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ESE- 2020 (Prelims) - Offline Test Series Test - 7

MECHANICAL ENGINEERING

Subject: Mechanisms and Machines + Design of Machine Elements — SOLUTIONS

01. Ans: (a)

Sol: The controlling force curve is straight line in case of spring controlled governors. By varying the initial compression of spring, spring controlled governor can become isochronous. By increasing initial compression of spring the mean speed can be increased. A governor is said to be stable if the radius of rotation increases as the speed increases.

02. Ans: (d)

Sol: From state of stress,

$\sigma_1 = \sigma_x$ and $\sigma_2 = \sigma_y$

and $\sigma_1 = -\sigma_2$

According to maximum distortion energy theory,

$$\sqrt{\sigma_1^{\,2} + \sigma_2^{\,2} - \sigma_1\sigma_2} = \frac{\sigma_{yt}}{(FOS)_{MDET}}$$

According to maximum strain energy theory,

$$\sqrt{\sigma_1^{\,2} + \sigma_2^{\,2} - 2\mu\sigma_1\sigma_2} = \frac{\sigma_{yt}}{(FOS)_{MSET}}$$

Given $(FOS)_{MDET} = (FOS)_{MSET}$

$$\therefore \quad \frac{\sigma_{yt}}{(FOS)_{MDET}} = \frac{\sigma_{yt}}{(FOS)_{MSET}}$$

$$\sqrt{\sigma_1^{\,2} + \sigma_2^{\,2} - \sigma_1\sigma_2} = \sqrt{\sigma_1^{\,2} + \sigma_2^{\,2} - 2\mu\sigma_1\sigma_2}$$

$\therefore 2\mu = 1$

$$\Rightarrow \mu = \frac{1}{2} = 0.5$$

03. Ans: (d)

Sol: Peaucellier's mechanism is actual straight line mechanism. Watt's, Grasshpooer and Robert's mechanisms are approximate straight line mechanisms.

04. Ans: (a)

Sol: $\sigma_m = 50$ MPa, $\sigma_a = 100$ MPa

$$\text{Stress ratio} = \frac{\sigma_m - \sigma_a}{\sigma_m + \sigma_a} = \frac{50-100}{50+100} = -\frac{1}{3}$$

05. Ans: (b)

Sol: According to Grashoff law, a four bar mechanism has atleast one revolving link if the sum of the lengths of the largest and shortest links is sum of the other two links.

$S + L \leq P + Q$

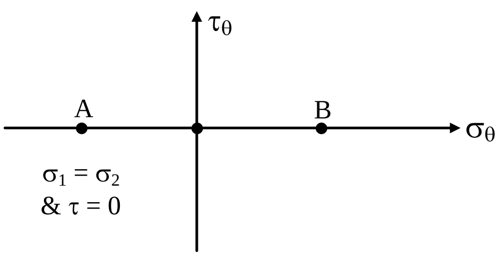
Where, S = shortest link length,

L = largest link length,

P and Q = length of other two links

06. Ans: (b)

Sol: Mohr's circle with zero radius is presented as



Mohr's circle with zero radius is a point on σ_θ-axis

At 'A' $\rightarrow$ $\sigma_1 = \sigma_2 \neq 0, \tau = 0$

At 'B' $\rightarrow$ $\sigma_1 = \sigma_2 \neq 0, \tau = 0$

07. Ans: (b)

Sol: When the two gears start transmitting motion, the initial contact occurs at a point where the flank of driving gear (pinion) tooth comes in contact with the face of the driven gear tooth. The contact ends when the face of tip of pinion comes in contact with the flank of the driven gear tooth. Interference will always start from the smaller gear (pinion) when gear ratio > 1.

08. Ans: (a)

Sol:

- Tangential component is uniformly distributed over the face width of the gear.
- Stress concentration effect is neglected in Lewis equation.

