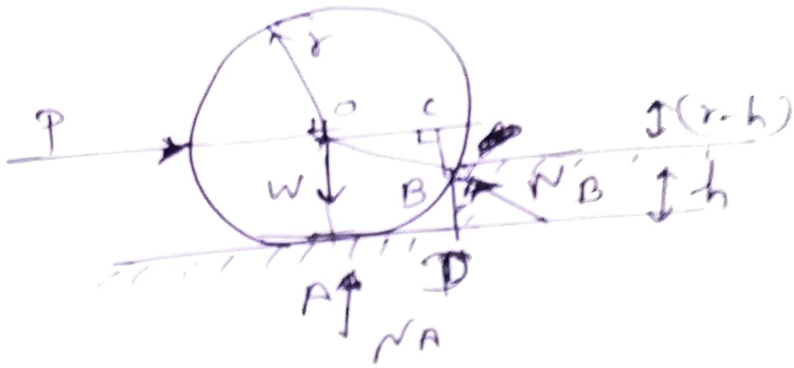
Total marks =216

Que (1)(a) Ans(i)



Applying $\Sigma M_B = 0$

$\Rightarrow \quad P(BC) + N_A(OC) = W.(OC)$

Here $BD = h$, $BC = (r-h)$ $\Big\} \Rightarrow OC = \sqrt{r^2 - (r-h)^2}$

$OC = \sqrt{r^2 - r^2 + 2rh - h^2}$

$OC = \sqrt{2rh - h^2}$

$\Rightarrow$ when it just begins to roll, $N_A = 0$

So $P(BC) + 0 = W(OC) = mg(OC)$

$\Rightarrow P(r-h) = mg\sqrt{2rh - h^2}$

$$\Rightarrow \boxed{P = \frac{mg\sqrt{2rh - h^2}}{(r-h)}}$$

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Ans (ii) $\Rightarrow$ Given $\Rightarrow$ dia of solid shaft $= d = 60$ mm

