Chapter-8

Machine Design (Solutions)

1. Bolted, Riveted & Wielded Joint

1. **(b)**

For single v – butt welds, the angle should be as (40º – 60º)

In double v – butt welds, it is (60º – 70º)

2. **(a)**

Given data:

Thickness of boiler plate $\Rightarrow$ t = 16 mm

We know that, Unwin's formula for rivet:

$$dr = 6\sqrt{t} = 6\sqrt{16}$$

$$\therefore \quad \boxed{dr = 24 \text{ mm}}$$

3. **(d)**

Given data:

$$F_s = 100\,N, \quad F_t = 120\,N, \quad F_c = 150N$$

Solid plate strength $\Rightarrow$ F = 200 N

$$\eta_{RJ} = \frac{\text{minimum of } (F_s, F_t, F_c)}{\text{solid plate strength}}$$

$$\therefore \quad \eta_{RJ} = \frac{100}{200} = 50\%$$

4. **(*)**

Given data:

$$(\tau_s)_1 = 50 \text{ N/mm}^2, \quad (dr)_2 = 2(dr)_1$$

$$\text{shearing strength,} \quad F_s = n \times \frac{\pi}{4}(dr)^2 \times \tau_s$$

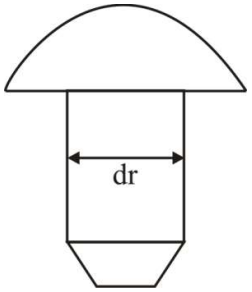
$$\tau_s \ \alpha \ \frac{1}{(dr)^2}$$

$$\therefore \quad (\tau_s)_2 = (\tau_s)_1 \times \frac{(dr)_1^2}{(dr)_2^2} = 50 \times \left(\frac{1}{2}\right)^2 = 12.5 \text{ N/mm}^2$$

Note: In question shearing strength should be as 50N then answer will be as 200 N.

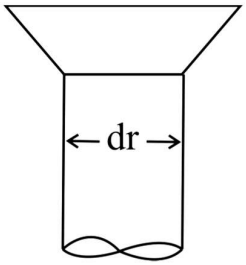
5. (d)

Rivets are generally specified by rivets nominal diameter.



6. (c)

In the figure, Rivet is called as countersunk head rivet.



It is generally used in submarines, submerged structures, etc.

7. (a)

A backing ring is used, when two pipes are butt welded. It is used as same material of pipe to ensure the sound joint (ideal joint) in butt weld.

8. (c)

Given data:

Tearing efficiency of rivet joint $\Rightarrow \eta_t = 60\%$

$$\eta_t = \frac{\text{tearing strength}}{\text{solid plate strength}} = \frac{(p - dr).t.\sigma_t}{P.t.\sigma_t}$$

$$\eta_t = \left(1 - \frac{dr}{P}\right) = 0.6$$

$$\therefore \boxed{\frac{dr}{P} = 0.4}$$, P = pitch of rivet joint

9. (d)

A rivetted joint may fail due to

(1) Shearing of rivets

(2) Crushing of rivets

(3) Tearing of the plates.

Note: which strength of joint is less, joint fails into that

10. (d)

Power transmitted by pulley -

$$\boxed{P = \text{force} \times \text{velocity} = (T_1 - T_2) \times \frac{\pi DN}{60}} \text{ watt.}$$

where, T_1 = Tension in tight side

T_2 = Tension in slack side

D = Dia of pulley

N = R.P.M

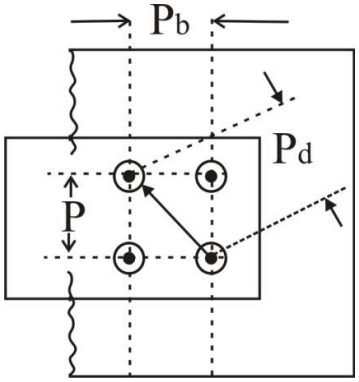
11. (a)

Power factor is defined as the ratio of actual power used in welding to the apparent power supplied in welding line.

It is usually as low as (0.3) in welding operation to improve the stability of arc and maintenance of it.