09. Ans. (a)

Sol: Factors on which the pressure angle of cam depends is

- lift of follower
- angle of ascent
- cam and follower centreline offset
- sum of base circle and roller follower radii

10. Ans: (c)

Sol: $R_i = 50$ mm ,

$R_o = 100$ mm

n = 2 (both sides effective)

$T = \mu\, w\, R_{eff} \times n$

$$R_{eff} = \frac{R_i + R_o}{2}$$

$$= \frac{50 + 100}{2} = 75\,\text{mm}$$

$w = 2\,\pi\, C\,(R_o - R_i)$

$C = P_{max} \times r_{min}$

$= 1 \times 50 = 50$

W = 2π × 50 × 50

T = 0.2 × 2 × π × 50 × 50 × 75 × 2

T = 150 π Nm

T = 470 Nm

11. Ans: (d)

Sol: Time period of disc

$$= 2\pi\sqrt{\frac{I_o}{mgd}} = 2\pi\sqrt{\frac{\frac{1}{2}mR^2 + mR^2}{mgR}} = 2\pi\sqrt{\frac{3R}{2g}}$$

$T_{\text{simple pendulum}} = 2\pi\sqrt{\frac{L}{g}}$

$$\Rightarrow 2\pi\sqrt{\frac{3R}{2g}} = 2\pi\sqrt{\frac{L}{g}}$$

$$\Rightarrow \frac{L}{g} = \frac{3R}{2g}$$

$$\Rightarrow L = \frac{3R}{2}$$

12. Ans: (d)

Sol: Total load = 4P (where 'P' is primary shear each rivet).

$$k = \frac{(4P)\times e}{r^2+r^2+r^2+r^2} \quad \text{[Load = 4P]}$$

$$k = \frac{Pe}{r^2}$$

Secondary shear force on rivet A = k × r

$$= \frac{Pe}{r^2}\times r$$

Secondary shear force = $\frac{Pe}{r}$

$$\Rightarrow r = \frac{s}{\sqrt{2}}$$

∴ Secondary shear force = $\frac{\sqrt{2}\,Pe}{s}$

13. Ans: (a)

Sol: Lift of sleeve = $h = \frac{a}{b}(r_1 - r_2)$

a = length of sleeve arm

b = length of ball arm

r_1 = maximum radius of rotation

r_2 = minimum radius of rotation

$$h = \frac{10}{20}(20-14) = 3\text{cm}$$

14. Ans: (b)

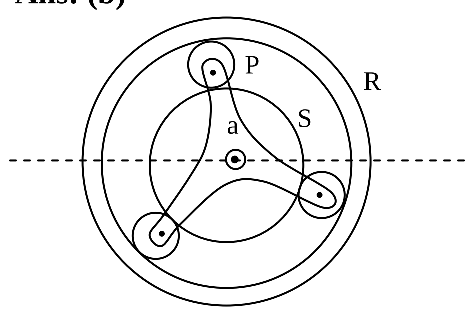
Sol: $S = \frac{Z}{P}\times\left(\frac{r}{c_r}\right)^2$

$$= \frac{0.06\times\frac{500}{60}}{\left(\frac{3000}{0.05\times 0.1}\right)}\times\left(\frac{25}{0.05}\right)^2$$

S = 0.208 ≈ 0.21

15. Ans: (b)

Sol:



$N_S = 0$ ($\because$ Fixed),

$N_a = 40$ rpm (Take Clockwise +ve),

$N_R = ?$

$$\frac{N_R - N_a}{N_S - N_a} = -\frac{T_S}{T_R}$$

$$\Rightarrow \frac{N_R - 40}{0 - 40} = \frac{-60}{100}$$

$\Rightarrow N_R = 64$ rpm (CW)

16. Ans: (c)

17. Ans: (c)

Sol: The displacement of cycloidal follower is given by

$$S = \frac{h}{\pi}\left(\frac{\pi\theta}{\phi} - \frac{1}{2}\sin\frac{2\pi\theta}{\phi}\right)$$

Where, S = stroke length of follower,

θ = cam angle of rotation,

ϕ = outstroke angle.

