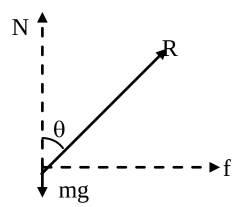
ESE- 2020 (Prelims) - Offline Test Series Test - 19

MECHANICAL ENGINEERING

Subject: Engineering Mechanics & Strength of Materials + Mechanisms And Machines + Design of Machine Elements — SOLUTIONS

01. Ans: (c)

Sol:



N = Normal reaction

f = friction force

R = Net contact force (Resultant of N & f)

R sin θ = ma

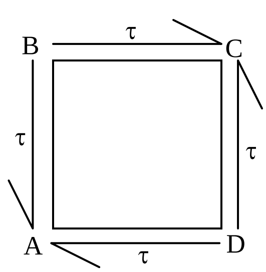
R cos θ = mg

$\therefore$ a = g tan θ

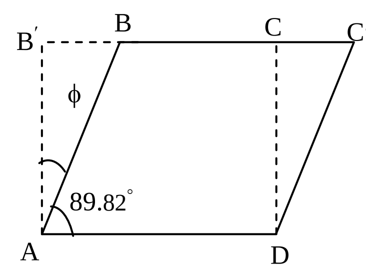
02. Ans: (a)

Sol:

Before shear deformation



After shear deformation

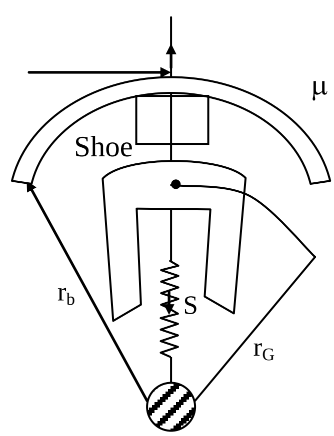


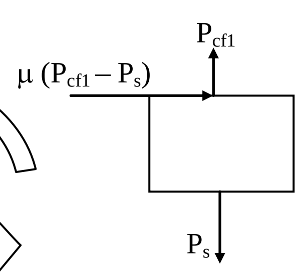
Shear strain (ϕ) = 90° – 89.82°

$$= 0.18° = 0.18 \times \frac{\pi}{180} = \frac{\pi}{1000}$$

03. Ans: (c)

Sol: Forces on a shoe in centrifugal clutch is shown below.





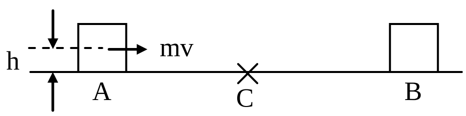
Forces on Shoe

Here, $(P_{cf})_1$ = centrifugal force = $m\omega_1^2 r_g$

- $(P_{cf})_1$ is balanced by an equal and opposite spring force. Thus, if rpm is doubled then spring force must be increased by factor of four.

04. Ans: (b)

Sol:



Let, m = mass of block

v = velocity of block at point A

h = height of centre of mass above ground

$\therefore$ Angular momentum about C, $\vec{L}_C = mvh$

$\therefore$ As v decreases $\therefore$ $|\vec{L}_C|$ decreases

05. Ans: (b)

Sol: Total free expansion deformation

$\delta = \delta_1 + \delta_2$

$= L\,\alpha\, t \times 2$

Total free expansion strain = $\varepsilon_1 + \varepsilon_2 = 2\alpha t$

As the cross sectional area is constant

$$\sigma_1 = \sigma_2 = \sigma$$

Total restricted strain $= \dfrac{\sigma}{E_1} + \dfrac{\sigma}{E_2}$

Displacement compatibility:

Total free expansion strain = Total restricted strain

$$\Rightarrow \quad \frac{\sigma}{E_1} + \frac{\sigma}{E_2} = 2\alpha t$$

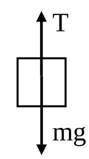
$$\sigma = 2\alpha t\left[\frac{E_1E_2}{E_1 + E_2}\right]$$

$$\therefore \quad \sigma = 2 \times \alpha \times 15 \times \left[\frac{2E_2 \times E_2}{2E_2 + E_2}\right]$$

$$\sigma = 30 \times \alpha\left[\frac{2E_2}{3}\right] = 20\alpha E_2$$

06. Ans: (b)

Sol: F.B.D. of man,



T = Tension in string

$\therefore$ $mg - T = ma$

$\Rightarrow$ $T = m\,(g - a)$

For rope to break,

$T \geq \eta mg$

$m\,(g - a) \geq \eta mg$

$\therefore$ $a \leq g\,(1 - \eta)$

$\therefore$ $a_{max} = g(1 - \eta)$

07. Ans: (c)

Sol: $\sigma_x = P_1$,

$\sigma_y = P_2$,

$\tau_{xy} = q$

Given both principal stresses have the opposite sign

$\sigma_2 < 0$

$$\therefore\ \sigma_2 < 0 \Rightarrow \frac{P_1+P_2}{2} - \sqrt{\left(\frac{P_1-P_2}{2}\right)^2 + q^2} < 0$$

$$\left(\frac{P_1+P_2}{2}\right)^2 < \left(\frac{P_1-P_2}{2}\right)^2 + q^2$$

$$\Rightarrow P_1P_2 < q^2$$

08. Ans: (c)

Sol:

- In uniform circular motion velocity changes but speed is constant, hence statement 2 is wrong.
- Since speed changes so velocity will also change, hence statement 4 is also wrong.

09. Ans: (a)

Sol: $F_D = 2$ kN, $L_D = 10^9$ rev,

$R = 0.90$

$$C_{10} = F_D\left(\frac{L_D}{L_R}\right)^{\frac{1}{3}} = 2\times\left(\frac{10^9}{10^6}\right)^{\frac{1}{3}} = 20\text{ kN}$$

10. Ans: (c)

Sol: $$\varepsilon_\theta = \frac{2\pi(r+u)-2\pi r}{2\pi r} = \frac{u}{r}$$

11. Ans: (b)

Sol: w.r.t observer on pulley, velocity of block B to the right is, "$v_B - u$" and velocity of block A is "v_A".

