Machine Design Test 5

Number of Questions 25 **Time:60 min.**

Directions for questions 1 to 25: Select the correct alternative from the given choices.

1. An Aluminum plate of thickness 5 mm has ultimate strength of 70 GPa. The shear force required by the punching tool to punch a hole of 28 mm diameter is

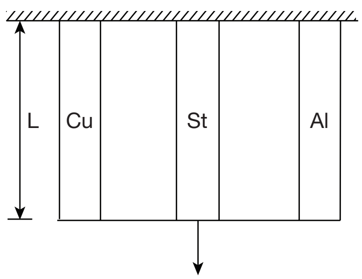
(A) 21.99 MN (B) 43.102 MN
(C) 30.788 MN (D) None

2. In case of shear stress and shear strain which of the statements are true?

(A) Modulus of rigidity has the units GPa.
(B) The area involved is parallel to the force applied.
(C) In double shear of rivets the area resisting the shear is twice the area resisting the shear in single shear.

(A) Only *A* (B) *A* and *B*
(C) *B* and *C* (D) *A*, *B* and *C*

3. A composite bar is made of three bars of material copper (E = 105 GPa), steel (E = 210 GPa) and Aluminum (E = 70 GPa). If the bars are of equal cross sectional area and length then the ratio of loads carried by the copper, steel, aluminum bars is



(A) 2 : 1 : 3 (B) 3 : 6 : 2
(C) 3 : 1 : 2 (D) 2 : 6 : 3

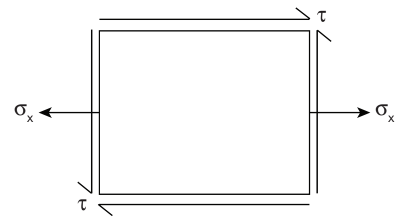
4. The hoop stress induced in a ring (E = 105 GPa) of diameter 20 mm, to increase its diameter to 24 mm by heating and fixing it at that diameter is

(A) 46.2 GPa (B) 23.1 GPa
(C) 21 GPa (D) 42 GPa

5. A solid shaft transmitting a torque of 5.2 kNm is rotating at 200 rpm. The shaft is not allowed to twist more than 0.5° in a length of 3.5 m. What is diameter of the shaft considering the stiffness for a rigidity modulus of 80 GPa?

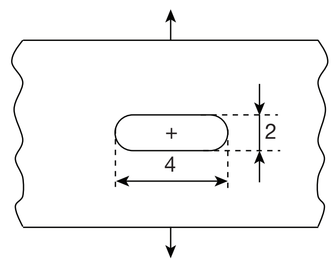
(A) 128 mm (B) 114 mm
(C) 256 mm (D) 156 mm

6. The stresses on a plane of machine part are acting as shown. What is the amount of compressive principle stress when σ_x = 50 MPa and τ = 29 MPa?



(A) 63.288 Mpa (B) 39.697 Mpa
(C) 13.288 Mpa (D) 10.303 Mpa

7. The theoretical stress concentration factor of the given plate is



(A) 2 (B) 1.5
(C) 3 (D) 5

8. Stress ratio is the ratio of maximum stress to the minimum stress. What is the stress ratio of completely reversed stresses?

(A) 0 (B) 1
(C) –1 (D) 2

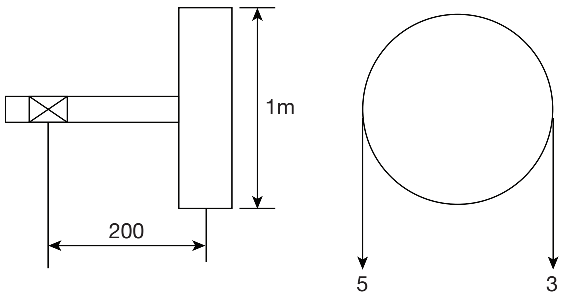
9. A metal specimen has the principal stresses as 250 MPa and 200 MPa with a Poison's ratio of 0.3. What is the ratio of Factor of safeties obtained by Rankine theory to Haigh's theory? (yield strength = 500 MPa)

(A) 1.077 (B) 0.9285
(C) 0.2 (D) 2

10. A solid shaft of diameter 30 mm transmits a torque of 900 Nm. The solid shaft is replaced by a hollow shaft of same material to transmit the same torque. If the space restriction limits the maximum diameter of a shaft that can be used to 40 mm then what is the thickness of the hollow shaft?