$$V = \frac{ds}{dt} = \frac{ds}{d\theta} \times \frac{d\theta}{dt}$$

$$= \left[\frac{h}{\phi} - \frac{h}{2\pi} - \frac{2\pi}{\phi}\cos\frac{2\pi\theta}{\phi}\right]\omega$$

$$= \frac{h\omega}{\phi} - \frac{h\omega}{\phi}\cos\frac{2\pi\theta}{\phi}$$

$$= \frac{h\omega}{\phi}\left(1 - \cos\frac{2\pi\theta}{\phi}\right)$$

$$V_{max} = \frac{2h\omega}{\phi} \quad \text{at} \quad \theta = \frac{\varphi}{2}$$

18. Ans: (d)

Sol: $L_{10} = 8000$ hr $\rightarrow$ R = 90%

L = 5000 hr $\rightarrow$ R = ?

$$\frac{L}{L_{10}} = \left(\frac{\ell n\left(\frac{1}{R}\right)}{\ell n\left(\frac{1}{R_{90}}\right)}\right)^{\frac{1}{1.17}}$$

$$\frac{5000}{8000} = \left(\frac{\ell n\left(\frac{1}{R}\right)}{\ell n\left(\frac{1}{0.9}\right)}\right)^{\frac{1}{1.17}}$$

R = 0.941 $\cong$ 0.95

Reliability is 95%

19. Ans: (c)

Sol: Without any power losses

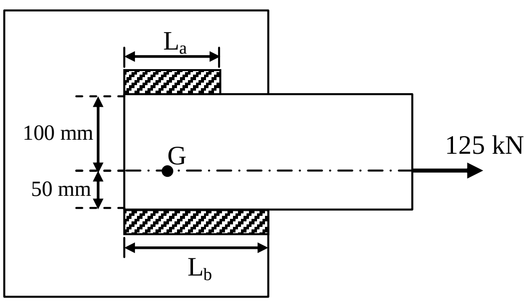
$T_G\omega_G = T_P\omega_P$

$$\frac{\omega_G}{\omega_P} = \frac{Z_P}{Z_G} = \frac{30}{90} = \frac{1}{3}$$

$$T_G = T_P \times \frac{\omega_P}{\omega_G} = 30 \times 3 = 90 \text{ N-m}$$

20. Ans: (c)

Sol:



$L = L_a + L_b$

Total length (L) = $\dfrac{P}{P_{allow}}$

$$= \frac{125}{665} \times 10^3 = 188 \text{ mm}$$

$100 \times L_a = 50 \times L_b$

$L_a + L_b = 188$

$L_b = 125$ mm,

$L_a = 63$ mm

Length of weld at bottom (L_b) = 125 mm

21. Ans: (c)

Sol: $2T_B + T_C = T_A$

$T_A = 2\times 20 + 32 = 72$

22. Ans: (a)

Sol: $M_{max} = \dfrac{P\times \ell}{4}$

Nominal stress, $\sigma_0 = \dfrac{32\,M_{max}}{\pi\, d_{min}^3}$

$$= \frac{32\times \frac{P\times\ell}{4}}{\pi\times d_1^3} = \frac{8\times P\times \ell}{\pi\, d_1^3}$$

Actual maximum stress due to stress concentration.

$\sigma_{act} = k_f \times \sigma_0$

$$= k_f \times \frac{8\times P\times\ell}{\pi d_1^3}$$

Failure condition due to completely reversed loading is (The component is not designed for static loading) :

$\sigma_{act} = \sigma_e'$

$$k_f \times \frac{8\times P\times \ell}{\pi d_1^3} = \sigma_e'$$

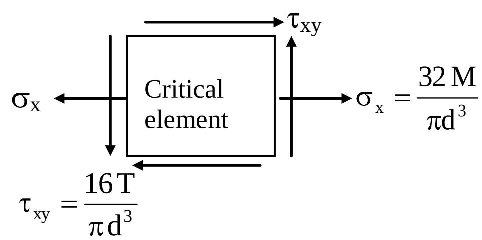
$$P = \frac{\pi d_1^3}{8\ell}\times\frac{\sigma_e'}{k_f}$$

23. Ans: (b)

Sol: In 4-stroke, 4 cylinder inline engines whatever may be the firing order, primary forces are always balanced. Primary couple depends on firing order.