$d = 0.06$ m

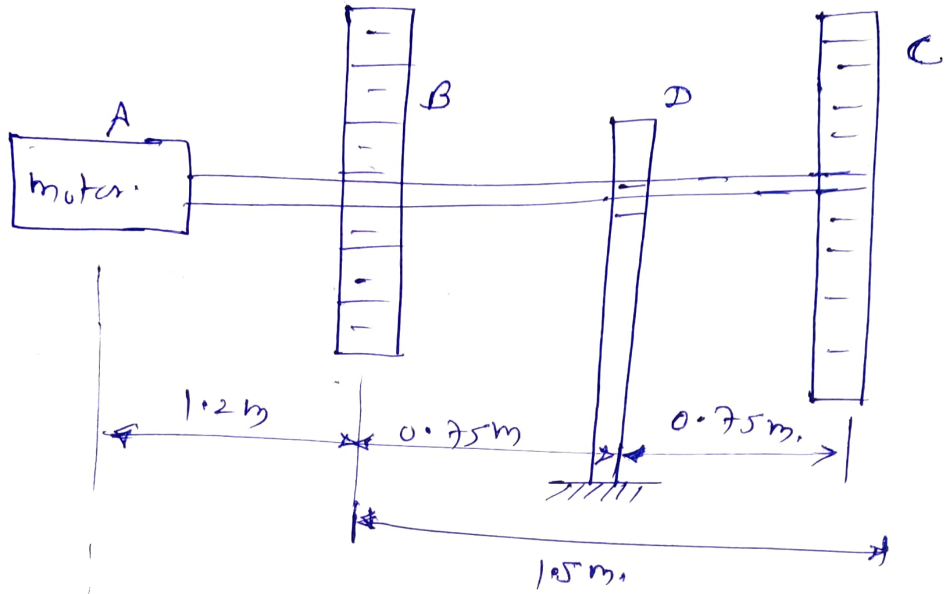
$P_A = 70$ kW, $P_B = 40$ kW,

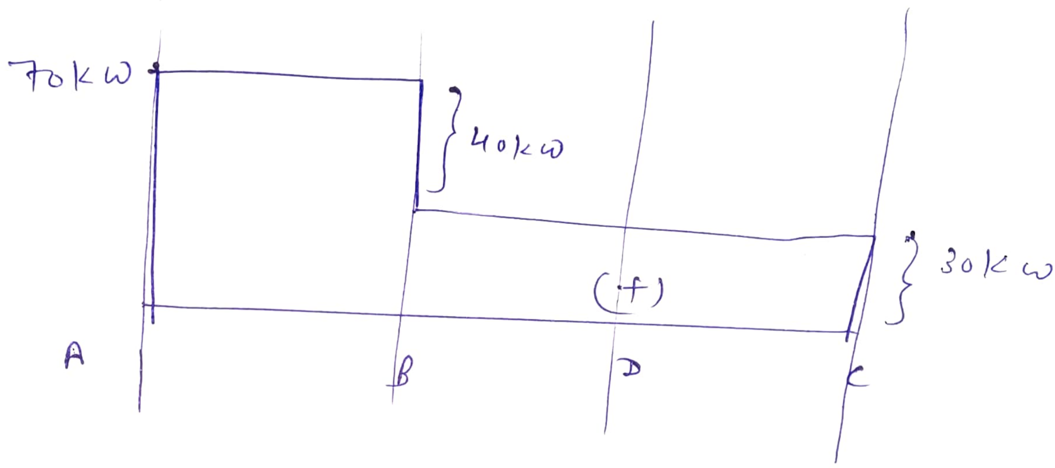
$P_C = 30$ kW

G = modulus of rigidity = 80 GPa

$G = (80 \times 10^3)$ MPa

To find $\Rightarrow$ (i) T_{max}. (ii) θ_A & θ_C





$$\tau_{max} = \frac{16\,T_A}{\pi d^3} = \frac{16 \times T_A}{\pi d^3}$$

$$T_A = \frac{P_A}{\omega} = \frac{70 \times 10^3}{62.83} = 1114.12 \text{ N-m}$$

here $\omega = 2\pi f = 2\pi(10) = 62.83$ rad/s

$$T_C = T_B = \frac{P_B}{\omega} = \frac{30 \times 10^3}{62.83} = 477.48 \text{ N-m}$$

$$\tau_{max} = \frac{16\,T_A}{\pi d^3} = \frac{16 \times 1114.12 \times 10^3}{\pi (80)^3} \text{ N-mm}$$

$$\boxed{\tau_{max} = 26.27 \text{ N/mm}^2}$$

$$\theta_A = \theta_{AB} + \theta_{BD} = \frac{T_A (AB)}{GJ} + \frac{T_{BD} (BD)}{GJ}$$

$$\theta_A = \frac{(1114.12\times10^3)(1.2\times1000)}{(80\times10^3)\times\frac{\pi}{32}d^4} + \left(\frac{477.48\times10^3\times0.75\times1000}{80\times10^3\times\frac{\pi}{32}d^4}\right)$$

$$\theta_A = \frac{10^6}{80\times10^3\times\frac{\pi}{32}(60)^4}\left[(1114.12\times1.2)+(477.48\times0.75)\right]$$

$$\boxed{\theta_A = 0.01665\ rad.}$$

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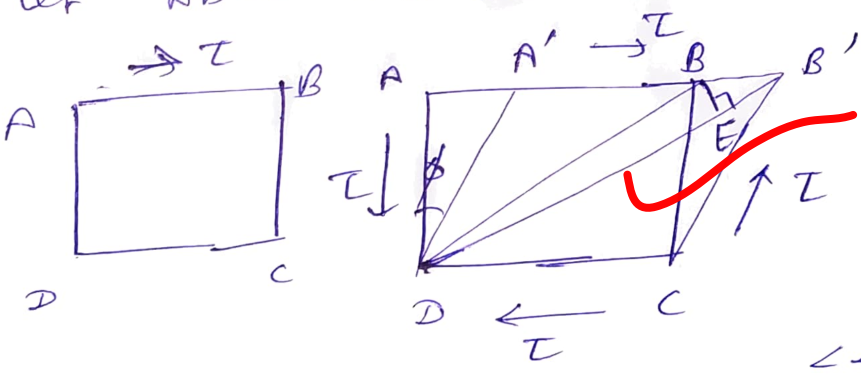
Refer to solutions

$$\theta_C = \frac{T_C(DC)}{GJ} = \frac{(477.48\times10^3)(0.75\times10^3)}{(80\times10^3)\times\left(\frac{\pi}{32}\right)(60)^4}$$

$$\boxed{\theta_C = 0.003518\ rad} \Rightarrow$$

Question(1)(b) ⇒ Ans ⇒

let ABCD cube (at top shear stress τ is applied)

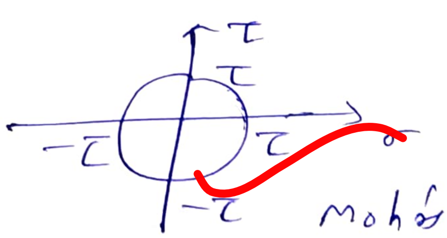


(ϕ is small)