12. (c)

Distance between two adjacent rows of rivet centre is known as back pitch (P_b)



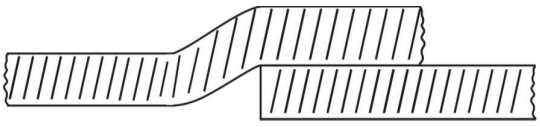
Lowest distance between two rivets centre in adjacent rows of a zig – zag riveting, called as diagonal pitch (P_d)

13. (c)

Aircraft's body usually fabricated by riveting because of low friction at the surface and low weight to strength ratio of joint.

14. (b)

Joggled welded joints are used for sever loading in vehicals and upper surface of both plats should in same planes.



15. (a)

Plain and butt welds are used for welding of plates upto 25 mm thickness.

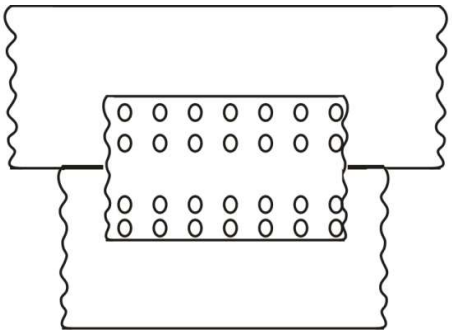
Lap joints are used to weld upto 5 mm thickness of plates.

16. (c)

Plug welds are used to joint two flat plate. And filler material is used as same of plate material. In this welding some holes are done on upper plate and filler material filled in those holes.

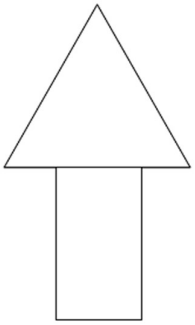
17. (b)

In joint shown in figure is known as double riveted butt joint (single cover plate)



18. (d)

The rivet given in the question is known as steeple rivet. It is used to boilers.



2. Cutter and Knuckle Joint

1. (d)

Cotter joints are used to connect two co-axial shafts/ rods which are under tension.

Cotter joints are weak in shear, so not used in shearing but design of cotter joint is to be done on shear failure.

3. Threads & Power screw

1. (b)

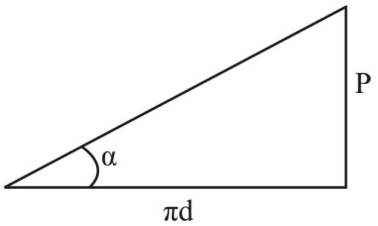
Acme threads are generally used for power transmission in both direction.

For example – spindles of bench vices, feed screws.

It is stronger than square threads.

2. (c)

Let for screw thread, P = pitch , d = dia of screw thread.



$\boxed{\tan \alpha = \frac{P}{\pi d}}$ For single start

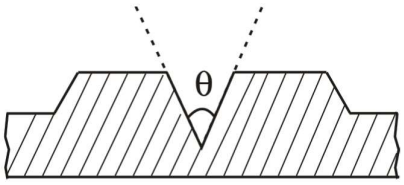
$$\boxed{\tan\alpha = \frac{n.P}{\pi d} = \frac{L}{\pi d}}, \quad n = \text{No. of starts, } L = \text{lead}$$

3. (a)

Acme threads are known as trapezoidal threads.

In trapezoidal threads, $\theta = 30^{o}$

In acme threads, $\theta = 29^{o}$



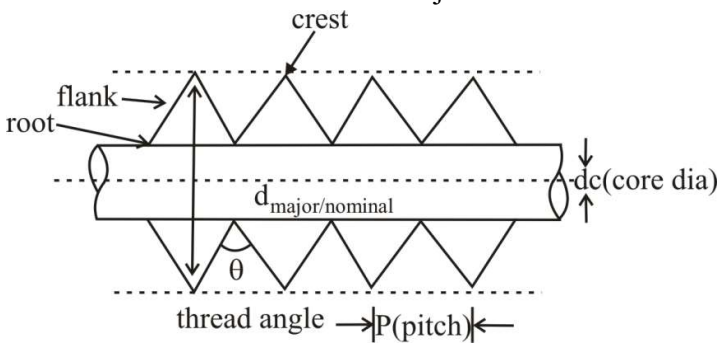
4. (b)

For self locking screws, efficiency $\eta_{SL} < 0.5(50\%)$

For overhauling screws, efficiency $\eta_{OH} > 0.5(50\%)$

5. (a)

The crest dia of screw thread is known as major or nominal dia.