24. Ans: (c)

Sol: Combined bending & twisting :



$\sigma_x = \dfrac{32\,M}{\pi d^3}$; $\sigma_y = 0$;

$\tau_{xy} = \dfrac{16\,T}{\pi\, d^3}$

The most accurate theory for ductile materials is maximum distortion energy theory.

According to MDET

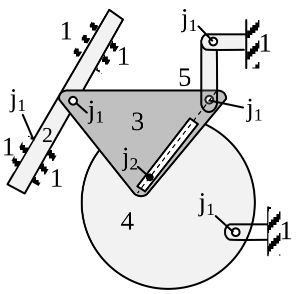
$$\sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x\sigma_y + 3{\tau_{xy}}^2} = \frac{\sigma_{yt}}{FOS}$$

$$\sqrt{\left(\frac{32M}{\pi d^3}\right)^2+3\times\left(\frac{16T}{\pi d^3}\right)^2}=\frac{\sigma_{yt}}{FOS}$$

$$\frac{16}{\pi d^3}\sqrt{4M^2+3T^2}=\frac{\sigma_{yt}}{FOS}$$

25. Ans: (b)

Sol:



The links and the joints of the mechanism are labelled as illustrated in figure. The number of links is 5, the number of lower pairs (j_1) is 5, and the number of higher pairs (j_2) is 1.

Substituting these values into the Kutzbach criterion (equation), the mobility of the mechanism is

$$F=3(5-1)-2(5)-1(1)=1$$

26. Ans: (d)

27. Ans: (a)

Sol: N_g = 300 rpm,

$$\omega_g=\frac{2\pi\times300}{60}=31.4\text{ rad/s}$$

$V_{s\,max}$ = 1260 mm/s

Path of recess = 8.06 mm and path of approach = 10.03 mm

Maximum velocity of sliding

$= (\omega_p + \omega_g)\times$maximum path

$$1260=\omega_g\left(\frac{\omega_p}{\omega_g}+1\right)\times10.03$$

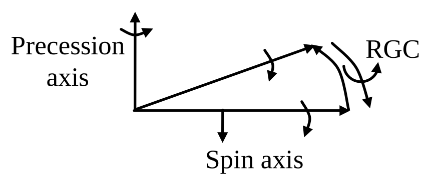
$$1260 = 31.4(G + 1)\times10.03$$

$\therefore$ G = 3

28. Ans: (b)

29. Ans: (a)

Sol:



Spin axis (S): CW from Tail end, using Right hand thumb (RHT) rule.

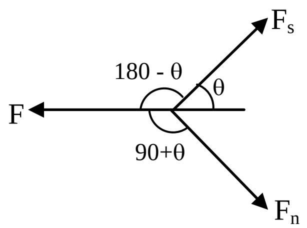
Precision Axis (P): Left turn with RHT rule