(A) 5 mm (B) 1.25 mm
(C) 2.5 mm (D) 10 mm

11. A solid shaft is belt driven by means of a motor through a pulley of 1 m in diameter. The maximum allowable shear stress of the shaft material is 40 MPa. What is the diameter of the shaft for the given tensions in the belts?



(A) 54 mm (B) 63 mm
(C) 79 mm (D) 40 mm

12. In an *S-N* diagram, the stress amplitude, where the *S-N* curve becomes asymptotic is given as
(A) Ultimate tensile strength
(B) Yield strength
(C) Endurance limit
(D) Mean bending stress.

13. Which of these is a radial friction clutch?
(A) Disc clutch (B) Cone clutch
(C) Spiral jaw clutch (D) Centrifugal clutch

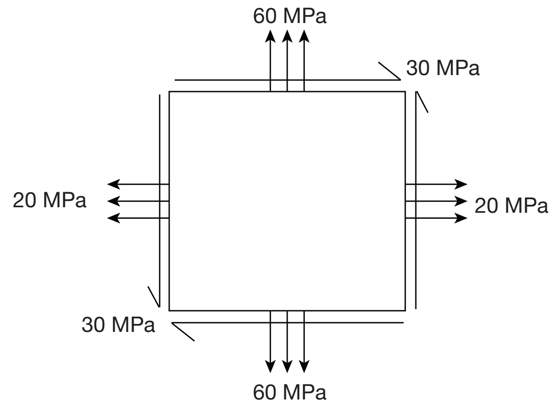
14. The torque transmitted by a multi plate clutch is 1216 N.m when the axial force is 4 kN. The coefficient of friction is 0.4 and number of discs on the driving shaft are 4. Assuming uniform pressure what are the number of discs on the driven shaft? The inside and outer side radii of the contact surfaces are 100 mm and 150 mm respectively.
(A) 3 (B) 2
(C) 4 (D) 5

15. What is the maximum intensity of pressure for a single plate clutch with inside and outside radii of the contact surface of 60 mm and 120 mm respectively? The axial force acting is 5 kN. Assume uniform wear.
(A) 229.3 kPa (B) 305.7 kPa
(C) 221.05 kPa (D) 301.07 kPa

16. A multiple disc clutch can also be sometimes used as
(A) Brake (B) Flywheel
(C) Crank (D) Gear

17. The intensity of pressure in case of disc or plate clutch is
(A) Maximum at outer radius and minimum at inner radius.
(B) Maximum at inner radius and minimum at outer radius.
(C) Maximum at inner radius and minimum at mean radius.
(D) Minimum at inner radius and maximum at mean radius.

18. A part of a machine element is subjected to stresses as shown. What is the factor of safety according to Von Misses theory if the yield strength in tension of the material is 120 MPa?



(A) 1.66 (B) 1.44
(C) 1.5 (D) 2.25

19. In a centrifugal clutch, the net outward radial force with which the shoe presses against the rim is
(A) The sum of centrifugal force and the spring force.
(B) The difference of centrifugal force and the spring force.
(C) Two times the difference of centrifugal force and the spring force.
(D) Half the sum of centrifugal force and the spring force.

