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Important Questions for GATE 2022

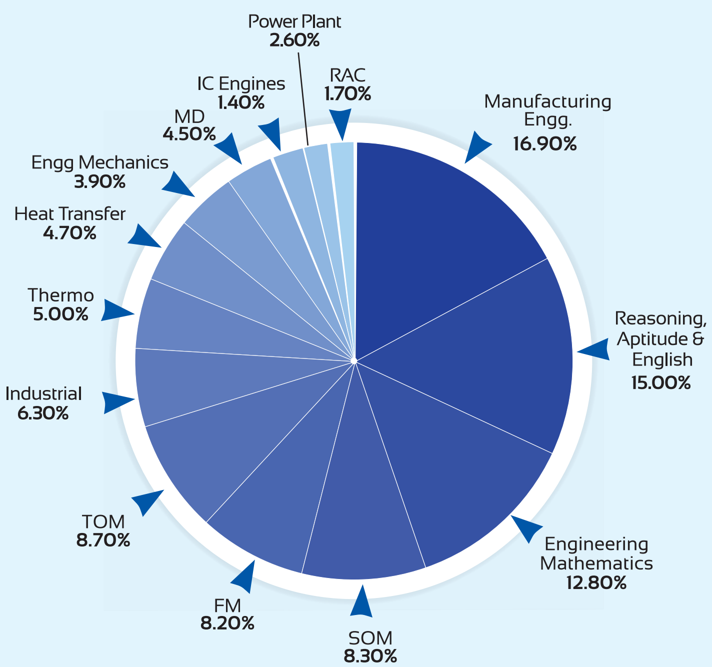
MECHANICAL ENGINEERING

Day 3 of 8

Q.51 - Q.75 (Out of 200 Questions)

Theory of Machines + Machine Design

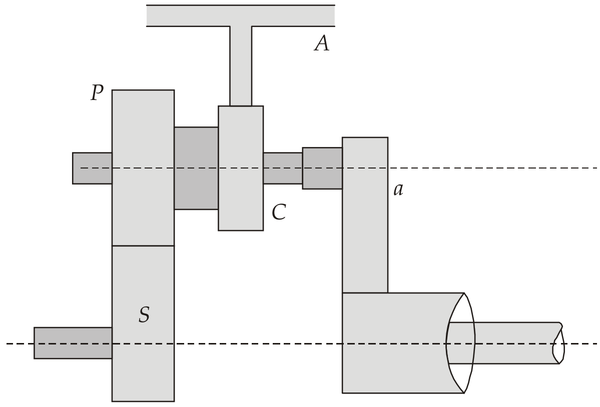
SUBJECT-WISE WEIGHTAGE ANALYSIS OF GATE SYLLABUS



Subject	Average % (last 5 yrs)
Manufacturing Engineering	16.90%
Reasoning, Aptitude & English	15.00%
Engineering Mathematics	12.80%
Strength of Materials	8.30%
Theory of Machines	8.70%
Fluid Mechanics & Hydraulic Machines	8.20%
Industrial Engineering	6.30%
Thermodynamics	5.00%
Heat Transfer	4.70%
Engineering Mechanics	3.90%
Machine Design	4.50%
Internal Combustion Engines	1.40%
Power Plant Engineering	2.60%
Refrigeration & Air Conditioning	1.70%
Total	**100%**

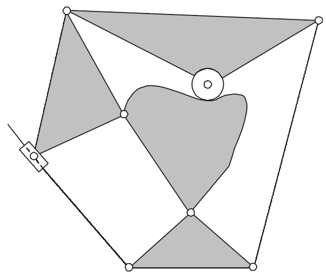
Theory of Machines + Machine Design

Q.51 For the gear train as shown in figure, T_S = 24, T_P = 30, T_C = 18, T_A = 90. P and C form a compound gear carried by the arm a and annular gear A is held stationary. The fixing torque required on A, if 5 kW is delivered to S at 800 rpm with an efficiency of 90%?



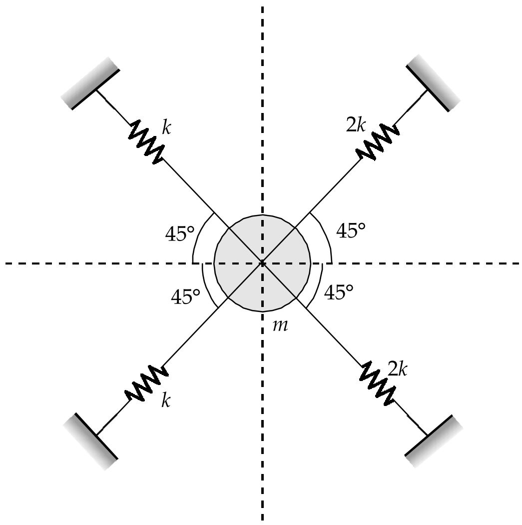
(a) 459 Nm
(b) 521 Nm
(c) 224 Nm
(d) 329.86 Nm

Q.52 Degree of freedom of the linkage shown in figure is



(a) 0
(b) 2
(c) 1
(d) – 1

Q.53 A mass is connected with four springs as shown in the figure. For small disturbances in the horizontal direction the natural frequency of the system is