$\angle DAB \simeq 90° \simeq \angle DAB'$

$\angle DBC = 45° \simeq \angle DB'C$

$$\phi = \frac{\tau}{G} = \frac{AA'}{AD}$$



normal stress along $DB = \sigma_1 = \tau\sin(2\times45°) = \tau$

normal stress $\perp$ to $DB = \tau\sin(2\times135°) = -\tau$

∴ normal strain in direction of DB

$$\epsilon = \frac{\tau}{E} - \nu\left(\frac{-\tau}{E}\right) = \frac{\tau(1+\nu)}{E}$$

$\Rightarrow$ Also $\epsilon = \dfrac{DB' - DB}{DB} = \dfrac{DB' - DE}{DB}$

$\epsilon = \dfrac{EB'}{\sqrt{2}\,AD} = \dfrac{\left(\frac{BB'}{\sqrt{2}}\right)}{\sqrt{2}AD} = \dfrac{AA'}{2\,AD}$

$(\because BB' = AA')$

$\therefore \dfrac{\tau(1+\gamma)}{E} = \dfrac{AA'}{2AD} = \dfrac{\phi}{2}$

$\Rightarrow$

$\because \phi = \dfrac{\tau}{G} = \dfrac{AA'}{AD}.$

$\Rightarrow$

$\dfrac{\tau(1+\gamma)}{E} = \dfrac{\tau}{2G} \Rightarrow \boxed{E = 2G(1+\gamma)}$

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Question (1)(c) $\Rightarrow$

Ans(i) $\Rightarrow$ Degree of freedom of linkage $\Rightarrow$

(F) $\Rightarrow$ It is number of independent motions required to define the position or state or motion of the linkage or system is called degrees of freedom.

$F = 6(l-1) - 5P_1 - 4P_2 - 3P_3 - 2P_4 - 1P_5$

(For 6DOF spatial mechanism)

$F = 3(l-1) - 2P_1 - 1P_2 = 3(l-1) - 2j - h$

(For 3 DOF planar mechanism)

For mechanism 1 link should be fixed

So $3(l-1)$, no. of motions.

of which 2 one DOF linkage motion & 1, two DOF linkage motion will be arrested,

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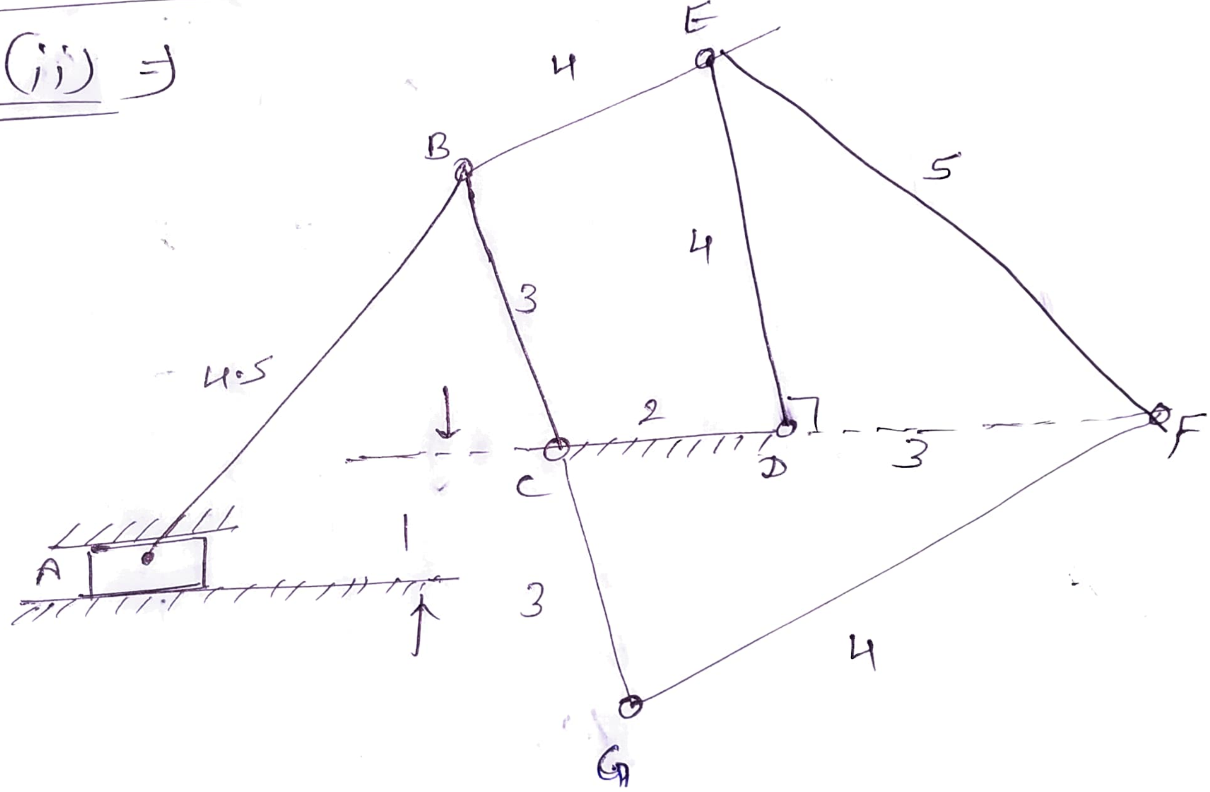
from Grubler's linkage.