Since, string is inextensible.

$\therefore\ v_B - u = v_A$ or $v_B = u + v_A$

12. Ans: (d)

Sol: Given $\varepsilon_x = kx^3$ Where x is constant

We know that $\varepsilon_x = \dfrac{\partial u}{\partial x}$

Where 'u' is the displacement in x – direction

$$\therefore \frac{\partial u}{\partial x} = \frac{du}{dx} = kx^2 \Rightarrow du = kx^3.dx$$

$$u = \int_0^L k.x^3.dx = \frac{kL^4}{4}$$

13. Ans : (a)

Sol: $u_y = 3$ m/s

$a_z = -g = -10$ m/s^2

$$z = u_z t + \frac{1}{2}a_z t^2$$

$$5 = \frac{1}{2}\times 10\times t^2 \qquad \Rightarrow t = 1\text{ sec}$$

$y = u_y t = 3 \times 1 = 3$ m ; $x = 2$ m

14. Ans: (d)

Sol: Beam bents into the form of circular arc only when it is subjected to pure bending.

When a simply supported beam is subjected to pure bending,

Deflection at centre, $\delta = \dfrac{M\ell^2}{8EI} = \dfrac{\ell^2}{8R}$

$$\left[\because \frac{1}{R} = \frac{M}{EI}\right]$$

$$\Rightarrow d = \frac{\ell^2}{8R}$$

$$\Rightarrow R = \frac{\ell^2}{8d} \quad (\because d << R)$$

$$\frac{\sigma}{y} = \frac{E}{R} \Rightarrow \frac{\sigma}{E} = \frac{y}{R}$$

$$\therefore \text{surface strain}\,(e) = \frac{\sigma}{E} = \frac{y}{R} = \frac{\frac{t}{2}}{\frac{\ell^2}{8d}} = \frac{t \times 8d}{2 \times \ell^2}$$

$$\therefore e = \frac{4td}{\ell^2}$$

15. Ans: (c)

Sol:

$$\sigma_{vonMises} = \sqrt{\frac{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}{2}}$$

$$\sqrt{\frac{(210-210)^2 + (210-210)^2 + (210-210)^2}{2}} = 0$$

$$\sigma_{vonMises} = \frac{s_y}{FOS}$$

$$FOS = \frac{S_y}{\sigma_{von\ Mises}} = \frac{210}{0} = \infty$$

16. Ans: (c)

Sol: $\vec{\tau}_{ext} = \frac{d}{dt}(\vec{L})$

where, $\vec{\tau}_{ext}$ = External torque

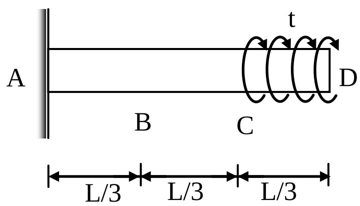
$\vec{L}$ = Angular momentum

Now, $\vec{\tau}_{ext} = 0$

$\therefore$ $\vec{L}$ = constant

17. Ans: (a)

Sol:



Angle of twist at D with respect to A

$\theta_{AD} = \theta_{AB} + \theta_{BC} + \theta_{CD}$

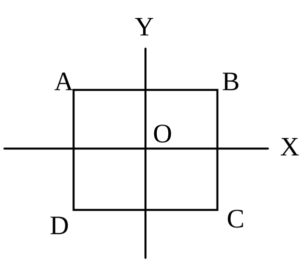
$$= \left(\frac{T\ell}{GJ}\right)_{AB} + \left(\frac{T\ell}{GJ}\right)_{BC} + \left(\frac{T\ell}{GJ}\right)_{CD}$$

$$= \frac{\left(t\times\frac{L}{3}\right)\times\frac{L}{3}}{GJ} + \frac{\left(t\times\frac{L}{3}\right)\times\frac{L}{3}}{GJ} + \frac{1}{GJ}\int_0^{\frac{L}{3}} t.x\,dx$$

$$\theta_{AD} = \theta_D = \frac{2tL^2}{9GJ} + \frac{t\times\left(L/3\right)^2}{2GJ} = \frac{tL^2}{3.6GJ}$$

18. Ans: (b)

Sol:



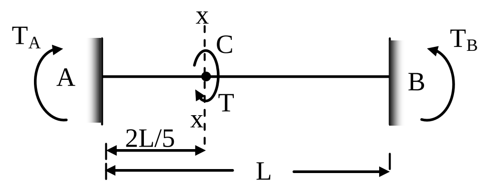
$$I_{AB} = I_{CD} = m\left(\frac{\ell}{2}\right)^2$$

$$I_{AD} = I_{BC} = \frac{m\ell^2}{12}$$

$$I_{total} = 2m\frac{\ell^2}{4} + \frac{2m\ell^2}{12} = \frac{2}{3}m\ell^2$$

19. Ans: (b)

Sol:



$T_A + T_B = T$

$\theta_{AB} = 0 \Rightarrow T\times\frac{2L}{5} = T_B\times L$

$\Rightarrow T_B = \frac{2T}{5}$

$T_A = \frac{3T}{5}$

$\therefore$ $\tau \alpha T \Rightarrow$ Max. shear stress is at A

$$\tau_A = \frac{16T_A}{\pi d^3} = \frac{16}{\pi d^3}\times\frac{3T}{5} = \frac{9.6T}{\pi d^3}$$