6. (d)

In bench vice, square threads are used which transmit power in both direction.

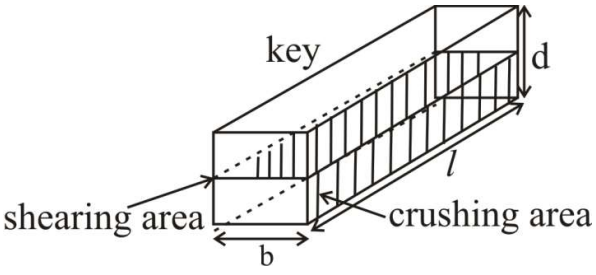
4. Keys and Couplings

1. (d)

Given data:

$$F_{shear} = F_{crush}$$

$$\sigma_{crush} = 2\tau_{shear}$$



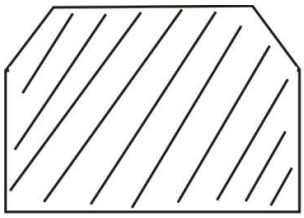
$$F_s = F_c = b \times l \times \tau_s = \frac{d}{2} \times l \times \sigma_c$$

$$b \times \tau_s = \frac{d}{2} \times 2\tau_s$$

$\therefore$ width of the key (b) = (d) thickness of key

2. (b)

Barth key is used in compression. It is a square key having two beveled corner's for easy fitting and low twisting tendency.



Cross-section of Barth key

3. (c)

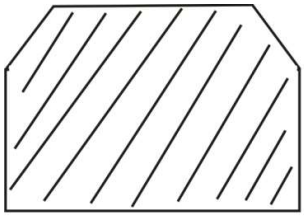
Shaft is subjected to both twisting and bending stresses.

Bending is present due to weight of shaft and pulleys.

Equivalent torque for shaft $Te = \sqrt{M^2 + T^2}$

4. (d)

Barth key is used in compression. It is a square key having two beveled corner's for easy fitting and low twisting tendency.



Cross-section of Barth key

5. (c)

Square key is strong in both shear and crushing $\boxed{F_{shear} = F_{crush}}$

6. (a)

Two flanges in flange coupling are fitted by reamed holes. Reamed holes are finish and have low tendency to stress concentration.

7. (d)

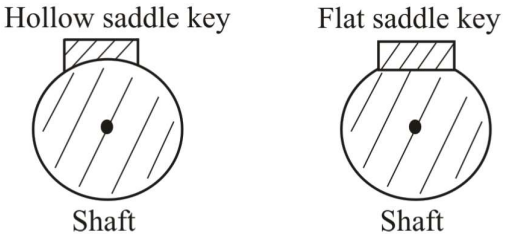
The sleeve or muff couplings are designed as hollow shaft because a hollow sleeve is used to join two shafts.

8. (a)

To ensure the better strength of joint metal to metal joint is used. It is used for high pressure range. It's strength is higher because of homogeneous joint.

9. (a)

Saddle key is used to transmit power by means of frictional resistance .



10. (c)

A key may fails due to shearing or crushing.

11. (a)

A feather key is a parallel key which is fitted in shaft by screw and free in hub. It is used to transmit power and permits the axial moment of hub.

12. (a)

A piece of cylindrical disc having segmental cross section is called woodruff key. It is adjustable and used in machine tools , automobiles etc.

5. Design Against Fluctuating Loads

1. (a)

When a variable load or cyclic load is applied on a body, fatigue produced in the body.

2. (c)

The value of maximum reversible stress below which body can posses infinite no. of cycles without any failure, called endurance limit/strength.
It is very important as design point of view.

3. (c)

Fatigue limit of material can be increased by developing some pre – stresses in the body by some following methods.

(1) Cold working
(2) Shot peening/sand blasting
(3) Under – stressing
(4) Coating on the surface of body.

4. (b) Stress concentration is more serious in brittle material under static loading because the material doesn't show any pre-indication to failure. It takes place suddenly.