Reactive Gyroscopic couple (RGC): Turn spin to precession

$\therefore$ Nose Lifts

30. Ans: (d)

Sol: F.B.D of forces acting on weld



$$\frac{F_s}{\cos\theta} = F \quad \Rightarrow F_s = F\cos\theta$$

$$\frac{F_n}{\sin\theta} = F \quad \Rightarrow F_n = F\sin\theta$$

$A_{weld} = \ell \times t$

$$= \frac{\ell \times h}{\sin\theta + \cos\theta}$$

Shear stress on θ-plane,

$$\tau_\theta = \frac{F\cos\theta\,(\sin\theta + \cos\theta)}{\ell \times h}$$

For shear stress to be maximum,

$$\frac{d\tau_\theta}{d\theta} = 0$$

$\therefore$ –sinθ (sinθ + cosθ) + cosθ (cos θ – sinθ) = 0

sin2θ = cos2θ

2θ = 45°

$\Rightarrow \theta_s = 22.5°$

Normal stress on θ-plane,

$$\tau_\theta = \frac{F\sin\theta\,(\sin\theta + \cos\theta)}{\ell \times h}$$

For normal stress to be maximum,

$$\frac{d\sigma_\theta}{d\theta} = 0$$

$\therefore$ cosθ (sinθ + cosθ) + sinθ (cos θ – sinθ) = 0

sin2θ = –cos2θ

2θ = 135°

$\Rightarrow \theta_n = 67.5°$

31. Ans: (d)

Sol:

- As there is no slip, the lowermost point of the disc has zero velocity.
- The tangential acceleration of lower most point is zero but it has normal acceleration of magnitude $\frac{v^2}{R}$

32. Ans: (d)

Sol: To transmit power, clutch should always be in engaged position. In case of car, radial space availability is more. Hence, single plate dry clutch is used.

33. Ans: (a)

Sol: $T_{mean} \times 2\pi = \int_0^{2\pi} T d\theta$

$$T_{mean} \times 2\pi = \int_0^{2\pi} (14250 + 2200\sin 2\theta - 1800\cos 2\theta)d\theta$$

$$= 14250 \times 2\pi + \frac{2200}{2}[-\cos 2\theta]_0^{2\pi} - \frac{1800}{2}(\sin 2\theta)_0^{2\pi}$$

$$T_{mean} = \frac{14250 \times 2\pi}{2\pi} = 14250 \text{ Nm}$$

34. Ans: (b)

Sol: Positive clutch is also said to be No-slip clutch. Positive clutches are collars with Jaws that interlock, one member being rigidly attached to its shaft while the other slides on its shaft.

35. Ans: (c)

Sol: Natural frequency, $\omega_n = \sqrt{25} = 5$ rad/s

Damped natural frequency,

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

As $\xi < 1$, $\omega_d < \omega_n$

Here $\omega_d = q$, $p = \omega_n$, $\omega = r = 10$ rad/sec

36. Ans: (d)

Sol:

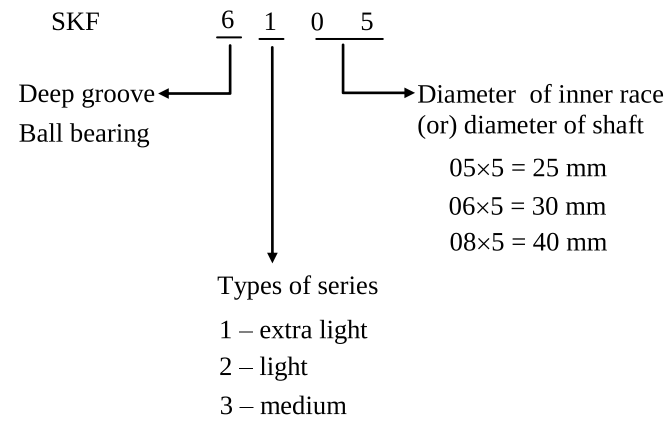
- Pitting is a surface fatigue failure due to many repetitions of high contact stresses.
- Scoring is a lubrication failure.
- Abrasion is wearing due to the presence of foreign material.

37. Ans: (b)

Sol: In static balancing, bending moment is not balanced

38. Ans: (d)

Sol: Designation of bearing :



39. Ans: (b)

Sol: Instantaneous centre for body rolling with slipping on normal passing through the point of contact.

40. Ans: (d)

Sol: There is no requirement of clutch or gears in an electric car.

41. Ans: (a)

Sol: In involute profile, the pressure angle remains constant throughout the mesh.

42. Ans: (c)

Sol: A bolt is said to be bolt of uniform strength only when the stress is constant throughout the length of bolt.