(a) $\sqrt{\frac{k}{m}}$ (b) $\sqrt{\frac{2k}{m}}$

(c) $\sqrt{\frac{3k}{m}}$ (d) $\sqrt{\frac{4k}{m}}$

Q.54 A single cylinder engine is supported on springs and dashpots. The mass of engine and the reciprocating parts is 400 kg and 15 kg respectively. The static deflection of spring due to system's weight is 50 mm. If the stroke of the engine is 200 mm and the ratio of consecutive amplitudes in free vibration is 1 : 0.42, the force transmitted to the ground at 250 rpm will be

(a) 224 N (b) 172 N

(c) 453 N (d) 327 N

Q.55 The crank and connecting rod of a vertical petrol engine, running at 1800 rpm are 60 mm and 270 mm respectively. The mass of reciprocating parts is 1.2 kg and the mass of connecting rod is negligible. During expansion stroke when the crank has turned 20° from the TDC, the magnitude of turning moment on the crankshaft will be ______N-m. [Correct upto two decimal places]

Q.56 The following data related to a cam profile in which the follower moves with uniform acceleration and deceleration during ascent and descent are given

Lift = 25 mm

Offset of follower axis = 12 mm towards right

Angle of ascent = 60°

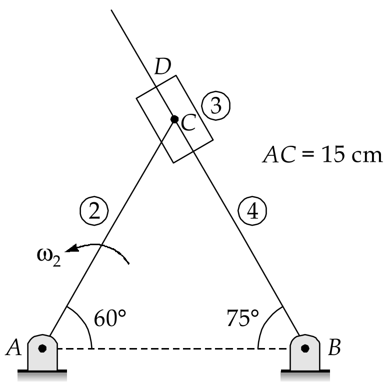
Angle of descent = 90°

Dwell angle between ascent and descent = 45°

Speed of the cam = 300 rpm

The ratio of uniform acceleration of the follower during the outstroke and return stroke will be_________. (Correct upto two decimal places)

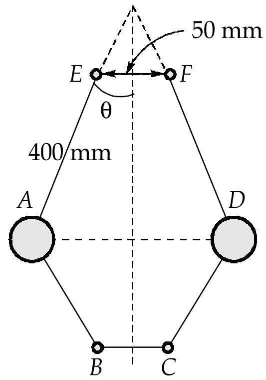
Q.57 In the mechanism shown below, the angular velocity of link 2 is 4 rad/s CCW. What is the velocity of slider (link 3) with respect to link 4?



(a) 0.3 m/s (b) 0.42 m/s

(c) 0.6 m/s (d) Information is insufficient.

Q.58 In an open-arm type Watt governor, AE = 400 mm, EF = 50 mm and angle, θ = 35°. The percentage decrease in speed when θ decreases to 30° is



(a) 0.966%
(b) 2.04%
(c) 3.44%
(d) 5.41%

Q.59 A flywheel is used to given up 18 kJ of energy in reducing its speed from 100 rpm to 98 rpm, then its kinetic energy at 140 rpm will be _________ kJ.(Correct upto two decimal places)

Q.60 The turning moment diagram for a petrol engine is drawn to a vertical scale of 1 mm = 600 Nm and a horizontal scale of 1 mm = 3°. The turning moment diagram repeats itself after every half revolution of the crankshaft. The areas above and below the mean torque line are 320, –680, 140, –520, 1045 and –305 mm^2. The rotating parts have a mass of 60 kg and radius of gyration of 2.4 m. If the engine speed is 1800 rpm, then the coefficient of fluctuation of speed will be __________%. (Correct upto three decimal places)

Q.61 The rotor of the turbine of a ship has a mass of 2550 kg and rotates at a speed of 3000 rpm counterclockwise when viewed from stern. The rotor has radius of gyration of 0.4 m. What will be the gyroscopic couple, if ship pitches 6 degrees above and 6 degrees below the normal position and the bow is descending with its maximum velocity and the pitching motion is simple harmonic with a periodic time of 50 seconds?

(a) 1285.53 Nm
(b) 18106.7 Nm
(c) 1685.53 Nm
(d) 16106.7 Nm

Q.62 The controlling force F (in N) and r the radius of rotation r (in mm) for a spring loaded governor are related by the expression

$F = 6r - 144$

Each ball has a mass of 20 kg and the extreme radii of ball rotation are 150 mm and 240 mm respectively. The minimum equilibrium speed is

(a) 151.59 rpm
(b) 153.59 rpm
(c) 156.9 rpm
(d) 161.59 rpm

Q.63 Two gears with stub-teeth of addendum 0.84 times module are engaged when the tangential force is 0.95 times the total force. The minimum number of teeth on gear and pinion to avoid the undercutting for the gear ratio of 3 are, respectively

(a) 42 and 14
(b) 48 and 16
(c) 51 and 17
(d) 54 and 18

Q.64 A rotating disc of 1 m diameter has two eccentric masses of 0.8 kg each at radii of 40 mm and 50 mm at angular positions of 0° and 150°, respectively. A balancing mass of 0.1 kg is to be used to balance the rotor. The radial position of the balancing mass is

(a) 201.7 mm
(b) 208.7 mm
(c) 210.9 mm
(d) 211.9 mm

Q.65 For a reciprocating engine running at 750 rpm, it is observed that the maximum magnitude of primary forces is 600 N. If the crank and connecting rod are having lengths of 220 mm and 1100 mm respectively, the maximum magnitude of secondary force is ________.

Q.66 Which of the following is/are the methods to prevent interference in gears?