20. Ans: (c)

Sol: $\frac{mr^2}{4} = mK^2$

$\therefore$ $K = \frac{r}{2} = \frac{4}{2} = 2\,cm$

21. Ans: (c)

Sol: $\frac{PL^3}{48EI}$ is the deflection without the spring

$$\delta = \frac{PL^3}{48EI} - \frac{P}{K}$$

$$= \frac{PL^3}{48\ EI} - \frac{PL^3}{144\ EI}$$

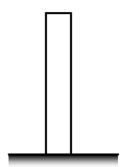
$$= \frac{PL^3}{EI}\left[\frac{3}{144} - \frac{1}{144}\right]$$

$$= \frac{PL^3}{EI} \times \frac{2}{144}$$

$$= \frac{PL^3}{72EI}$$

22. Ans: (b)

Sol:



Since height of centre of mass = $\frac{1}{2}$m (from O)

So Potential energy = $mg \times \frac{1}{2}$

Using conservation of mechanical energy

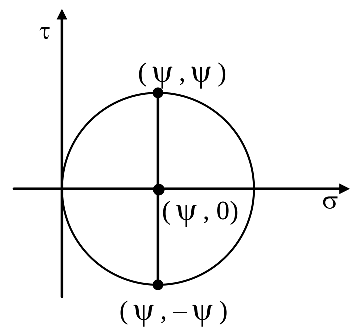
$$mg \times \frac{1}{2} = \frac{1}{2} I\omega^2$$

$I = \frac{m \times 1^2}{3}$, About O

Solving we get $\omega = 5.4$ rad/s

23. Ans: (a)

Sol:



Center $\rightarrow (\psi, 0)$

Radius $\rightarrow \psi$

24. Ans: (a)

Sol: For a prismatic bar having weight 'W', maximum stress is given by,

$$\sigma = \frac{W}{A} = \frac{\rho V g}{A} = \rho L g$$

here, V = Volume of the bar = $A \times L$

A = Cross-sectional area

L = Length of the bar

ρ = Density of the bar

Given that, $L' = kL$

ρ = Material constant.

$\Rightarrow \sigma' = \rho L' g$

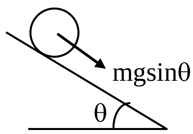
$= \rho(kL)g$

$= \sigma \times k$

$$\Rightarrow \frac{\sigma'}{\sigma} = k$$

25. Ans: (b)

Sol:



On smooth inclined surface mgsinθ acts along incline as shown in figure.

So, $V_{c.m}$ increases . 'ω' remains constant, since there is no torque .

So, $V_{c.m} \neq \omega R$

26. Ans: (d)

Sol: Case 1 **Case 2**

$(\ell_e)_1 = \dfrac{\ell}{2}$ $(l_e)_2 = 2l$

$P_1 = 4000$ N $P_2 = ?$

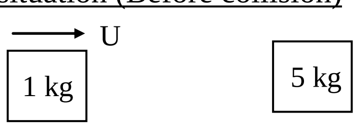
$$P = \frac{\pi^2}{\ell_e^2} EI_{min} \Rightarrow P \alpha \frac{1}{(\ell_e)^2}$$

$$\frac{P_2}{P_1} = \frac{(\ell_e)_1^2}{(\ell_e)_2^2} = \left(\frac{\ell}{2} \times \frac{1}{2\ell}\right)^2 = \frac{1}{16}$$

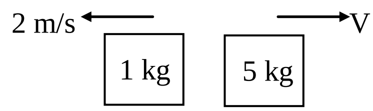
$$\frac{|P_2 - P_1|}{P_1} \times 100 = \frac{15}{16} \times 100 = 93.75\%$$

27. Ans: (a)

Sol: <u>Initial situation (Before collision)</u>



<u>Final situation (After collision)</u>



By using conservation of linear momentum

$1 \times U = -1 \times 2 + 5 \times V$ .... (i)

$e = 1 = \dfrac{V + 2}{U}$ .... (ii)

From (i) and (ii)