6. Belt, Rope & Chain Dives

1. (d)

In the belt and pulley system, the belt passes through a tension and compression in cyclic order, this uneven contraction and extension developed the creep**.**

2. (b)

Due to centrifugal effect of belt, it reduces the friction between belt and pulley.
So power transmitted get reduced.
Note: it reduced the power transmitted , not power input.

3. (d)

In the belt and pulley system, the belt passes through a tension and compression in cyclic order, this uneven contraction and extension developed the creep**.**

4. (c)

Power transmitted by pulley, $P=\left(T.v-mv^3\right).\left(1-\frac{1}{e^{\mu\theta}}\right)$,

For maximum power transmission, $\frac{dP}{dv}=0$

We will get, $\boxed{T=3T_c=3mv^2}$

5. (c)

Given data

$v = 880$ m/min, $P=22.5$ kW

We know that, $P = F\times v=\left(T_1-T_2\right)\times v$

$$\therefore \quad \left(T_1-T_2\right)=\frac{P}{v}=\frac{22.5\times10^3}{880/60}$$

$$\boxed{T_1-T_2 = 1534.09 \approx 1540\,N}$$

6. (d)

Power transmitted by belt and pulley (centrifugal effect is taken)

$$\boxed{P=\left(T.v-mv^3\right)\left(1-\frac{1}{e^{\mu\theta}}\right)}$$

So, power is depend on T, v, μ and θ

$\theta=$ arc angle of belt on the pulley.

7. (a)

Given data

$\left(T_1 - T_2\right) = 3000\,N$, $v = 15$ m/sec

Power $= \left(T_1-T_2\right)\times v = 15 \times 3000 = 45000$ watt

$$\boxed{P=45\,kW}$$

8. (a)

Given data :

Mass per unit length $m = 1.5$ kg/m

$v = 10$ m/sec

we know that centrifugal tension in the belt

$$T_c = mv^2$$

$$\therefore T_c = 1.5\times(10)^2$$

$$\boxed{T_c = 150 \text{ N}}$$

9. (c)

Include angle of v – belt is (40º). If we reduce the angle, wedging action increases due to which sliping will occur.

10. (c)

For constant length of belt,

Increase in length on tight side = decrease in length of slack side.

$$K.(T_1 - T_0) = K(T_0 - T_2)$$

$$T_0 = \left(\frac{T_1 + T_2}{2}\right) \qquad \{K = \text{expansion coefficient of belt.}\}$$

If we considered the centrifugal effect

$$T_0 = \left(\frac{T_1 + T_2}{2}\right) + T_c$$

$$\therefore \quad \boxed{T_1 + T_2 = 2(T_0 - T_c)}$$

$$\boxed{T_1 + T_2 < 2T_0}$$

Note : Sum of (T_1) and (T_2) should be less than twice of initial tension in ideal condition. But in actual, material of belt is not perfectly elastic, so sum of (T_1) and (T_2) is more than twice the initial tension.

11. (a)

Given data

$T_{max} = 100$ N, $T_{min} = 60$ N, $b = 10$ cm, $t = 4$ cm.

We know that, maximum tension $(T_{max}) = \sigma.b.t.$

$$\therefore \quad \sigma = \frac{100}{4\times10} = \boxed{2.5 \text{ N/cm}^2}$$

12. (c)

In the belt and pulley system, the belt passes through a tension and compression in cyclic order, this uneven contraction and extension developed the creep**.**

13. (d)

Belt drive, rope drive and cone pulley drive are known as negative drive due to presence of slip. Chain drive is use as a positive drive which has no slip condition.

14. (c)

Power transmitted by pulley, $P=\left(T.v-mv^3\right).\left(1-\frac{1}{e^{\mu\theta}}\right)$

for maximum power transmission, $\frac{dP}{dv}=0$

We will get, $\boxed{T=3T_c=3mv^2}$

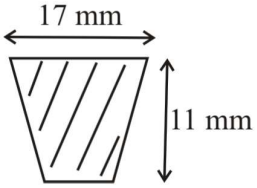
15. (d)

V – belts are classified into different types on the basis of power transmitting capacity and dimension of the cross section.