(a) Stubbing the gear teeth
(b) Undercutting the gears
(c) Decreasing pressure angle
(d) Increasing number of teeth

Q.67 A flywheel running at 700 rpm has a safe hoop stress of 3.872 MPa. If the density of the rim material is 8000 kg/m^3, then which of the statements is/are correct?

(a) Rim velocity of flywheel is 22 m/s.
(b) Rim velocity of flywheel is 44 m/s.
(c) Suitable diameter of flywheel is 0.6 m.
(d) Suitable diameter of flywheel is 0.8 m.

Q.68 A single plate clutch consists of one pair of frictional contact surfaces. Because of space limitations, the outer diameter of the plate is fixed as D. The permissible intensity of pressure is P and the coefficient of friction between plates is μ. Assuming uniform wear theory, the ratio $\left(\frac{d}{D}\right)$ for which the torque transmitting capacity of the clutch is maximum is (d is the inner diameter of the friction plate)

(a) 0.577
(b) 0.333
(c) 0.693
(d) 0.707

Q.69 A rotating bar made of steel 45C8(S_{ut} = 630 N/mm^2) is subjected to a completely reversed bending stress. The corrected endurance limit of the bar is 315 N/mm^2, the fatigue strength of the bar for a life of 90000 cycles is

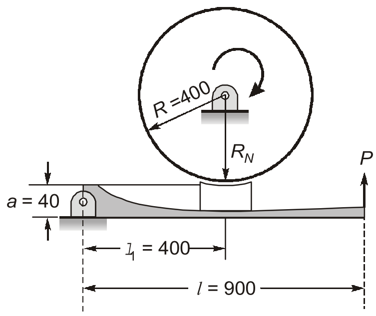
(a) 387 N/mm^2
(b) 316 N/mm^2
(c) 351 N/mm^2
(d) 332 N/mm^2

Q.70 A cylindrical pressure vessel is joined by lap joint. Pressure inside vessel is 10 MPa. The inner diameter is 100 mm and thickness is 16 mm. What are the number of rivets required per unit length if diameter of rivet is 25 mm and yield shear stress is 200 MPa? (Take FOS = 2)

(a) 35
(b) 21
(c) 16
(d) 18

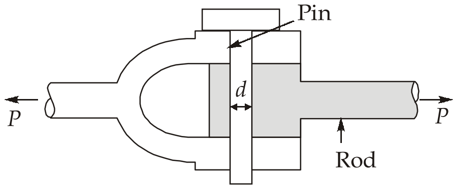
Q.71 In a taper roller bearing if load is increased by 25%, then life of the bearing will be reduced by _____%. (Correct up to two decimal places)

Q.72 A 400 mm radius brake drum contacts a single shoe as shown below and sustains 225 Nm torque at 500 rpm. If coefficient of friction is 0.3, then the required force P to apply the brake for clockwise rotation is ________ N. [Correct upto 1 decimal place]



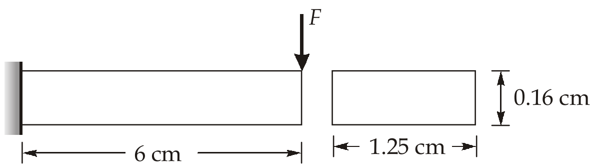
(All dimensions are in mm)

Q.73 Two rods are connected by means of a pin joint. The axial force P acting on the rod is 25 kN. The rods are made of plain carbon steel 45C8 (S_{yt} = 380 N/mm^2) and the factor of safety is 2.5. Take the allowable shear stress based on distortion energy theory. What is the diameter of the pin?



(a) 14.47 mm
(b) 9.152 mm
(c) 19.05 mm
(d) 13.47 mm

Q.74 For the cantilever beam shown in figure, which is acted upon by a fluctuating tip force (F) varying between 10.8 N and 25.2 N. The ultimate strength of the material is 595 MPa. Endurance strength of the material and yield strength are 229 MPa and 270 MPa respectively. The factor of safety using the Goodman theory is ____________. (Correct upto 2 decimal place)



Multiple Select Question (MSQ)

Q.75 A closed coiled helical spring absorbs 72 Nm of energy when compressed through 60 mm. There are 8 coils in the spring. The coil diameter is 10 times the wire diameter then which of the statements is/are correct? [Take G = 82 GPa]

(a) Maximum shear stress is 125.6 MPa.
(b) Maximum shear stress is 62.8 MPa.
(c) The coil diameter is 312 mm.
(d) The coil diameter is 156 mm.

■■■■

Detailed Explanation

51. (d)

Taking clockwise direction as positive.

Action	Arm	S(24)	P(30) and C(18)	A(90)
Fix arm and give $+x$ rotation to S	0	$+x$	$-x \times \frac{24}{30} = -0.8x$	$-0.8x \times \frac{18}{90} = -0.16x$
Give $+y$ rotation to arm	y	$y + x$	$y - 0.8x$	$y - 0.16x$

$$N_A = y - 0.16x$$

If A is fixed, $N_A = 0$

$\therefore \quad y = 0.16x \qquad \text{... (i)}$

$$N_S = 800$$

$y + x = 800 \qquad \text{... (ii)}$

From equation (i) and (ii),

$$x = 689.65 \text{ rpm}$$

$$N_{arm} = y = 110.34 \text{ rpm}$$

$$T_S = \frac{\text{Power input}}{\frac{2\pi N_s}{60}} = \frac{5000}{\frac{2 \times \pi \times 800}{60}} = 59.7 \text{ Nm}$$