43. Ans: (b)

Sol: No. of instantaneous centre

$$\frac{n(n-1)}{2} = 28$$

n(n–1) =56

n = 8

$\therefore$ F = 3(n – 1) – 2j – h

= 3(8–1)–2×5–2 = 21 – 12 = 9

44. Ans: (c)

Sol:

- When plate is weaker than rivet $\rightarrow$ tearing of plate.
- When rivet is weaker than rivet $\rightarrow$ shearing of rivet.

45. Ans: (c)

Sol: Maximum possible length of path of contact

L_{max} = (R + r) sinϕ

$$R = \frac{mT_G}{2} = \frac{5\times 40}{2} = 100\,\text{mm}$$

$$r = \frac{mT_P}{2} = \frac{5\times 32}{2} = 80\,\text{cm}$$

L_{max} = 180sin(14.5) = 45 mm

46. Ans: (a)

Sol: A cam follower system is equivalent to a system in which the higher pair is replaced by two lower pairs.

47. Ans: (b)

Sol: Turn buckle is a mechanical element for adjusting the tension or length of ropes, cables, tie rods. It consists of both right hand threading and left hand threading.

48. Ans: (b)

Sol: Magnification factor

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

where ξ = 0.1 and $\frac{\omega}{\omega_n} = 1$ (Given)

$$\therefore \text{ Magnification factor} = \frac{1}{2\xi\frac{\omega}{\omega_n}} = \frac{1}{2\times 0.1} = 5$$

49. Ans: (b)

Sol: Torque transmitted using multi plate clutch

$T_m = \mu \times w \times r_{eff} \times (n -1)$ ----- (1)

where, (n-1) = number of contacting surfaces,

n = no. of plates.

Torque transmitted using cone-clutch

$$T_c = \mu\times w\times r_{eff} \times \frac{1}{\sin\alpha} \quad \text{--------(2)}$$

where, w = axial load.

equating (1) and (2), we get $n-1 = \frac{1}{\sin\alpha}$

50. Ans: (c)

Sol: The relative velocity of sliding in the teeth of gears in mesh

$= (\omega_1 - (-\omega_2)).\ PC$

$= (\omega_1+\omega_2).\ PC$

At pitch point PC = 0

$\therefore$ Relative velocity of sliding is zero.

51. Ans: (b)

Sol: $\sigma_t = \rho V^2$ $(V = r\omega)$

$$= 7100 \times \left(0.5 \times \frac{2\pi \times 360}{60}\right)^2$$

$= 7100 \times (6\pi)^2$

$\sigma_t = 2.5$ MPa

52. Ans: (d)

Sol:

- Due to friction between contacting surfaces side thrust is large in knife edge follower and the guide.
- Pitch curve is the curve drawn by the trace point assuming that the cam is fixed and the trace point of the follower rotates around the cam.
- With roller follower, the friction between contacting surfaces is reduced. Therefore, rate of wear between the surfaces is greatly reduced.

53. Ans: (c)

Sol: $P_b = 16$ kN

$P_m = -4$ kN

$P_b = P_i + CP_E$

$16 = 10 + CP_E$

$CP_E = 6$

$P_m = (1 - C)P_E - P_i$

$-4 = (1 - C)\ P_E - 10$

$6 = P_E - CP_E$

$P_E = 12$

$\therefore$ C = 0.5

54. Ans: (a)

Sol: The overdamped system under free vibration condition is non-oscillatory.

55. Ans: (b)

Sol:

$n_t = 0.7$, $n_s = 0.5$

$$n_t = 1 - \frac{d}{P} \Rightarrow \frac{d}{P} = 0.3$$

$$n_s = \frac{\sigma_s \times \frac{\pi}{4} d^2}{\sigma_t \times P \times t}$$

$$0.5 = \frac{30 \times \pi \times 0.3}{4 \times 40 \times 10} \times d$$

$d = 28.294 \cong 30$ mm

P = 100 mm

56. Ans: (d)

Sol: $x = x_o \sin^2\omega t = \frac{x_o}{2}(1-\cos 2\omega t)$

Frequency = 2ω

$\Rightarrow \frac{2\pi}{T} = 2\omega$

$\Rightarrow T' = \frac{\pi}{\omega}$

Amplitude = $\frac{x_o}{2}$

57. Ans: (a)

Sol: $\sigma_{max} = 200$ MPa, $\sigma_{min} = -100$ MPa,

$\sigma_a = 150$ MPa $\sigma_{mean} = 50$ MPa

$\sigma_e = 200$ MPa, $\sigma_{ut} = 400$ MPa

According to Goodman criterion,

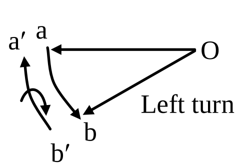
$$\frac{\sigma_a}{\sigma_e} + \frac{\sigma_{mean}}{\sigma_{ut}} = \frac{1}{FOS}$$

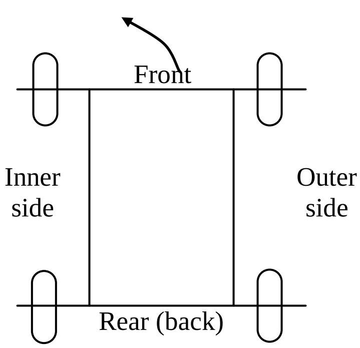
$$\frac{150}{200} + \frac{50}{400} = \frac{1}{FOS}$$

FOS = 1.15

58. Ans: (a)

Sol:





∴ a′ b′ is the gyroscopic couple which tends to lift the inner wheels.

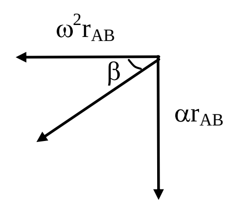
59. Ans: (a)

60. Ans: (b)

Sol: The method of direct and reverse crank is used in reciprocating radial engines to balance the forces.

61. Ans: (b)

Sol:



Acceleration of B wrt A along link is

$a_r = \omega^2 r_{AB}$

Acceleration of B wrt A perpendicular to link is

$a_t = \alpha\, r_{AB}$

$$\tan\beta = \frac{\alpha r_{AB}}{\omega^2 r_{AB}}$$

$$\beta = \tan^{-1}\frac{\alpha}{\omega^2}$$

62. Ans: (d)

Sol: C = 24000 N

P = 5000 N

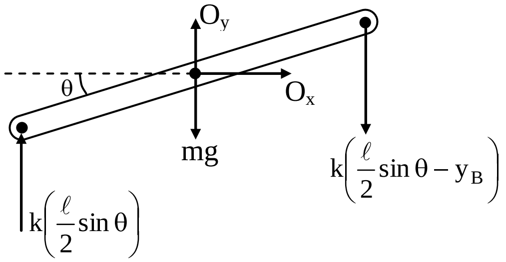
Loading ratio = $\frac{C}{P} = \frac{24000}{5000} = 4.8$

$$L_{90} = \left(\frac{C}{P}\right)^3 = (4.8)^3$$

= 110.6 million revolution.

63. Ans: (a)

Sol:



Take moment about 'O'

$$-\left(k\frac{\ell}{2}\sin\theta\right)\frac{\ell}{2}\cos\theta - k\left(\frac{\ell}{2}\sin\theta - y_B\right)\frac{\ell}{2}\cos\theta = \frac{1}{12}m\ell^2\ddot{\theta}$$

Assuming small deflections and simplifying

$$\ddot{\theta} - \frac{6k}{m}\theta = \frac{6kb}{m\ell}\sin\omega t$$

Resonance frequency, $\omega_c = \omega_n = \sqrt{\frac{6k}{m}}$

64. Ans: (a)

Sol: The smallest circle drawn tangent to the pitch curve is called as prime circle.

65. Ans: (c)

Sol: By considering factor of safety more material will be provided to the component. As more material is provided it leads to extra capacity of the component.