For B – grade V – belt

power range – 0.5 kW to 6 kW

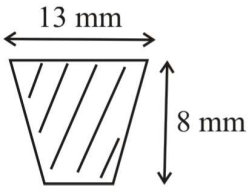
used in fan of automobiles



For - A-grade V–belt

Power range – 0.1 kW to 3 kw

Used in-lathe m/c gear box



16. (a)

Include angle of V – belt lies in range of (30º – 40º) but usually uses as (40º)

17. (c)

In one belt is damaged in multiple V – belt system, then all belts should be change due to uneven stresses.

If all belt are changed then stress or loading are uniform in all belts.

18. (b)

In v – belt drives, belt touches the sides only. It does not touch the bottom of pulley because of power losses.

19. (b)

Power transmitted by pulley, $P=\left(T.v-mv^3\right).\left(1-\frac{1}{e^{\mu\theta}}\right)$,

for maximum power transmission, $\frac{dP}{dv}=0$

We will get, $\boxed{T=3T_c=3mv^2}$

20. (b)

In horizontal belt drive, the top side of belt should be as slack side because due to this angle of contact increases, further slip decreases. It can be done with the help of idler pulley in the slack side (bottom side)

21. (b)

In V-belt drives, belt touches the sides only. It does not touch the bottom of pulley because of power losses.

22. (a)

Bush roller type chain is used in motor cycles because rolling elements have low frictional resistance.

23. (a)

In belt drives, the phenomenon of uneven extensions and contractions of belt is known as creep.

24. (b)

Wire rope shows more strength in tension and more slip for high speeds. So it is used in low speed and high tension.

7. Gears

1. (c)

Lewis equation for gear

$$\boxed{\left(f_t\right)_{gear}=m.b.Y\left(\sigma_b\right)}$$

where, f_t = tangential force

m = module of gear

b = bidth of tooth

Y = Lewis form factor

σ_b = bending strength of tooth

It is always used for design a weaker pinion or gear.

Note 1: Design pinion first, when the material of both pinion and gear are same

2: Calculate $(Y.\sigma_b)$ for both first, then which has low value of $(Y.\sigma_b)$, design it. (For different material of pinion and gear)

2. (a)

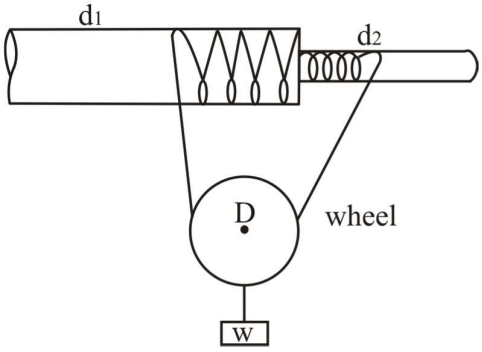
In Lewis equation

$(F_t) = bYm.(\sigma_b)$

$Y.\sigma_b$ is known as strength factor.

3. (c)

Velocity ratio of differential axle and wheel:



$$V.R = \frac{\text{distance moved by effort}}{\text{distance moved by load}}$$

$$V.R = \frac{\pi D}{(\pi d_1 - \pi d_2)/2}$$

$$\boxed{V.R = \frac{2D}{(d_1 - d_2)}}$$

4. (c)

Efficiency of worm gear

$$\boxed{\eta_w = \frac{\cos\phi - \mu \tan\lambda}{\cos\phi + \mu \tan\lambda}}$$

where,

λ = helix angle

ϕ = pressure angle

μ = coefficient of friction

It generally lies between 40% to 80%

5. (a)

The minimum centre distance between two gears is decided by Lewis equation of bending strength of gear.

$$\boxed{(F_t)_{max} = m.b.Y(\sigma_b)}$$

Here , module (m) decided the centre distance.

6. (b)

Gear teeth are made harder to avoid wear between the mating tooth. Boron is added to material of gear for this purpose.

7. (c)

The upper curve of cycloidal tooth from pitch circle is known as epicycloid curve and addendum is equal to epicycloid.

The lower curve of cycloidal gear from pitch curve is known as hypocycloidal curve. Dedendum is equal to hypocycloid .

8. (b,c)

For non – parallel and non intersecting shafts, spiral or skew gear is used .Hypoid gear is a small part of skew bevel gear. So both options are correct

Worm gear is also used for this type arrangement.

9. (a)

In involute gears, to avoiding interference the base circle must be lies at root or root circle.