20. A cone clutch of semi cone angle of 14° is used to transmit a torque of 10 N-m. The contact surfaces have an effective diameter of 70 mm with a coefficient of friction of 0.4. What is the amount of normal force acting on the friction surface? (Assume uniform wear)
(A) 693.07 N (B) 172.8 N
(C) 714.3 N (D) 178.09 N

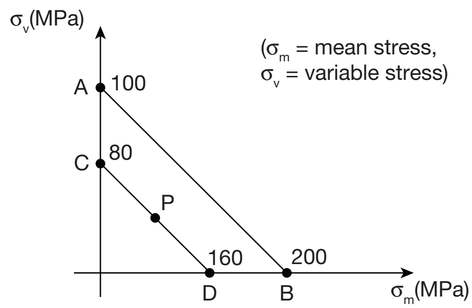
21. Match List-I with List-II

	List-I		List-II
A.	$\sigma_1 = \sigma_y/F.S$	**1.**	Haigh's theory
B.	$\tau_{max} = \sigma_y/2.\ F.S$	**2.**	Von Mises theory
C.	Maximum strain Energy theory	**3.**	Rankine's theory
D.	Maximum distortion Energy theory	**4.**	Tresca's theory

Where, σ_1 = maximum principle stress, τ_{max} = maximum shear stress, σ_y = yield stress under tension, *F.S* = factor of safety

	A	*B*	*C*	*D*
(A)	4	3	1	2
(B)	4	3	2	1
(C)	3	4	1	2
(D)	3	4	2	1

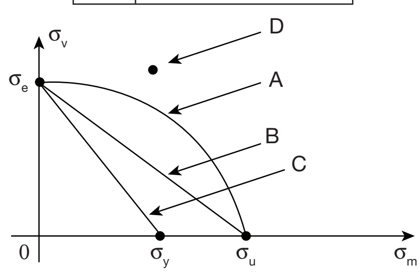
22. A metal with endurance limit and ultimate tensile stress of 100 MPa and 200 MPa respectively has the safe stress line according to Goodman method as shown. If the mean stress at point P is 50 MPa what is the variable stress at point *P*?



(A) 60 MPa (B) 62.5 MPa
(C) 50 MPa (D) 55 MPa

23. Match List-I with the graph

List –I	
1.	Goodman line
2.	Soderberg line
3.	Failure point
4.	Gerber line



	1	2	3	4
(A)	*B*	*C*	*D*	*A*
(B)	*B*	*C*	*A*	*D*
(C)	*C*	*B*	*D*	*A*
(D)	*C*	*B*	*A*	*D*

24. Power transmitted by a hollow shaft at 300 rpm is 800 kW. The ratio of outer diameter to the inner diameter of the shaft is 1.5. The maximum torque transmitted exceeds the mean torque by 40%. What is the outer diameter of the shaft if the maximum permissible shear stress of the shaft material is 80 Mpa.

(A) 142 mm (B) 213 mm
(C) 95 mm (D) 426 mm

25. A shaft of alloy steel transmits a torque of *T* Nm when the diameter is *d*. Another shaft of mild steel is used to transmit a torque of 4*T*. If the ratio of permissible shear stresses of mild steel to alloy steel is 7.35 then what is the diameter of the mild steel shaft?

(A) 3.086 d (B) 0.816 d
(C) 1.225 d (D) 0.324 d

Answer Keys

1. C	**2.** D	**3.** B	**4.** C	**5.** A	**6.** C	**7.** D	**8.** C	**9.** A	**10.** C
11. B	**12.** C	**13.** D	**14.** A	**15.** C	**16.** A	**17.** B	**18.** A	**19.** B	**20.** C
21. C	**22.** D	**23.** A	**24.** A	**25.** B					

Hints and Explanations

1. P = shear force required = $A \times \tau_u$

$\tau_u = 70\ GPa = 70 \times 10^9\ Pa$

$A = \pi.d.t$

Where, $d = 28\ mm = 28 \times 10^{-3}$ m

$t = 5\ mm = 5 \times 10^{-3}$ m

$\therefore \quad P = \pi \times 28 \times 10^{-3} \times 5 \times 10^{-3} \times 70 \times 10^9$

$P = 30.788$ MN Choice (C)

3. The extension/elongation of the three bars is same

$\therefore \quad \delta_{CU} = \delta_{ST} = \delta_{Al}$

$$\therefore \frac{P_{cu}\,L}{A\,E_{cu}} = \frac{P_{st}\,L}{A\,E_{st}} = \frac{P_{Al}\,L}{A\,E_{Al}}$$

$$\therefore \frac{P_{cu}}{E_{cu}} = \frac{P_{st}}{E_{st}} = \frac{P_{Al}}{E_{Al}}$$