$F = 1$

$$1 = 3(l-1) - 2j - h \Rightarrow \boxed{3l - 2j - h = 4}$$

Ans(ii) ⇒



$DOF = F = 3(l-1) - 2j - h$

$l = 9$, $j = 11$, $h = 0$

$$F = 3(9-1) - 2(11) - 0 = 24 - 22 = 2$$

so it is movable mechanism with two degrees of freedom,

since for four bar linkage,

$l + s <$ sum of other two links

$(2+4) < (3+4)$

and shortest link is fixed so link BC will revolve completely ($\because$ double crank mechanism)

Hence CG link will also revolve completely.

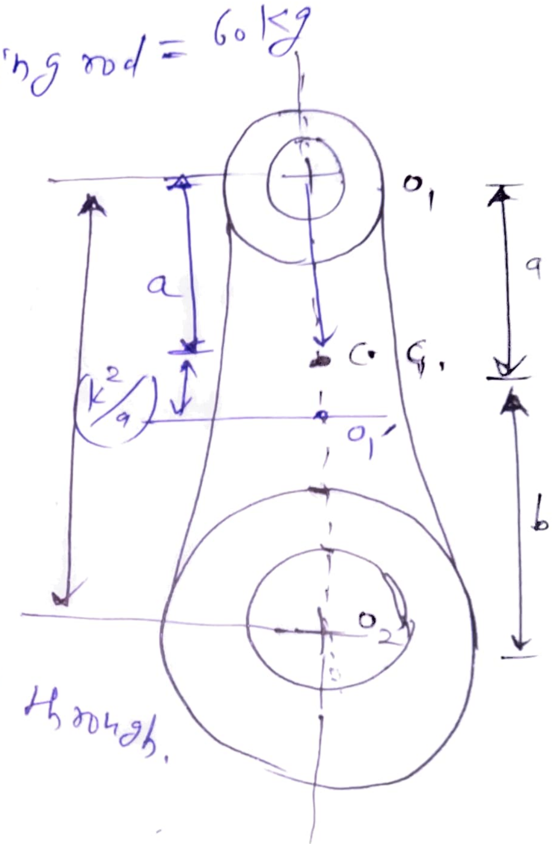
4

Question (1) (d) $\Rightarrow$

let m = mass of connecting rod = 60 kg

K = radius of gyration about C.G.

$\boxed{a + b = 1\,m}$



To find $\Rightarrow$ (1) $I_{C.G.}$

(2) $a = ?$

Soln

when it is connected through small end centre

$$\omega_{01} = 2\pi\left(\frac{100}{189}\right) = 3.324 \text{ rad/s.}$$

$$T_{01} = 1.89\,s = 2\pi\sqrt{\frac{\left(a + \frac{k^2}{a}\right)}{g}}$$

$$1.89 = 2\pi\sqrt{\frac{a + \left(\frac{k^2}{a}\right)}{9.81}}$$

$$\Rightarrow a + \frac{k^2}{a} = 0.8876\,m \rightarrow (i)$$

when suspended through big end radius.

$$T_{02} = \frac{162}{100} = 1.62\,s = 2\pi\sqrt{\frac{b + \frac{k^2}{b}}{g}}$$

$\Rightarrow$

$$b + \frac{k^2}{b} = 0.65214 \text{ m} \rightarrow \text{(ii)}$$

from (i) + (ii) eliminating (k^2)

$$\Rightarrow \left[(0.88763) - a\right] a = (0.65214 - b)\, b$$

$$\Rightarrow (0.88763 - a)(a) = (0.65214 - 1 + a)(1 - a)$$

$$\left[\because a + b = 1 \text{ m. given}\right]$$

$$\Rightarrow (0.88763 - a)(a) = (a - 0.34786)(1 - a)$$

$$\Rightarrow \boxed{a = 0.75584 \text{ m}}$$

(Ans) $\Rightarrow$

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$\therefore$ from, $a + k^2/a = 0.88763$ m

