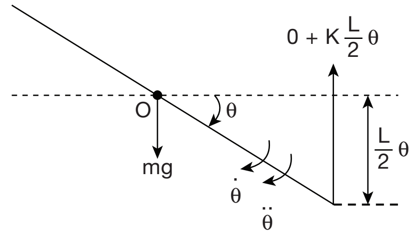


Static Free body diagram



$\Sigma M_o = 0 \Rightarrow F_{s1} = 0$

Dynamic Free body diagram



$$\left[K\frac{L}{2}\theta\right]\frac{L}{2} = I_o\left(-\ddot{\theta}\right) \qquad \{\Sigma M_o = I_o\alpha\}$$

$$I_o\ddot{\theta} + \frac{KL^2}{4}\theta = 0$$

Comparing with $m\ddot{x} + kx = 0$

$$\therefore K_e = \frac{KL^2}{4} = \frac{400\times 2^2}{4} = 400 \text{ N-m}$$ Choice (D)

35. $\omega_n = \sqrt{\dfrac{K_e}{m}} = \sqrt{\dfrac{400}{I_o}}$

$$I_o = \frac{mL^2}{12} = \frac{2\times 2^2}{12} = 0.67$$

$\therefore \quad \omega_n = \sqrt{\dfrac{400}{0.67}} = 24.4$ rad/sec Choice (B)