($\because$ *A* and *L* are equal for the three bars)

$$\therefore \frac{P_{cu}}{105} = \frac{P_{st}}{210} = \frac{P_{Al}}{70} = \text{Constant } (k)$$

$\therefore \quad P_{cu} : P_{St} : P_{Al} = 105\ k : 210\ k : 70\ k$

$= 3 : 6 : 2$ Choice (B)

4. $D = 24$ mm, $d = 20$ mm

$$\text{Hoop stress} = E\left(\frac{D-d}{d}\right) = 105 \times 10^9 \times \left(\frac{24-20}{20}\right)$$

$\sigma = 21 \times 10^9\ Pa = 21$ GPa

Choice (C)

5. Considering the stiffness

$$\frac{\tau}{r} = \frac{G\theta}{L}$$

$$\text{also, } \frac{T}{J} = \frac{G\theta}{L}$$

$$\therefore \frac{5.2\times10^3}{\frac{\pi}{32}\times d^4}=\frac{80\times10^9\times\left(\frac{0.5\times\pi}{180}\right)}{3.5}$$

$\Rightarrow$ $d = 0.1276$ m = 127.65 mm $\cong$ 128 mm

Choice (A)

6. The principle stress of a plane member is

$$\sigma_{1,2}=\frac{\sigma_x+\sigma_y}{2}\pm\sqrt{\left(\frac{\sigma_x-\sigma_y}{2}\right)+\tau^2}$$

$$\sigma_2=\frac{\sigma_x}{2}-\sqrt{\left(\frac{\sigma_x}{2}\right)^2+\tau^2}\quad(\therefore \sigma y=0)$$

$= 25 - \sqrt{25^2+29^2}$

$\sigma_2 = -13.288$ (compressive)

Choice (C)

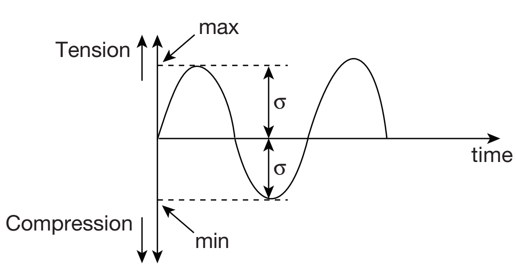
7. $K_t=\frac{\sigma_{\max}}{\sigma}=\left(1+\frac{2a}{b}\right)$

a = major radius, b = minor radius

$\therefore K_t=\left(1+\frac{2\times2}{1}\right)=5$

Choice (D)

8.



$\therefore$ stress ratio $=\frac{\sigma_{\max}}{\sigma_{\min}}=\frac{\sigma}{-\sigma}=-1$

Choice (C)

9. $\sigma_1 = 250$ MPa, $\sigma_2 = 200$ MPa, $\mu = 0.3$

According to Rankine theory,

$$\sigma_1=\left(\frac{\sigma_y}{F.S}\right)\Rightarrow(F.S)_R=\frac{\sigma_y}{\sigma_1}=\frac{500}{250}=2$$

According to Haigh's theory, (Max. strain energy theory)

$$\sigma_1^2+\sigma_2^2-2\mu\sigma_1\sigma_2=\left(\frac{\sigma_y}{FS}\right)^2$$

$$250^2+200^2-(2\times0.3\times250\times200)=\left(\frac{500}{FS}\right)^2$$

$$\sqrt{72500}=\frac{500}{F.S}$$

$\Rightarrow$ $(F.S)_H = 1.857$

$$\therefore \frac{(FS)_R}{(FS)_H}=\frac{2}{1.857}=1.077$$

Choice (A)

10. Torque transmitted by solid shaft $=\frac{\pi}{16}.\tau\, d^3$

Torque transmitted by hollow shaft $=\frac{\pi}{16}d_0^3.\left(1-k^4\right).\tau$