$$T_A N_A^{\nearrow 0} + T_S N_S + \frac{T_{arm} N_{arm}}{\eta} = 0$$

$$59.7 \times 800 + \frac{T_{arm}}{0.9} \times 110.34 = 0$$

$$T_{arm} = -389.56 \text{ Nm}$$

$$\text{Net torque} = 0$$

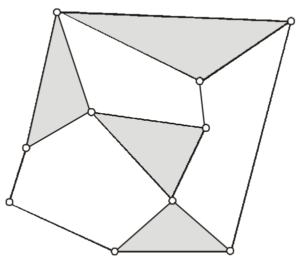
$$T_S + T_{arm} + T_{fix} = 0$$

$$59.7 - 389.56 + T_{fix} = 0$$

$$T_{fix} = 329.86 \text{ Nm}$$

52. (c)

Equivalent linkage of the linkage given in question is



$$DOF = N - (2L + 1)$$

Total number of links, $N = 8$

Total number of loops, $L = 3$

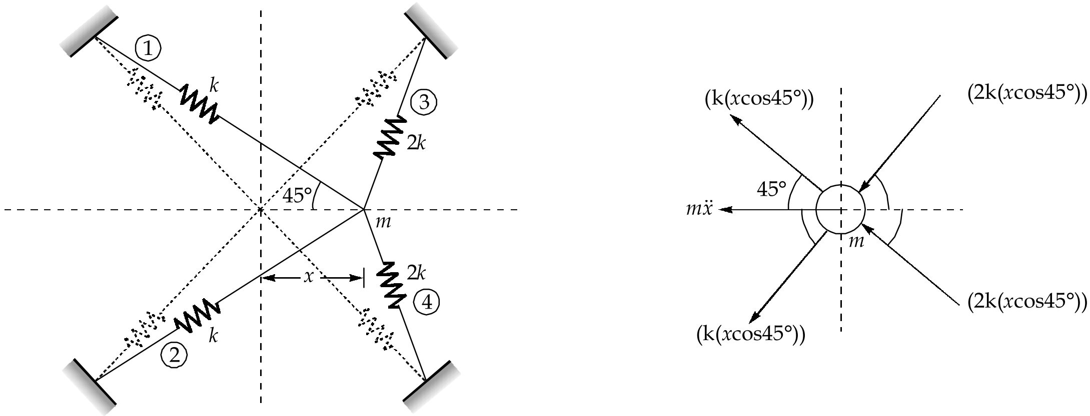
$$DOF = 8 - [2 \times 3 + 1] = 1$$

or $\quad \text{DOF} = 3(N-1) - 2j - h - F_r$

$= 3(7) - 2 \times 10 - 0 - 0 = 21 - 20 = 1$

53. **(c)**

Considering small displacement 'x' of mass in right direction.



From the figure, for small x, the extension in the springs (1) and (2) is $x\cos 45°$ and compression in the springs (3) and (4) is $x\cos 45°$.

By D'Alembert's principle

$$m\ddot{x} + x\cos 45°(k + k + 2k + 2k)\cos 45° = 0$$

$$m\ddot{x} + 3kx = 0$$

$$\omega_n = \sqrt{\frac{3k}{m}}$$

54. **(c)**

$$\omega_n = \sqrt{\frac{g}{\Delta_{static}}} = \sqrt{\frac{9.81}{0.05}} = 14 \text{ rad/s}$$

$$\omega_n = \sqrt{\frac{k}{m}} = 14 \Rightarrow k = (14)^2 \times m$$

$$= 14^2 \times 200 = 78400 \text{ N/m}$$

Ratio of consecutive amplitude, $e^{\delta} = 1 : 0.42$

$$\delta = \ln\left(\frac{1}{0.42}\right)$$

$$\frac{2\pi\zeta}{\sqrt{1-\zeta^2}} = \ln\left(\frac{1}{0.42}\right) \Rightarrow \zeta = 0.1367$$

Now, $\quad F_{un} = m_{reci} \times \left(\frac{\text{Stroke}}{2}\right) \times \left(\frac{2\pi \times 250}{60}\right)^2$

$$F_{un} = 15 \times \left(\frac{0.200}{2}\right)\left(\frac{2\pi \times 250}{60}\right)^2$$

$$F_{un} = 1028.08 \text{ N}$$

$$\omega = \frac{2\pi \times 250}{60} = 26.18 \text{ rad/s}$$

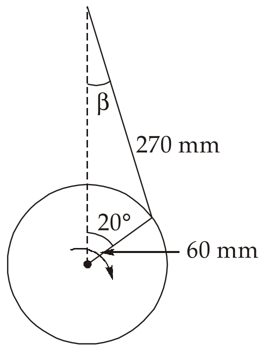
$$\text{Transmissibility, } \tau = \frac{\sqrt{1+\left(2\zeta\frac{\omega}{\omega_n}\right)^2}}{\sqrt{\left(1-\left(\frac{\omega}{\omega_n}\right)^2\right)^2+\left(2\zeta\frac{\omega}{\omega_n}\right)^2}}$$

$$\tau = \frac{\sqrt{1+\left(2\times 0.1367\times\frac{26.18}{14}\right)^2}}{\sqrt{\left(1-\left(\frac{26.18}{14}\right)^2\right)^2+\left(2\times 0.1367\times\frac{26.18}{14}\right)^2}}$$