V = 1 m/s

U = 3 m/s

Total momentum of system

= 1 × 3 = 3 kg m/s

Momentum of 5 kg mass after collision

= 5 × 1 = 5 kg m/s

Momentum of 1 kg mass after collision

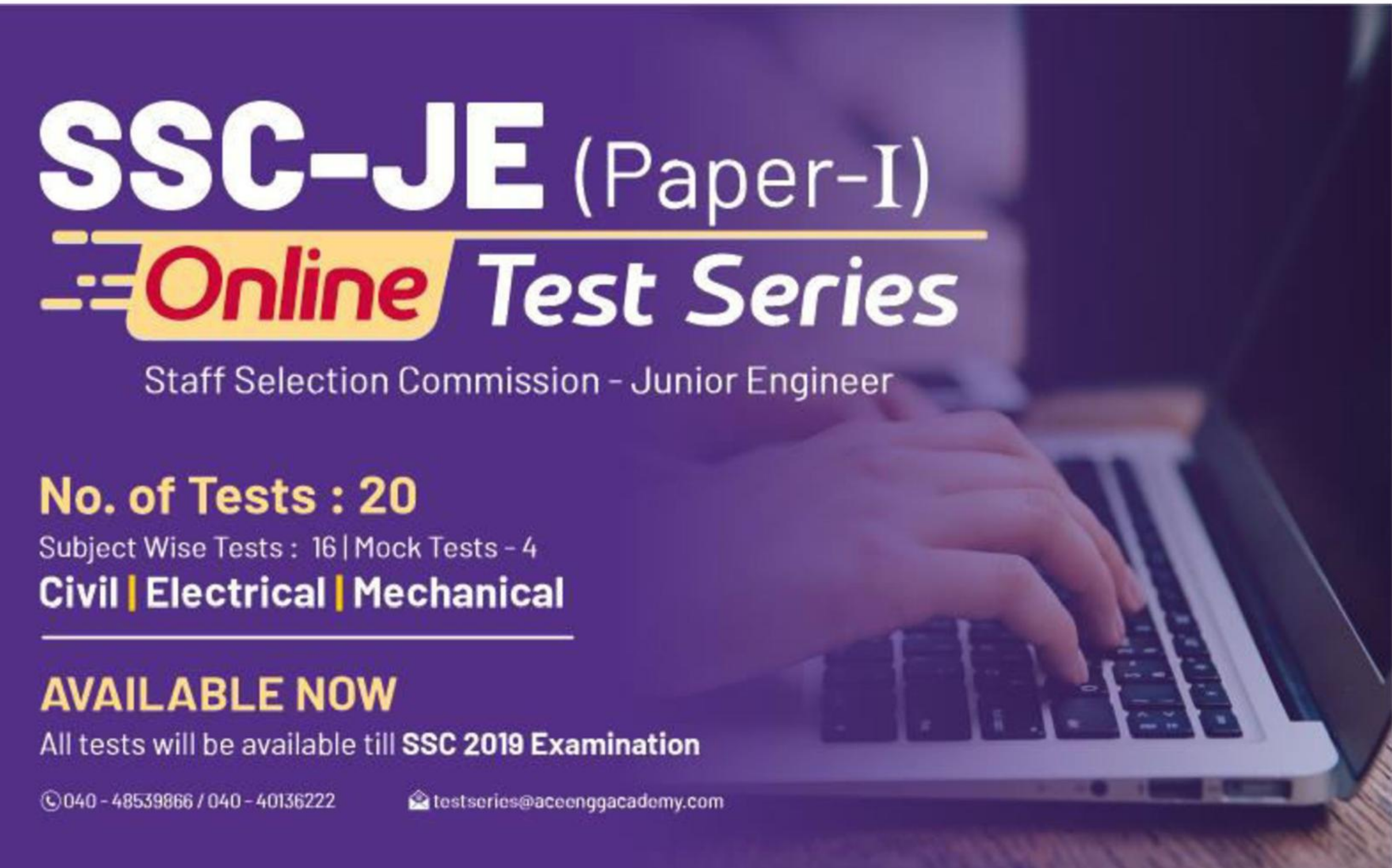
= 1 × 2 = 2 kg m/s (Towards left)

Kinetic energy of system

$$= \frac{1}{2} \times 1 \times 2^2 + \frac{1}{2} \times 5 \times 1^2$$

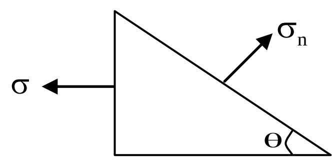
= 4.5 J


TEST YOUR PREP
IN A REAL TEST ENVIRONMENT
Pre GATE - 2020
Date of Exam : 18th January 2020
Last Date to Apply : 31st December 2019
Highlights:
Get real-time experience of GATE-20 test pattern and environment.
Virtual calculator will be enabled.
Post exam learning analytics and All India Rank will be provided.
Post GATE guidance sessions by experts.
Encouraging awards for GATE-20 toppers.
PAN INDIA
PRESENCE AVAILABLE IN MORE THAN
30
CITIES


SSC-JE (Paper-I)
Online Test Series
Staff Selection Commission - Junior Engineer
No. of Tests : 20
Subject Wise Tests : 16 | Mock Tests - 4
Civil | Electrical | Mechanical
AVAILABLE NOW
All tests will be available till SSC 2019 Examination
040 - 48539866 / 040 - 40136222
testseries@aceenggacademy.com

28. Ans: (c)

Sol: When a member is subjected to uniaxial load then the normal stress acting on an inclined plane is



$\sigma_n = \sigma_x \sin^2\theta$

$$\therefore \frac{\sigma_{n2}}{\sigma_{n1}} = \frac{(\sin\theta_2)^2}{(\sin\theta_1)^2} = \frac{(\sin 120)^2}{(\sin 30)^2} = 3$$

29 Ans: (c)

Sol. In the horizontal direction, momentum must be conserved, as the floor is frictionless and there is no horizontal force.

$\therefore$ $m \times u \times \sin\theta = m \times v \times \sin\phi$ ………. (i)

In vertical direction, $e = 1 = \dfrac{v\cos\phi}{u\cos\theta}$

$\Rightarrow$ $e\, u \cos\theta = v \cos\phi$ …. (ii)

From (i) and (ii)

$$v = u\sqrt{\sin^2\theta + e^2\cos^2\theta}$$

30. Ans: (b)

Sol: We know that

$$\sigma = \frac{P}{A} = \varepsilon \times E$$

$E = 3K(1 - 2\mu)$

$$\frac{P \times 4}{\pi d^2} = \frac{\delta}{L} \times 3K(1 - 2\mu)$$

$$k = \frac{4PL}{3\pi d^2(1-2\mu)}$$

$$= \frac{2PL}{1.5\pi d^2(1-2\mu)}$$

31. Ans: (c)

Sol: Let k = force constant of the spring.

Potential energy of the spring after the first stretching $= E_1 = \dfrac{1}{2}kx^2$.

Potential energy of the spring after the second stretching $= E_2 = \dfrac{1}{2}k(2x)^2$.

$W_1 = E_1$, $W_2 = E_2 - E_1 = 3E_1$

$\Rightarrow$ $W_2 = 3W_1$

32. Ans: (b)

Sol: The compatibility condition for the strains

$$\frac{\partial^2\varepsilon_x}{\partial y^2} + \frac{\partial^2\varepsilon_y}{\partial x^2} = \frac{\partial^2(\gamma_{xy})}{\partial x\partial y}$$

Given $\varepsilon_x = py^2 + 8x^2$

$$\frac{\partial\varepsilon_x}{\partial y} = 2py, \quad \frac{\partial^2\varepsilon_x}{\partial y^2} = 2p$$

$\varepsilon_y = 10xy + 4y^2$,

$$\frac{\partial\varepsilon_y}{\partial x} = 10\ y,$$

$$\frac{\partial^2\varepsilon_y}{\partial x^2} = 0$$

$\gamma_{xy} = 4(x^2 + xy)$,

$$\frac{\partial\gamma_{xy}}{\partial x} = 4(2x + y)$$

$$\frac{\partial^2\gamma_{xy}}{\partial y\partial x} = 4$$

$2p + 0 = 4 \Rightarrow p = 2$

33. Ans: (d)

Sol: Consider total upward and downward motion at a time.