10. (d)

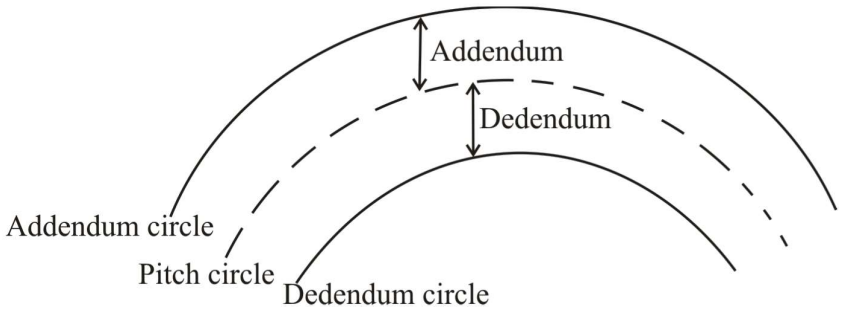
Gear teeth are made harder to avoid the wear. Boron is added to gear material at the teeth to make harder.

11. (a)

A reverted gear train is used in clocks. In this gear train driver and driven shafts are coaxial.

12. (b)

The radial distance between pitch circle and addendum circle is known as addendum. The part of tooth between these two circles is known as flank.



13. (a)

The gears whose axis are non – parallel and non – intersecting, called as skew bevel gears or spiral gears.

8. Breaks & Clutches

1. (d)

Frictional torque in case of flat pivot bearing for uniform wear theory

$$\boxed{(T_f)_{U.W.T} = \frac{1}{2}(\mu.W.R)}$$

2. (c)

Positive drive clutches have no slip.

Example – jaw clutch, toothed clutch.

3. (d)

A clutch is a device which transferred the power from one shaft to another shaft i.e driver to driven shafts. It can engage and disengage when required.

Both (A) and (R) are correct and (R) is correct explanation of (A)

4. (b)

Given data :

$r_i = 50$ mm, $r_o = 100$ mm, $W = 4$ kN

We known that, $P = \dfrac{W}{2\pi r(R_o - R_i)}$

$$P_{max} = \frac{W}{2\pi R_{min}(R_o - R_i)} \quad .....(1)$$

$$P_{min} = \frac{W}{2\pi R_{max}(R_o - R_i)} \quad .....(2)$$

$$\frac{P_{max}}{P_{min}} = \frac{R_{max}}{R_{min}} = \frac{100}{50} = 2$$

5. (d)

Couplings are used to connect the shafts to transmitted power from one to another shafts which are in alignment (small) or coaxial.

It is not used for parallel shafts.

6. (c)

The device which permits the connection and disconnection when requires, called clutch.

7. (a)

Frictional torque for clutches assuming uniform pressure theory-

$$(T_f)_{UPT} = \frac{2}{3}\mu W.R$$

Assuming uniform wear theory

$$(T_f)_{U.W.T} = \frac{1}{2}.\mu\, WR$$

$$\frac{(T_f)_{U.P.T}}{(T_f)_{U.W.T}} = \frac{2}{3} \times \frac{2}{1} = \frac{4}{3} = 1.33$$

$$\boxed{(T_f)_{U.P.T} > (T_f)_{U.W.T}}$$

Note: same formula is applied for clutch.

9. Bearings

19. (d)

In hydrostatic bearing amount of pressure is developed by external source due to which direct contact between journal and bearing does not occur at the steady or dynamic condition. Lubricating oil forms a layer between journal and bearing.

20. (a)

Roller and ball bearings are known as antifriction bearings. Because they show the less friction compare to sliding bearings. Needle roller bearing is a type of roller bearing

21. (b)

Frictinal coefficient for journal bearing.

$$\mu = 2\pi^2 . \left(\frac{Zn}{p}\right)\left(\frac{D}{c}\right), \quad \boxed{\mu \propto n}$$

where, Z = viscosity of fluid.

n = r.p.s = $\dfrac{\text{R.P.m}}{60}$

p = pressure

D = dia

C = clearance

22. (c)

In railway axle boxes, cylindrical roller bearings are used because it has high radial load bearing capacity and also having large contact area.

It is used for moderate speeds.