$$\tau = 0.4407$$

So, $F_{\text{transmitted}} = \tau \times F_{un} = 453 \text{ N}$

55. (70.185) (69 to 71)



$$\omega = \frac{2\pi N}{60} = \frac{2\pi \times 1800}{60} = 188.5 \text{ rad/s}$$

$$\sin\beta = \frac{\sin\theta}{n} \quad [\because \theta = 20°]$$

$$n = \frac{l}{r} \Rightarrow \frac{270}{60} = 4.5$$

$$\sin\beta = \frac{\sin 20}{4.5} = 0.076$$

$$\beta = 4.36°$$

Inertia force on piston, $F_I = -ma = -m \times r\omega^2\left(\cos\theta + \frac{\cos 2\theta}{n}\right)$

$$= -1.2 \times 0.06 \times 188.5^2\left(\cos 20 + \frac{\cos 40}{45}\right) = -2839.544 \text{ N}$$

Force due to weight of reciprocating parts,

$$F_w = mg = 1.2 \times 9.81 = 11.772 \text{ N}$$

Net force, $F_{net} = F_I + F_w = -2839.544 + 11.772$

$$= -2827.772\text{N}$$

$$\text{Turning moment (T)} = F_{net}\frac{\sin(\theta+\beta)}{\cos\beta}\times r = \frac{-2827.772\times\sin(20+4.36)}{\cos 4.36}\times 0.06$$

$$T = -70.185 \text{ Nm} = 70.185 \text{ N-m (Only magnitude)}$$

56. (2.25)(2.24 to 2.26)

Given, Lift, h = 25 mm

Offset, x = 12 mm

Speed, N = 300 rpm

$$\omega = \frac{2\pi N}{60} = \frac{2\pi \times 300}{60} = 10\pi \text{ rad/s}$$

Ascent angle, ϕ_a = 60°

Descent angle, ϕ_d = 90°

Dwell angle, δ_1 = 45°

Now, δ_2 = 360° – (60° + 90° + 45°) = 165°

During out stroke:

$$(a_{\text{uniform}})_{o.s} = \frac{4h\omega^2}{\phi_a^2} = \frac{4 \times 25 \times (10\pi)^2 \times 10^{-3}}{\left(60 \times \frac{\pi}{180}\right)^2}$$

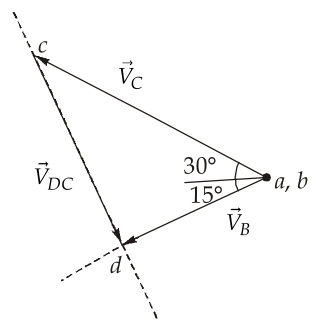
$$= 100 \times 100 \times 10^{-3} \times 9 = 90 \text{ m/s}^2$$

During return stroke:]

$$(a_{\text{uniform}})_{r.s} = \frac{4h\omega^2}{\phi_d^2} = \frac{4 \times 25 \times (10\pi)^2 \times 10^{-3}}{\left(90 \times \frac{\pi}{180}\right)^2} = 40 \text{ m/s}^2$$

$$\therefore \quad \frac{(a_{\text{uniform}})_{o.s}}{(a_{\text{uniform}})_{r.s}} = \frac{90}{40} = 2.25$$

57. (b)



Drawing velocity diagram,

From geometry, $\angle dca = \angle cad = 45°$

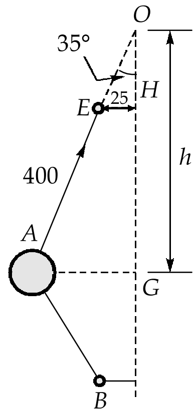
$$|\vec{V}_C| = \omega_2 AC = 4 \times 15 \text{ cm/s}$$

$$= 60 \text{ cm/s} = 0.6 \text{ m/s}$$

Velocity of slider wrt link 4 = $|\vec{V}_{CD}| = |\vec{V}_{DC}| = |\vec{V}_C| \sin 45°$

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

58. (c)



$$h = GO = GH + HO = AE\cos\theta + EH\cot\theta$$
$$h = 400\cos 35° + 25\cot 35° = 363.4 \text{ mm}$$
$$h' = 400\cos 30° + 25\cot 30° = 389.7 \text{ mm}$$

Now, $h = \dfrac{g}{\omega^2}$ and $h' = \dfrac{g}{\omega'^2}$

$$\frac{\omega'}{\omega} = \sqrt{\frac{h}{h'}} = \sqrt{\frac{363.4}{389.7}} = 0.966$$

Decrease in speed $= (1 - 0.966) \times 100 = 3.44\%$

59. (890.91)(845 to 930)

Given, $\Delta E = 18$ kJ
$N_1 = 100$ rpm
$N_2 = 98$ rpm

We know that, $\Delta E = \frac{1}{2}(I\omega_1^2) - \frac{1}{2}(I\omega_2^2) = \frac{1}{2}I(\omega_1^2 - \omega_2^2)$

$$18 \times 10^3 = \frac{I}{2} \times \left[\left(\frac{2\pi \times 100}{60}\right)^2 - \left(\frac{2\pi \times 98}{60}\right)^2\right]$$