Let t be the total time taken by ball.

By using equation of motion,

$$y = u_y t + \frac{1}{2}a_y t^2$$

$$0 = u_y t - \frac{1}{2}gt^2$$

$$\Rightarrow \quad t = \frac{2u_y}{g} \text{ .... (i)}$$

Considering only upward motion

$v_y = u_y + a_y t$

$0 = u_y - 10 \times 40$

$\Rightarrow u_y = 400$ m/s .... (ii)

From (i) and (ii)

$$t = \frac{2\times 400}{10} = 80 \text{ sec}$$

$\therefore$ Time for downward journey = 80 − 40

= 40 sec

34. Ans: (d)

Sol: $$\sigma_{impact} = \sigma_{st}\left(1+\sqrt{1+\frac{2h}{\delta_{st}}}\right)$$

$$20 = \frac{1000}{6000}\left(1+\sqrt{\frac{2h}{\delta_{st}}}\right)$$

$$(121)^2 = \frac{2h}{\delta_{st}}$$

$$14642 = \frac{2h}{\delta_{st}}$$

$$h = 7321\times\frac{1000\times 6000}{6000\times 10\times 10^3} = 732.1 \text{ mm}$$

35. Ans: (d)

Sol: Taking anticlockwise as positive,

$T_A = -100$ kNm , $\omega_A = 50$ rpm,

$\omega_C = -200$ rpm

$T_A + T_B + T_C = 0$ ---------- (1)

Assuming no power loss,

$T_A\,\omega_A + T_C\,\omega_C = 0$ ------------ (2)

$\Rightarrow -100\times 50 + T_C \times (-200) = 0$

$$T_C = \frac{-100\times 50}{200} = -25$$

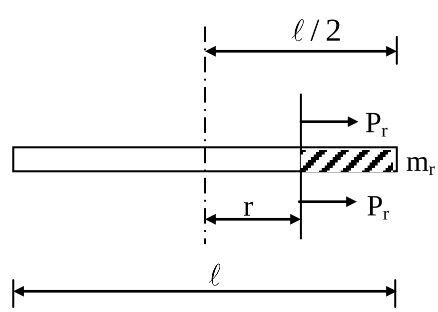
or 25 kNm clockwise

$\therefore -100 + T_B - 25 = 0$

$T_B = 125$ kNm anticlockwise

36. Ans: (d)

Sol:



Elongation, $\delta = 2\times\int_0^{\ell/2}\frac{P_r\,dr}{EA}$

$$P_r = m_r\,r\,\omega^2 = \rho A\left(\frac{\ell}{2}-r\right)r\,\omega^2$$

$$\delta = 2\times\int_0^{\ell/2}\frac{P_r\,dr}{EA}$$

$$\delta = \frac{2\rho\omega^2}{E}\int_0^{\ell/2}\left(\frac{\ell}{2}r-r^2\right)dr$$

$$\delta = \frac{2\rho\omega^2}{E}\left(\frac{\ell^3}{16}-\frac{\ell^3}{24}\right)$$

$$=\frac{\rho\,\omega^2\,L^3}{24E}$$

37. Ans: (d)

Sol: For a Hook's joint angular speed ratio is given by

$$\frac{\omega_2}{\omega_1}=\frac{\cos\alpha}{1-\sin^2\alpha\cos^2\theta}$$

$\frac{\omega_2}{\omega_1}$ is minimum when $1-\sin^2\alpha\cos^2\theta$ is maximum i.e. $\theta = 90°$ and $270°$.

38. Ans: (c)

Sol: $\sigma_1=\sigma_h=\frac{Pr}{t}$

$$\sigma_2=\sigma_\ell=\frac{Pr}{2t}-\frac{F}{2\pi rt}$$

For pure shear, $\sigma_1 = -\sigma_2$

$$\frac{Pr}{t}=-\left(\frac{Pr}{2t}-\frac{F}{2\pi rt}\right)$$

$$\frac{F}{2\pi rt}=\frac{3Pr}{2t}$$

$$\Rightarrow F = 3\pi Pr^2$$

39. Ans: (b)

Sol: $3\ddot{x}+10\dot{x}+27x=0$

$$\omega_n=\sqrt{\frac{27}{3}}=3,\ c = 10,\ m = 3$$

$$\xi=\frac{c}{2m\omega_n}=\frac{10}{2\times3\times3}=\frac{10}{18}=\frac{5}{9}=0.556$$

40. Ans: (b)

Sol: Strain energy, $U=\frac{T^2L}{2GJ}$

But, $T=\frac{\tau J}{R}$

$$U=\left(\frac{\tau J}{R}\right)^2\frac{L}{2GJ}$$

$$=\frac{\tau^2J}{R^2}\times\frac{L}{2G}=\frac{\tau^2\left(\frac{\pi}{2}R^4\right)L}{2R^2G}$$