23. (b)

For conical pivot bearing, load carrying capacity of bearing is given as:

$\left(W_{max}\right) = P \times \pi\left(R_0^2 - R_1^2\right)$ ..... for U.P.T

$\left(W_{max}\right) = P \times 2\pi\left(R_0 - R_1\right)r$ ..... for U.W.T

In both theories, load carrying capacity does not depend on angle of cone.

So load capacity will remain same.

24. (a)

Angular contact bearing provides large contact area and high load carrying capacity for both axial and radial load.

25. (b)

Spherical roller bearings are self aligning bearings which is used in pair for high load carrying capacity.

26. (d)

Hydrostatic bearings are used for high load and low speeds whereas hydrodynamic bearings are used for low and moderate load and high velocities.

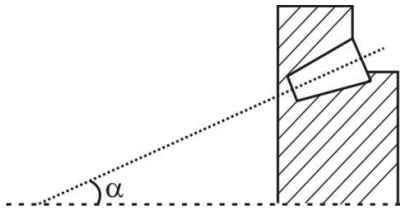
27. (d)

Ball and roller bearings are known as antifriction bearings because rolling elements show less friction compare to sliding elements.

28. (d)

Taper angle of outer raceway of taper roller bearings is generally lie between (20^o –25^o)

$\boxed{\alpha = 20^o \text{ to } 25^o}$



29. (a)

Roller contact bearing requires less lubrication but initial cost is very high. It is also noisy at higher speeds.

30. (d)

For friction circle of journal bearing:

Radius $\boxed{r_f = R.\sin\theta}$

For small value of (θ), $\sin\theta = \tan\theta = \mu$

$\therefore$ $\boxed{r_f = \mu.R}$

R = radius of journal

r_f = friction circle radius.

31. (a)

For hydrodynamic bearings, starting torque is high whereas, for hydrostatic bearing, the starting torque is very low**.**

Because in hydrostatic bearings, fluid is filled between the journal and bearing so surface contact is not possible at steady condition.

32. (d)

Taper roller bearing is capable to bear both axial and radial loads.

Generally taper rollers are used in pairs .

Applications – trucks, heavy duty vehicles , etc.

$$\boxed{\frac{f_r}{f_a} > 1 \quad \text{and} \quad \frac{L}{D} < 1}$$

33. (a)

In hydrostatic bearing, pressure of lubrication is developed by external source like pump. Metal to metal contact is avoided at low speeds.

10. Theory of Spring

1. **(d)** $\boxed{spring\ index = \frac{D}{d} > 1}$ D=mean coil dia, d=dia of wire.

2. **(a)** Leaf spring is assumes as a simple supported beam which is subjected to bending stress.

3. **(d)** When springs are in series –

$$\frac{1}{K_e} = \frac{1}{K_1} + \frac{1}{K_2} = \frac{K_1 + K_2}{K_1 K_2}$$

Equivalent stiffness $\boxed{K_e = \frac{K_1 K_2}{K_1 + K_2}}$

4. **(a)** Stiffness of helical spring – $(K) = \frac{Gd^4}{8.D^3.n}$

$$K \alpha \frac{d^4}{D^3}$$

Given data: $d_2 = 2d_1$, $D_2 = 2D_1$

$$\therefore \frac{K_2}{K_1} = \frac{d_2^4}{D_2^3} \times \frac{D_1^3}{d_1^4} = \frac{16 d_1^4 \times D_1^3}{8 D_1^3 \times d_1^4}$$

$\boxed{K_2 = 2K_1}$

5. **(b)** The two concentric helical springs wound with opposite hand helix because it prevents the locking of two coils in case of misalignment or buckling of springs.

6. **(a)** Given data - $m = 1000kg$, $h = 8cm$, $k = 500 \frac{kg}{cm}$

Applying energy balance –

$$m\ g(h + x) = \frac{1}{2}\ k\ x^2$$

$$1000 \times 9.81 \times (8 + x) = \frac{1}{2} \times 500 \times 9.81 \times x^2$$

$$32 + 4x = x^2$$

$$x^2 - 4x - 32 = 0$$

$x^2 - 8x + 4x - 32 = 0$

$(x-8)(x+4) = 0$

$x = -4$ which is not possible

$\therefore \quad \boxed{x = 8\text{cm}}$