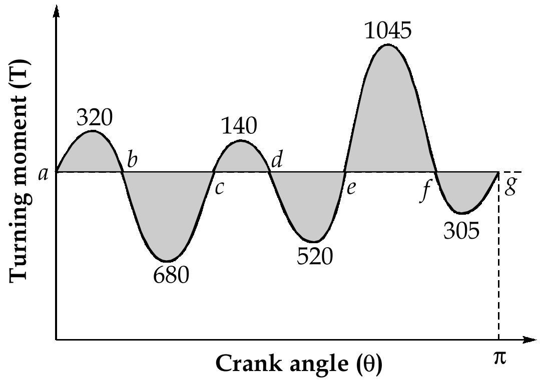
$$I = \frac{36 \times 10^3 \times 60^2}{4\pi^2(100^2 - 98^2)}$$

$$I = 8289.915 \text{ kgm}^2$$

Kinetic energy at 140 rpm, $E = \frac{1}{2}I\omega^2 = \frac{1}{2} \times 8289.915 \times \left(\frac{2\pi \times 140}{60}\right)^2 = 890909.088$ J

Kinetic energy at 140 rpm, $E = 890.91$ kJ

60. **(0.2712)(0.270 to 0.273)**



Let, flywheel kinetic energy at $a = E$

$$\begin{aligned}
\text{At } b &= E + 320\\
\text{At } c &= E + 320 - 680 = E - 360\\
\text{At } d &= E - 360 + 140 = E - 220\\
\text{At } e &= E - 220 - 520 = E - 740\\
\text{At } f &= E + 740 + 1045 = E + 305\\
\text{At } g &= E - 305 - 305 = E\\
\text{Maximum energy} &= E + 320\\
\text{Minimum energy} &= E - 740
\end{aligned}$$

Maximum fluctuation of energy,

$$\Delta E_{max} = [(E + 320) - (E - 740)] \times \text{Horizontal scale} \times \text{Vertical scale}$$

$$= 1060 \times \left(3 \times \frac{\pi}{180}\right) \times 600$$

$$\Delta E_{max} = 33300.88 \text{ Nm}$$

Coefficient of fluctuation of speed, $C_s = \frac{\Delta E_{max}}{I\omega^2} = \frac{(\Delta E)_{max}}{mk^2\omega^2}$

$$C_s = \left[\frac{33300.88}{60 \times (2.4)^2 \times \left(\frac{2\pi \times 1800}{60}\right)^2}\right] \times 100\% = 0.2712\%$$

61. **(c)**

$$\theta_o = 6 \times \frac{\pi}{180} \text{ rad}$$

Natural vibration, $T_n = 50$

$$\omega_n = \frac{2\pi}{50} = 0.12566 \text{ rad/s}$$

Now, SHM equation

$$\theta = \theta_o \sin(\omega_n t)$$

$$\omega_p = \frac{d\theta}{dt} = \theta_o \cos(\omega_n t) \cdot \omega_n = (\theta_o \omega_n) \cdot \cos \omega_n t$$

$$(\omega_p)_{max} = \theta_o \omega_n = \frac{6\pi}{180} \times 0.12566 = 0.01315 \text{ rad/s}$$

Gyroscopic couple, $C = I\omega\omega_p = (mk^2)\omega\omega_p$

$$= (2550\times0.4^2)\times\left(2\times\frac{\pi\times3000}{60}\right)\times0.01315$$

$$C = 1685.53 \text{ Nm}$$

62. (a)

At r = 150 mm, F = 6 × 150 – 144 = 756 N,

At r = 240 mm, F = 6 × 240 – 144 = 1296 N

$$F_1 = m\omega_1^2 r_1$$

$$\omega_1 = \sqrt{\frac{F_1}{mr_1}} = \sqrt{\frac{756}{20\times0.15}} = 15.8745 \text{ rad/s}$$

$$\omega_2 = \sqrt{\frac{F_2}{mr_2}} = \sqrt{\frac{1296}{20\times0.24}} = 16.4317 \text{ rad/s}$$

$$\omega_{min} = 15.8745 \text{ rad/s}$$

$$N_{min} = \frac{60\times\omega_{min}}{2\pi} = \frac{60\times15.8745}{2\pi} = 151.59 \text{ rpm}$$

63. (b)

a_w = 0.84, Pressure angle, $\phi = \cos^{-1}(0.95) = 18.195°$, G = 3

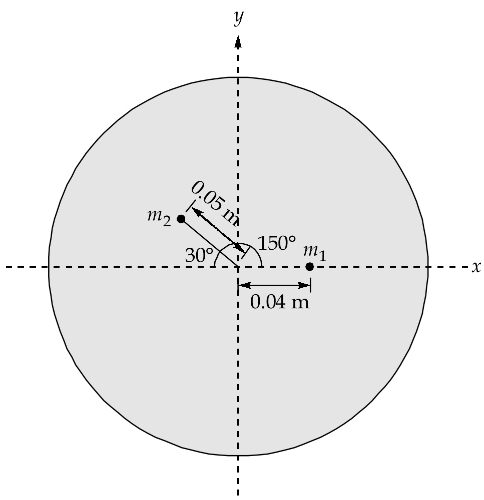
$$T = \frac{2a_w}{\sqrt{1+\frac{1}{G}\left(\frac{1}{G}+2\right)\sin^2\phi}-1} = \frac{2\times0.84}{\sqrt{1+\frac{1}{3}\left(\frac{1}{3}+2\right)\sin^2 18.195°}-1} = 45.14$$