$$=\frac{\tau^2\times\pi R^2\times L}{4G}$$

$$U=\frac{\tau^2AL}{4G}$$

So, K = 4


ACE Engineering Academy
Leading Institute for ESE/GATE/PSUs
HEARTY CONGRATULATIONS
TO OUR ESE - 2019 TOP RANKERS
AIR 1 KARTIKEYA SINGH EE
AIR 1 RAJAT SONI E&T
AIR 1 HARSHAL BHOSALE ME
AIR 1 ABUZAR GAFFARI CE
AIR 2 SHAMBHAVI EE
AIR 2 ANKUSH MANGLA E&T
AIR 2 SAHIL GOYAL ME
AIR 3 ABHISHEK ANAND EE
AIR 3 ROHIT KUMAR E&T
AIR 3 KUMAR CHANDAN ME
AIR 3 AMARJEET CE
AIR 4 ANKIT TAYAL EE
AIR 4 AMIR KHAN E&T
AIR 4 SAURAV ME
AIR 4 AMAN GULIA CE
AIR 5 KUMAR MAYANK EE
AIR 5 AYUSH CHANDRA CE
AIR 6 RITESH LALWANI EE
AIR 6 PUSHPAK ME
AIR 6 KABIL BHARGABAVA CE
AIR 7 KARTIKEY SINGH EE
AIR 7 RAHUL JAIN E&T
AIR 7 MANISH RAJPUT ME
AIR 8 KULDEEP KUMAR E&T
AIR 8 HEMANT KUMAR ME
AIR 8 YOGESH KUMAR CE
AIR 9 DEEPITA ROY EE
AIR 9 SHUBHAM KARNANI E&T
AIR 9 D SABAPARA ME
AIR 9 ANKIT KUMAR CE
AIR 10 ANKITA SHARMA EE
AIR 10 GAURAV SRIVASTAVA E&T
AIR 10 SUMIT BHAMBOO ME
and many more...
TOTAL SELECTIONS in Top 10: 33
(EE: 9, E&T: 8, ME: 9, CE: 7) and many more...


ACE ENGINEERING ACADEMY
Since 1995
ACE
DIGITAL CLASSES
for
ESE 2020/2021
General Studies &
Engineering Aptitude
GATE 2020/2021
Computer Science &
Information Technology
Access the Course at
www.deep-learn.in

41. Ans: (c)

Sol: For an isochronous governor radius of rotation is same irrespective of speed.

42. Ans: (d)

Sol: At a distance x from the free end

$$M_x = \left(\frac{1}{2}\frac{w\,x}{\ell}\times x\right)\frac{x}{3} = \frac{w\,x^3}{6\ell}$$

$$Z_x = \frac{b_x\,d^2}{6}$$

$$\sigma_x = \frac{M_x}{Z_x} = \frac{w\,x^3}{\ell\times b_x\times d^2}$$

Maximum bending stress

$$\sigma_{max} = \frac{wL^2}{bd^2}$$

To have the same maximum stress at all sections

$$\sigma_x = \sigma_{max}$$

$$\frac{wx^3}{\ell\,b_x d^2} = \frac{w\,L^2}{b\,d^2}$$

$$b_x = b\frac{x^3}{L^3}$$

$$b_x \propto x^3$$

The breadth is proportional to x^3

43. Ans: (b)

Sol: The resultant acceleration of block centre will become zero, when below conditions are satisfied:

(i) The tangential acceleration of link is equal and opposite of Coriolis acceleration.

(ii) The radial acceleration of link and acceleration of slider is equal and opposite.

44. Ans: (c)

Sol: For no tensile stress in the cross section

$$\frac{P}{A} - \frac{Pe}{Z} \geq 0$$

Maximum eccentricity for no tensile stress condition,

$$\frac{P}{A} - \frac{Pe_{max}}{Z} = 0$$

$$\frac{Pe}{Z} = \frac{P}{A}$$

$$e_{max} = \frac{Z}{A} = \frac{\frac{\pi}{32}d^3}{\frac{\pi}{4}d^2}$$

$$e_{max} = \frac{d}{8}$$

45. Ans: (c)

Sol: The equation of motion is

$$m\ddot{x}R + \frac{MR^2}{2}\ddot{\theta} + ka^2\theta = 0$$ (Take moment about O)

$$x = R\theta$$

$$\ddot{x} = R\ddot{\theta}$$

$$\Rightarrow\ mR^2\ddot{\theta} + \frac{MR^2\ddot{\theta}}{2} + ka^2\theta = 0$$

$$\omega_n = \sqrt{\frac{k_{eq}}{m_{eq}}} = \sqrt{\frac{ka^2}{mR^2 + \frac{MR^2}{2}}}$$

$$= \sqrt{\frac{100\times 0.1^2}{0.5\times 0.2^2 + \frac{1\times 0.2^2}{2}}} = 5 \text{ rad/sec}$$

$$\Rightarrow f = \frac{5}{2\pi} = 0.8\,\text{Hz}$$

46. Ans: (d)

Sol: Due to symmetric loading, shear force at centre of simply supported beam is zero.

47. Ans (a)

Sol: ω = angular velocity,

$$\frac{2\pi N}{60} = \frac{2\pi\times 1200}{60} = 125.66\,\text{rad/s}$$

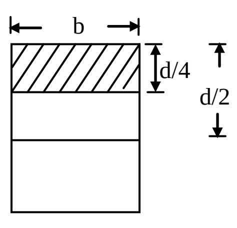
Maximum velocity during the follower rise with SHM:

$$v_{max} = \frac{h}{2}\times\frac{\pi\omega}{\beta_1}$$

$$= \frac{25}{2\times 1000}\times\frac{\pi\times 125.66}{120^\circ\times\pi/180} = 2.35\,\text{m/s}$$

48. Ans: (b)

Sol:



Shear stress at ¼th beam depth = 120 MPa

$$\tau = \frac{VA\bar{y}}{Ib}$$

$$120 = \frac{V\times b\times\frac{d}{4}\times\left(\frac{d}{4}+\frac{d}{8}\right)}{\frac{bd^3}{12}\times b}$$

$$120 = \frac{V}{bd}\left(\frac{9}{8}\right)$$

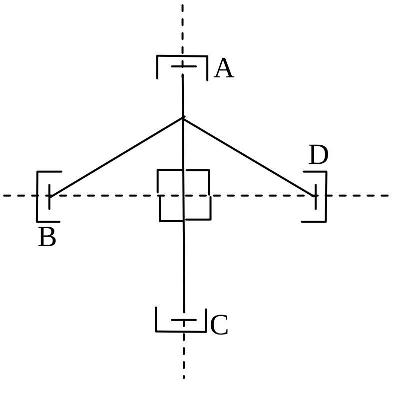
$$\tau_{avg} = \frac{V}{bd} = \left(\frac{120\times 8}{9}\right) = 106.67 \text{ mPa}$$