$\therefore \frac{\pi}{16}d_0^3\left(1-k^4\right)\tau=\frac{\pi}{16}.\tau\, d^3$ (where $k=\frac{d_i}{d_o}$)

d = diameter of solid shaft = 30 mm

d_i = internal diameter

d_o = outside diameter = 40 mm

$\because$ torque is equal

$\therefore d_0^3\left(1-k^4\right)=d^3$

$40^3\,(1-k^4) = 30^3$

$\Rightarrow k^4=\frac{37}{64}\Rightarrow k=0.872$

$\therefore$ $d_i = 0.872\times40 = 34.88 \cong 35$ mm

$\therefore$ Thickness of hollow shaft $=\frac{d_o-d_i}{2}=\frac{40-35}{2}=2.5$ mm

Choice (C)

11. T = Torque transmitted = $(T_1 - T_2)\,R = (5 - 3)\times 0.5$

$\therefore$ $T = 2\times0.5 = 1$ kN-m

Bending moment = $M = (T_1 + T_2)\times(200\times10^{-3})$

$= (5 + 3)\times 0.2$

$M = 8\times0.2 = 1.6$ kN-m

Equivalent twisting moment = $T_e=\sqrt{M^2+T^2}$

$T_e=\sqrt{1^2+1.6^2}$ = 1.887 kN-m

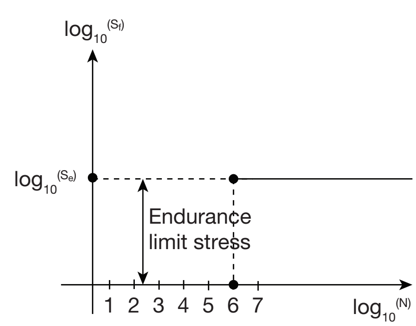
By shear stress theory

$$\frac{\pi}{16}\times\tau\times d^3=\sqrt{M^2+T^2}$$

$$\Rightarrow\frac{\pi}{16}\times40\times10^6\times d^3=1.887\times10^3$$

$\Rightarrow$ $d = 0.06216$ m = 62.16 mm $\cong$ 63 mm Choice (B)

12.



Choice (C)

13. Choice (D)

14. $T = n\,\mu\,W R$

$T = 1216$ Nm, $W = 4000$ N

$R=\frac{2}{3}\left(\frac{r_1^3-r_2^3}{r_1^2-r_2^2}\right)$, r_1 = 150 mm = 0.15 m

r_2 = 100 mm = 0.1 m

$\therefore$ $1216 = n \times 0.4 \times 4000 \times \frac{2}{3} \times \left(\frac{0.15^3 - 0.1^3}{0.15^2 - 0.1^2}\right)$

$\Rightarrow$ $n = 6$

Number of pairs of contact surfaces = $n = n_1 + n_2 - 1$

n_1 = number of discs on the driving shaft = 4

$\therefore$ $6 = 4 + n_2 - 1 \Rightarrow n_2 = 3$

$\therefore$ n_2 = number of discs on driven shaft = 3

Choice (A)

15. $P_{max} \times r_2 = C$

r_2 = inside radius, C = constant

$\therefore$ $P_{max} \times 60 \times 10^{-3} = C \Rightarrow P_{max} = \frac{C}{60} \times 10^3$

$$C = \frac{W}{2\pi(r_2 - r_1)} = \frac{5 \times 10^3}{2\pi(120-60) \times 10^{-3}} = 13262.911$$

$\therefore P_{max} = \frac{C}{60} \times 10^3 = 221.05$ kPa Choice (C)

16. Choice (A)

17. Choice (B)

18. $\sigma_x = 20$ MPa, $\sigma_y = 60$ MPa and $\tau_{xy} = 30$ MPa

$\therefore$ The principal stresses are

$$\sigma_{1,2} = \frac{\sigma_x + \sigma_y}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$\sigma_1 = 40 + \sqrt{20^2 + 30^2} = 40 + 10\sqrt{13} \text{ MPa}$$

$$\sigma_2 = 40 - \sqrt{20^2 + 30^2} = 40 - 10\sqrt{13} \text{ MPa}$$

$\therefore$ By Von Misses theory

$$\sigma_1^2 + \sigma_2^2 - 2\sigma_1\sigma_2 = \left(\frac{\sigma_y}{FS}\right)^2$$

$$(40+10\sqrt{3})^2 + (40-10\sqrt{13})^2 - 2(40+10\sqrt{13})(40-10\sqrt{13})$$

$$= \left(\frac{120}{FS}\right)^2$$

$\Rightarrow$ $5200 = \frac{14400}{FS^2}$

$\Rightarrow$ $FS = 1.66$ Choice (A)