Thus minimum number of teeth on gear = 46

Number of teeth on pinion $= \frac{46}{3} = 15.33$ *i.e.* 16

Number of teeth on gear = 16 × 3 = 48

64. (a)



Given: $m_1 = m_2$ = 0.8 kg, r_1 = 0.04 m, r_2 = 0.05 m, balancing mass m = 0.1 kg

$\Sigma F_x = 0$

$0.8\,[-0.05\cos 30° + 0.04\cos 0°]\omega^2 + 0.1\,\omega^2 x = 0$

$$0.8\,[-0.0433 + 0.04] + 0.1x = 0$$

$$x = 8 \times 3.3 \times 10^{-3}\text{ m} = 26.4\text{ mm}$$

$\Sigma F_y = 0$

$0.8\,[0.05\sin 30° + 0.04\sin 0°]\omega^2 + 0.1\,\omega^2 y = 0$

$$0.8 \times 0.05 \times \frac{1}{2} \times 1000 + y = 0$$

$$y = -200\text{ mm}$$

Position of balancing mass, $r = \sqrt{x^2 + y^2} = \sqrt{(26.4)^2 + (-200)^2} = 201.735\text{ mm}$

65. (120)(119 to 121)

As per given data: $(F_p)_{max} = 600$ N

$N = 750$ rpm

$r = 220$ mm

$l = 1100$ mm

$$(F_p)_{max} = mr\omega^2 = 600\text{ N} \quad \{F_p = mr\omega^2\cos\theta\}$$

$$(F_s) = \left(\frac{mr\omega^2\cos 2\theta}{n}\right)$$

$$(F_s)_{max} = \frac{mr\omega^2}{n}$$

$$n = \frac{l}{r} = \frac{1100}{220} = 5$$

$$(F_s)_{max} = \frac{(F_p)_{max}}{n} = \frac{600}{5} = 120\text{ N}$$

66. (a, b, d)

(i) Stubbing the gear teeth decreases the path of contact and contact ratio, thereby decreasing interference.

(ii) Undercutting of gear, eliminates interference, however weaken the gears.

(iii) Increasing pressure angle decreases interference.

(iv) Increasing number of teeth also decreases interference.

67. (a, c)

Rim velocity, $V = \sqrt{\frac{\sigma}{\rho}} = \sqrt{\frac{3.872 \times 10^6}{8000}} = 22$ m/s

$$V = \frac{\pi D N}{60}$$

$$\Rightarrow \quad D = \frac{V \times 60}{\pi \times N} = \frac{22 \times 60}{\pi \times 700}$$

$$D = 0.6\text{ m}$$

68. **(a)**

For uniform wear theory,

$$P = \frac{W}{2\pi R_i (R_o - R_i)}$$

$$T_f = \mu W\left(\frac{R_o + R_i}{2}\right) = \mu\pi P R_i \left(R_o^2 - R_i^2\right)$$

$$T_f = \mu\pi P R_i R_o^2 \left(1 - \frac{R_i^2}{R_o^2}\right)$$

Let, $\frac{R_i}{R_o} = x$

$\therefore$ $T_f = \mu\pi P R_o^3 \left[x\left(1 - x^2\right)\right]$

For maximum torque transmitting capacity,

$$\frac{\partial}{\partial x}(T_f) = 0$$

$\Rightarrow$ $\frac{\partial}{\partial x}(x - x^3) = 0$

$\Rightarrow$ $1 - 3x^2 = 0$

$\Rightarrow$ $x^2 = \frac{1}{3}$

$\Rightarrow$ $x = \sqrt{\frac{1}{3}}$

$\Rightarrow$ $\frac{R_i}{R_o} = 0.577$

$$\frac{d}{D} = 0.577$$

69. **(a)**

Given: $S_{ut} = 630$ N/mm^2, $S_e = 315$ N/mm^2, $N = 90000$ cycles

Step I: Construction of S-N diagram

$$0.9S_{ut} = (0.9)(630) = 567 \text{ N/mm}^2$$

$$\log_{10}(S_e) = \log_{10}(315) = 2.4983$$

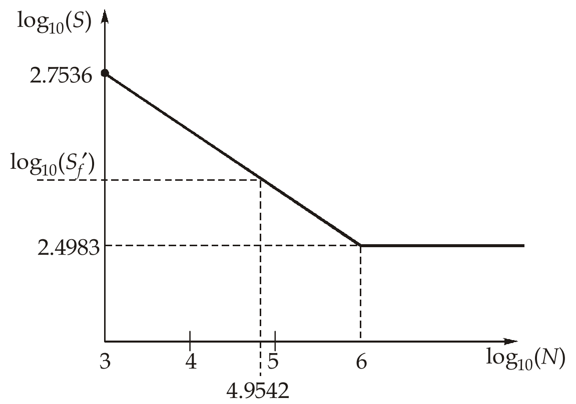
$$\log_{10}(0.9S_{ut}) = \log_{10}(567) = 2.7536$$

$$\log_{10}(90000) = 4.9542$$

Also, $\log_{10}(10^3) = 3$

and $\log_{10}(10^6) = 6$

S-N curve for the bar



Step II: Fatigue strength for 90000 cycles

$$\log_{10}(S_f') = 2.7536 - \frac{(2.7536 - 2.4983)}{6-3} \times (4.9542 - 3)$$

$$S_f' = 386.63 \text{ N/mm}^2 \approx 387 \text{ N/mm}^2$$

70. (b)