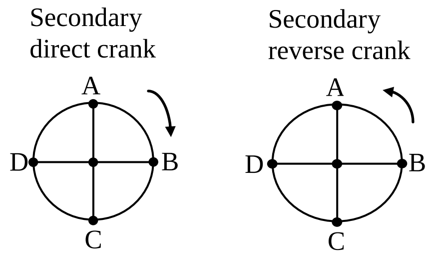
$$\therefore \tau_{max} = \frac{3}{2}(106.67) = 160 \text{ MPa}$$

49. Ans (b)

Sol: Balancing of several masses in different planes can be done by 2 masses in 2 planes on either side of reference planes. Hammer blow in the locomotive engine occurs due to unbalanced force perpendicular to line of stroke.

For Four cylinders :





So secondary force is completely balanced for four cylinder radial engines.

50. Ans: (c)

Sol: If braking force required is zero, it is called self locking brake but the shoe brake behaves as self locking brake only when it is self energising.

51. Ans (a)

Sol: If angular velocity of link AB in clockwise direction then angular velocity of coupler is in anti-clockwise direction.

$\therefore$ Velocity of rubbing at pin

$= r_{pin} \times (\omega_{AB} + \omega_{BC})$

$= 20 \times 10^{-3} \times (16 + 6) = 0.44$ m/s

52. Ans: (c)

Sol: $I = mk^2 = 500 \times 0.3^2 = 45$ kg-m^2

$T = 900 \text{ Nm} = I\alpha \Rightarrow \alpha = \frac{T}{I}$

$\alpha = 20$ rad/s^2 ; $\omega_i = 0$; $t = 10$ s

$\omega_f = \omega_i + \alpha t = 200$ rad/s

$$KE = \frac{1}{2} I\omega_f^2 = \frac{1}{2} \times 45 \times 200^2$$

$$= 900 \text{ kJ}$$

53. Ans. (c)

Sol: The necessary condition for placing two masses such that the system becomes dynamically equivalent is

$$\ell_1 \times \ell_2 = k_g^2$$

$$20 \times 45 = k_g^2$$

Substituting respective values, we get $k_g = 30$ mm

54. Ans: (b)

Sol: For anticlockwise rotation, side A is tight side and side B is slack

$\frac{T_1}{T_2} = 1.5$

$T_1 + T_2 = 500$

Take moment about paint O

$P \times L = T_1 b - T_2 a$, Where L is distance between applied load and point O.

For self locking,

$P.L \le 0$

$T_1 b - T_2 a \le 0$

$\frac{b}{a} \le \frac{T_2}{T_1}$

$\frac{a}{b} = \frac{3}{2}$

55. Ans: (a)

Sol: The spin axis and precession axis are parallel (both are vertical) hence there is no gyroscopic effect

56. Ans: (d)

Sol: Bending due to weight of gear.

Torsion due to tangential load (power transmission)

$$T = \frac{60P}{2\pi N}$$

57. Ans: (b)

Sol: $X_{static} = \frac{F_0}{k} = \frac{250}{10\times10^3}$ = 25 mm

At resonance $\frac{X}{X_{static}} = \frac{1}{2\xi}$

$\Rightarrow \frac{50}{25} = \frac{1}{2\xi} \Rightarrow \xi = 0.25$

$\omega_n = \sqrt{\frac{k}{m}} = \sqrt{\frac{10\times10^3}{1}}$ = 100 rad/sec

$C = 2\xi m\omega_n = 2 \times 0.25 \times 1 \times 100 = 50$ N-s/m

58. Ans: (a)

Sol: For bolt of uniform strength,

$(A)_{shank} = (A)_{threaded}$

$$\frac{\pi}{4}\left(d^2 - d_h^2\right) = \frac{\pi}{4}d_c^2$$

$$d_h = \sqrt{d^2 - d_c^2}$$

$d_c = 0.80\ d$

$$d_h = \sqrt{(10)^2 - (0.80\times10)^2}$$

$d_h = 6$ mm , $r_h = d_h/2 = 3$ mm

59. Ans: (c)

Sol: In Involute gear profile pressure angle is constant at each point of contact. In Cycloidal gear variation of centre distance is not permitted otherwise it will affect the velocity ratio.

The relative velocity of sliding when two gears are in mesh = $(\omega_1 + \omega_2)\times PC$

At pitch point path of contact = 0

$\therefore$ The velocity of sliding is zero at the pitch point.

60. Ans: (b)

Sol: K = 102.4 N/mm

G = 100 GPa, n = 8

We know that, $K = \frac{G\,d^4}{8D^3\,n}$

D = 100 mm,

$$102.4 = \frac{100\times10^3\times d^4}{8\times100^3\times8}$$

d = 16 mm

$C = \frac{D}{d} = \frac{100}{16}$ = Spring Index

$$K_s = 1 + \frac{1}{2C} = 1 + \frac{1}{2\times 100/16}$$

$\therefore K_s = 1.08$

61. Ans: (c)

Sol: TR > 1 for $0 < \frac{\omega}{\omega_n} < \sqrt{2}$

TR = 1 for $\frac{\omega}{\omega_n} = \sqrt{2}$

TR < 1 for $\frac{\omega}{\omega_n} > \sqrt{2}$

62. Ans: (a)

Sol: At high speed, it becomes necessary to consider the dynamic load resulting from the impact between the mating teeth. The dynamic force induced due to following factors.