66. Ans: (c)

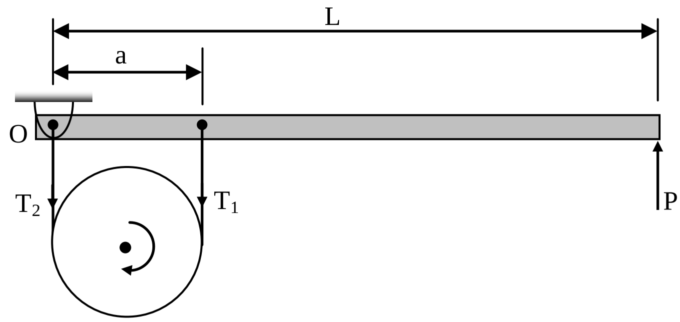
Sol: Welding process is used to fabricate all kind of component not only steel, so Statement (II) is wrong.

67. Ans: (c)

Sol: MF<1 at $\frac{\omega}{\omega_n} > \sqrt{2}$, irrespective of the amount of damping present.

68. Ans: (a)

Sol: Simple band brake :



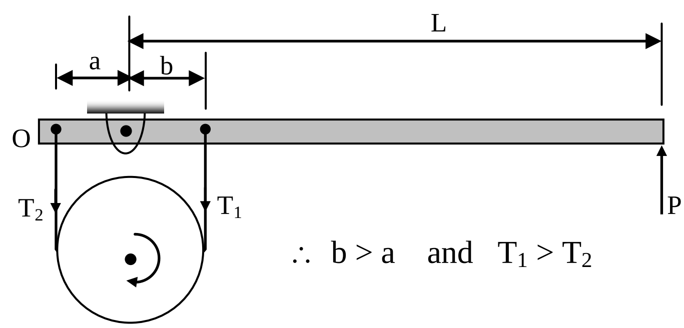
$\Sigma M_0 = 0$

$P \times L = T_1 \times a$

$$P = \frac{T_1 \times a}{L}$$

In simple band brake only two moments are acting about fulcrum $\Rightarrow$ self energizing is not possible.

Differential band brake :



$\therefore$ b > a and $T_1 > T_2$

$\Sigma M_0 = 0$

$P \times L + T_2 a - T_1 b = 0$

$$P = \frac{T_1 b - T_2 a}{L}$$

Band brake to behave as self energizing differential band brake is used, because it has 3 moments about fulcrum ⇒ additional moment (T_2 a) is acting in the direction of applied load.

69. Ans: (d)

Sol: In the case of spur gears the mating-gears execute rolling and sliding motion with respect to each other from the commencement of engagement to its termination.

70. Ans: (d)

Sol:

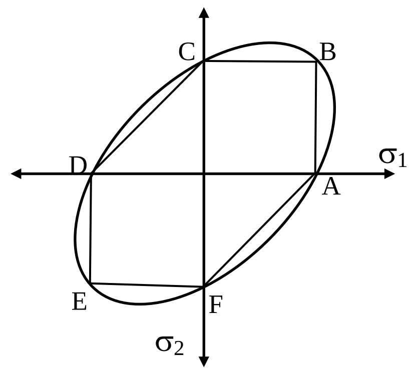
- For new clutch, uniform pressure theory applicable. So, statement (I) is wrong.
- When clutch is brand new uniform presence of material throughout the surface of friction lining hence its follows uniform pressure condition.
- Once clutch is subjected to operation more material is wears out at outer radius compare to inner radius of friction lining. Due to variation in presence of material more pressure will act at inner radius and less pressure at outer radius leading to uniform wear condition.

71. Ans: (c)

72. Ans: (b)

73. Ans: (d)

Sol:



- At points A, B, C, D, E, F both theories gives same results that means principal stresses need not be equal.
- According to MSST factor of safety less as compared to MDET (Area of MSST is less compare to MDET) ⇒ M.S.S.T is more conservative theory.

74. Ans: (b)

75. Ans: (a)

Sol:

- Curvature factor can be applied in the same way as the stress concentration factor.
- For static loading the curvature factor is normally neglected because any localized yielding leads to localized strain strengthening.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