19. Choice (B)

20. $R = \frac{70}{2} = 35$ mm = 0.035 m

$T = 10$ N-m, $\mu = 0.4$, $\alpha = 14^o$

$\therefore$ By Assuming uniform wear,

$T = \mu W R \operatorname{Cosec}\alpha$

$\therefore$ $10 = 0.4 \times W \times 0.035 \times \operatorname{Cosec} 14$

$W = 693.07$ N

Normal force on the friction surface = $W_n = W \operatorname{Cosec}\alpha$

$\therefore$ $W_n = 693.07 \times \operatorname{Cosec} 14$

$W_n = 714.3$ N Choice (C)

22. From the figure points C and D are the endurance limit and ultimate stress respectively by applying a factor of safety

$\sigma_e = 100$ MPa, $\sigma_u = 200$ MPa

$$(\sigma_e)_c = \frac{\sigma_e}{F.S} = 80 \text{ MPa} \Rightarrow FS = \frac{10}{8} = 1.25$$

Similarly

$$(\sigma_n)_D = \frac{\sigma_u}{F.S} = 160 \text{ MPa} \Rightarrow F.S = \frac{10}{8} = 1.25$$

From the Goodman relation

$$\frac{\sigma_m}{\sigma_u} + \frac{\sigma_v}{\sigma_e} = \frac{1}{F.S}$$

$\therefore$ $(\sigma_m)_p = 50$ MPa

$\Rightarrow$ $\frac{50}{200} + \frac{\sigma_V}{100} = \frac{1}{1.25} \Rightarrow (\sigma_V)_p = 55 \text{ MPa}$ Choice (D)

23. Choice (A)

24. $P = \frac{2\pi NT}{60} = 800 \text{ kW} \Rightarrow T = \frac{60P}{2\pi N}$

$$\therefore T = \frac{60 \times 800 \times 10^3}{2 \times \pi \times 300} = 25464.8 \text{ N-m}$$

This is the mean torque

$\therefore$ $T_{max} = (1 + 0.4) \times T = 1.4T = 35650.72$ Nm

$\therefore$ From twisting moment equation

$$\frac{T}{J} = \frac{\tau}{r} \Rightarrow T = \frac{\pi}{32} \times \frac{2\tau}{d_o} \times \left(d_0^4 - d_i^4\right)$$

$$\Rightarrow T_{max} = \frac{\pi}{16} \times \tau_{max} \times d_o^3\left(1 - k^4\right)$$

Where, $k = \frac{d_i}{d_o}$

$\therefore$ $35650.72 = \frac{\pi}{16} \times 80 \times 10^6 \times d_0^3\left[1 - \left(\frac{1}{1.5}\right)^4\right]$

$\therefore$ $d_o = 0.141419$ m = 141.419 mm ≅ 142 mm

Choice (A)

25. $T = \frac{\pi}{16}\tau d^3$

For alloy steel, $T = \frac{\pi}{16} \cdot \tau_a . d^3 \rightarrow (1)$

For mild steel, $4T = \frac{\pi}{16}\tau_m\, d_m^3 \rightarrow (2)$

Dividing equations (1) and (2)

$$\frac{1}{4} = \frac{\tau_a}{\tau_m} \cdot \left(\frac{d}{d_m}\right)^3$$

$$\frac{\tau_m}{\tau_a} = 7.35$$

$\therefore \frac{1}{4} = \frac{1}{7.35} \cdot \left(\frac{d}{d_m}\right)^3 \Rightarrow d_m = 0.816$ d Choice (B)