- Inaccuracies in tooth profile
- Error in tooth spacing
- Misalignment between gears
- Elasticity of parts
- Inertia of rotating disc

63. Ans: (c)

Sol: Diameter of base circle is more than diameter dedendum circle interference doesn't occur. Because involute portion will not come in contact with non involute portion

64. Ans: (b)

Sol: $\xi = 0.5$; $c_r = 0.1$ mm

$$\xi = 1 - \frac{h_o}{c_r}$$

$h_0 = 0.05$ mm

65. Ans: (c)

Sol: The controlling force equation is given as

F = ar + b

$1600 = a \times 400 + b$ .... (1)

$800 = a \times 240 + b$ .... (2)

By solving these equations

a = 5, b = – 400

To make the governor isochronous, the controlling force line must pass through the origin. So, the initial tension is = 400

66. Ans: (c)

Sol: $r_1 = 150$ mm, $r_2 = 100$mm,

W = 1 kN, $\mu = 0.5$, T = ?

$T = \mu W\, r_m = 0.5 \times 1\text{kN} \times \left(\frac{0.150 + 0.1}{2}\right) = 62.5$ N-m

67. Ans (d)

Sol:

- For stability of governor, slope of controlling force curve should be more than slope of straight line representing centripetal force passing through origin at point of intersection. The condition for stability is given by

$$\therefore \frac{dF}{dr} > m\omega^2$$

When load on prime mover drops, the speed of centrifugal governor would increase and sleeve moves to top-most position. This closes the throttle valve and reduces fuel supply.

- The condition for the stability of governor is that the slope of the curve for the controlling force should be more than that of the line representing centripetal force at the speed considered. Therefore, if a centrifugal governor is stable at a particular position, it would be stable at all other position only if the condition of stability is satisfied.

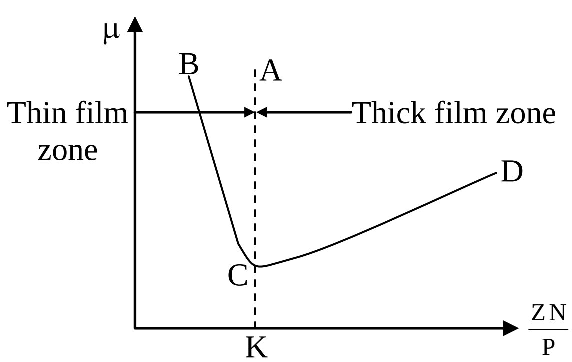
68. Ans: (b)

Sol: Bearing modulus (K) = 950

Bearing characteristic number = $\frac{ZN}{P}$

Where, Z = viscosity, N = speed (rpm),

P = pressure



From the data given in the problem,

$$\frac{ZN}{P} > 4K$$

It means bearing is operating in thick film zone as shown in above figure.

69. Ans: (d)

Sol: h = total rise;

ϕ_a = angle of ascent

θ = cam rotation angle;

ω = cam rotation speed

Displacement, D = $\frac{h}{2\pi}\left(\frac{2\pi\theta}{\phi_a} - \sin\left(\frac{2\pi\theta}{\phi_a}\right)\right)$;

Velocity, V = $\frac{h\omega}{\phi_a}\left(1-\cos\left(\frac{2\pi\theta}{\phi_a}\right)\right)$

Acceleration, A = $\frac{2\pi g h\omega^2}{\phi_a^2}\sin\left(\frac{2\pi\theta}{\phi_a}\right)$;

Jerk, J = $\frac{4\pi^2 h\omega^3}{\phi_a^3}\cos\left(\frac{2\pi\theta}{\phi_a}\right)$

70. Ans: (d)

Sol: According to flexural formula,

$$\frac{\sigma_b}{y} = \frac{M}{I} = \frac{E}{R} \Rightarrow \sigma_b = \frac{M}{I}y$$

- For a given bending moment (M) maximum bending stress developed will be the same as bending stress developed for a given bending moment is independent of material properties. However, the maximum bending moment taken by aluminium beam at failure is less, as the maximum stress taken by aluminium beam is lesser. Hence, statement (I) is incorrect.

- Thus, bending stress does not depend on Young's modulus of the material. Hence, statement (II) is correct.

71. Ans: (b)

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

72. Ans: (a)

Sol: The Young's modulus which is represented by the slope of the stress-strain curve in its linear portion is the same in tension and compression.

Thus, according to Hook's law,

$\Rightarrow \sigma = E\varepsilon$

$\Rightarrow \varepsilon = \dfrac{\sigma}{E} \quad \Rightarrow \quad \varepsilon \propto \sigma$

Hence, both the statements are correct and statement (II) is the correct explanation of statement (I).

73. Ans: (b)

Sol: $x = a\sin\omega t$ and $v = \dfrac{dx}{dt} = a\omega\cos\omega t$. It is clear that phase difference between 'x' and 'v' is $\pi/2$.

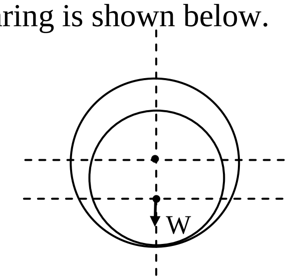
74. Ans: (d)

Sol: Bending moment at that section along the length of beam when subjected to lateral loading is the sum of complete area of shear force diagram either to the right or left upto that section and concentrated moments upto that section.

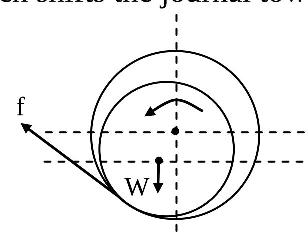
Bending moment = (Area of shear force diagram) + (sum of concentrated moments)

75. Ans: (d)

Sol: At rest the position of journal inside bearing is shown below.



At low speed, there is metal to metal contact and due to this frictional force is very high which shifts the journal towards left.



where, f = Friction force, W = Load

Wedging action are dominant at high speed and move the journal toward right.

Thus, the statement (I) is correct and statement (II) is incorrect.