Given data: P = 10 MPa, D = 100 mm, t = 16 mm, L = 1 m

F_1 = Circumferential force

F_2 = Longitudinal force

$$F_1 = P \times DL = 1000 \text{ kN}$$

$$F_2 = P \times \frac{\pi}{4} D^2 = 78.54 \text{ kN}$$

Let, n = Number of rivet.

$$\text{Total strength of rivet} = n \times \frac{\pi}{4} d^2 \times \left(\frac{\sigma_y}{FOS}\right)$$

$$\Rightarrow \quad n \times \frac{\pi}{4} d^2 \times \frac{\sigma_y}{FOS} > \sqrt{F_1^2 + F_2^2}$$

$$\Rightarrow \quad n > 20.43$$

$$\Rightarrow \quad n = 21$$

71. (52.47) (52 to 53)

For taper roller bearing,

$$C = P(L)^{0.3} \quad \text{... (i)}$$

load, $P' = 1.25P$

Then the life L' will be:

So, $C' = P'(L')^{0.3}$

$$C' = 1.25P(L')^{0.3} \quad \text{... (ii)}$$

Divide (i) by (ii)

$$\frac{C}{C} = \frac{P(L)^{0.3}}{1.25P(L')^{0.3}}$$

$$\frac{L'}{L} = \left(\frac{1}{1.25}\right)^{10/3}$$

$$L' = 0.4753\ L$$

$$\%\ \text{decrease} = \frac{L - L'}{L} \times 100$$

$$= (1 - 0.4753) \times 100$$

$$= 52.47\%$$

72. 808.3 (807.5 to 809 .0)

$$T = \mu R_N r$$

$$\Rightarrow \quad 225 = 0.3 \times R_N \times 0.4$$

$$\Rightarrow \quad R_N = 1875\ \text{N}$$

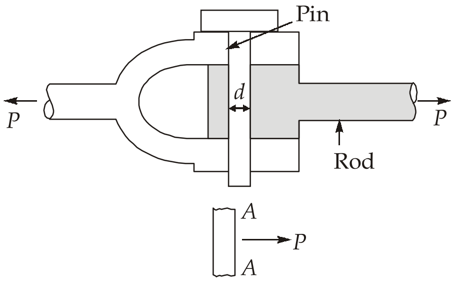
Summation of moments about the Pivot = 0 (for Clockwise rotation)

$$a \times \mu R_N + Pl - l_1 \times R_N = 0$$

$$\Rightarrow \quad 40 \times 0.3 \times 1875 + P \times 900 - 400 \times 1875 = 0$$

$$\Rightarrow \quad P = 808.3\ \text{N}$$

73. (d)



$$\text{Shear stress, } \tau = \frac{P}{2A}$$

$$A = \frac{\pi}{4} \times d^2$$

$$\tau = \frac{4P}{2 \times \pi d^2}$$

According to distortion energy theory, $\tau_{max} = 0.577\ S_{yt}$ (where S_{yt} is 380 MPa)

$$\tau_{max} = 219.26\ \text{N/mm}^2$$

Now, $$\tau \le \frac{\tau_{max}}{N}$$

$$\frac{4 \times 25 \times 10^3}{2 \times \pi \times d^2} \le \frac{219.26}{2.5}$$

$$d \ge 13.471\ \text{mm}$$

74. (1.44)(1.4 to 1.6)

$$\text{Mean force, } F_m = \frac{F_{max} + F_{min}}{2} = \frac{(25.2 + 10.8)}{2} = 18\ \text{N}$$

$$\text{Alternating force, } F_a = \frac{F_{max} - F_{min}}{2} = \frac{(25.2 - 10.8)}{2} = 7.2\ \text{N}$$

$$\text{Moment of inertia, } I = \frac{bh^3}{12} = \frac{1}{12} \times (1.25) \times (0.16)^3\ \text{cm}^4 = 4.27 \times 10^{-12}\ \text{m}^4$$

$$\sigma_m = \frac{M_m \times y}{I} = \frac{F_m L \times y}{I} = \frac{18 \times 6 \times 0.08 \times 10^{-4}}{4.27 \times 10^{-12} \times 10^6} = 202.34\ \text{MPa}$$

$$\sigma_a = \frac{M_a \times y}{I} = \frac{F_a L \times y}{I} = \frac{7.2 \times 6 \times 0.08 \times 10^{-4}}{4.27 \times 10^{-12} \times 10^{6}} = 80.937 \text{ MPa}$$

Goodman equation

$$\frac{1}{N} = \frac{\sigma_a}{S_e} + \frac{\sigma_m}{S_{ut}} = \frac{80.937}{229} + \frac{202.34}{595}$$

$$N = 1.44$$

75. (b, c)

$$U = \frac{1}{2} \times W \times \delta$$

$$\Rightarrow \quad W = \frac{2U}{\delta} = \frac{2 \times 72000}{60} = 2400 \text{ N}$$

$$d = \frac{8 \times 2400 \times 1000 \times 8}{82000 \times 60} = 31.2 \text{ mm}$$

$$\Rightarrow \quad D = 312 \text{ mm}$$

$$\text{Maximum shear stress} = \frac{8WD}{\pi d^3} = \frac{8 \times 2400 \times 312}{\pi \times (31.2)^3} = 62.8 \text{ MPa}$$

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