$$\Rightarrow 0.75584 + \frac{k^2}{0.75584} = 0.88763$$

$$\Rightarrow \boxed{k^2 = 0.099612 \text{ m}^2}$$

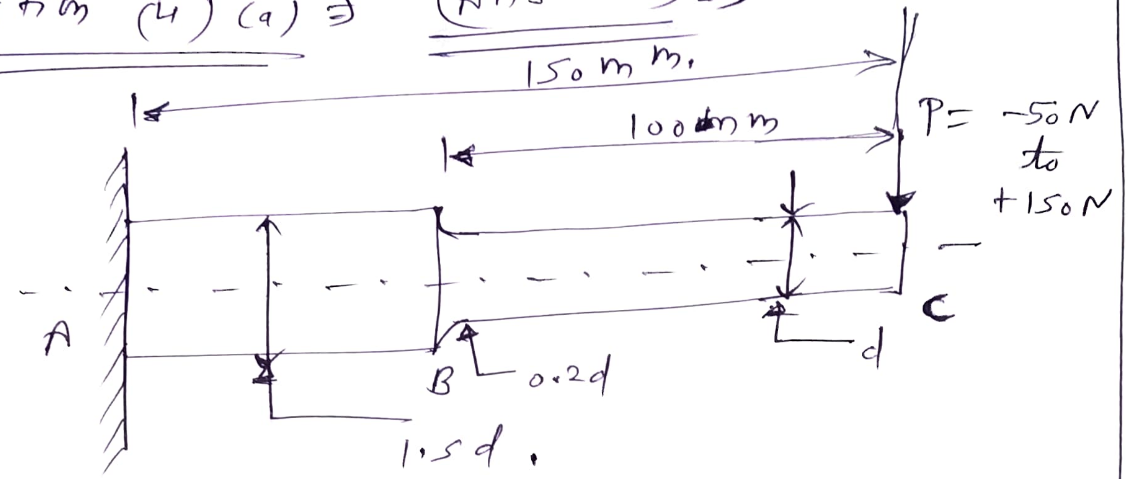
M.O.I. about C.G. $= mk^2$

$$I_{C.G.} = (60)(0.099612)$$

$$\boxed{I_{C.G.} = 5.97672 \text{ kg-m}^2}$$

question (1) (e) $\Rightarrow$

Question (4) (a) ⇒ (Answer) ⇒



Given ⇒ $\sigma_{ut} = 600\ N/mm^2$; $\sigma_{yt} = 380\ N/mm^2$

f = factor of safety = 2

q = notch sensitivity factor = 0.9

$K_a = 0.78$; $K_b = 0.85$; $K_c = 0.897$ (for 90% reliability)

K_t = (theoretical stress concentration factor)

$K_t = 0.90$

To find ⇒ diameter of shaft $(d) = ?$

Soln

$$P_m = \frac{-50+150}{2} = 50\ N/mm^2$$

$$P_v = \frac{150-(-50)}{2} = 100\ N/mm^2$$

$$(M_m)_B = (P_m)(100) = (50)(100) = 5000\ N\text{-}mm$$

$$(M_m)_C = (P_m)(150) = (50)(150) = 7500\ N\text{-}mm$$

$$(\sigma_m)_B = \frac{32(M_m)_B}{\pi d_B^3},\quad (\sigma_m)_C = \frac{32 M_C}{\pi d_C^3}$$

$$\frac{(\sigma_m)_B}{(\sigma_m)_C} = \frac{(M_m)_B}{(M_m)_C} \times \frac{d_C^3}{d_B^3} = \frac{5000}{7500} \times \left(\frac{1.5d}{d}\right)^3$$

$$\frac{(\sigma_m)_B}{(\sigma_m)_C} = 2.25 \Rightarrow \because (\sigma_m)_B > (\sigma_m)_C$$

Hence B is critical point. (design for B)

$$(\sigma_m)_B = \frac{32 M_{m_B}}{\pi d_B^3} = \frac{(32)(5000)}{\pi d^3}$$

$$(\sigma_m) = \left(\frac{50929.58}{d^3}\right) N/mm^2$$

$$(\sigma_v)_B = \sigma_v = \frac{32 M_v}{\pi d_B^3} = \frac{(32)(100)(100)}{\pi d^3}$$

$$(\sigma_v) = \left(\frac{95492.97}{d^3}\right) N/mm^2$$

For bending, $\sigma_e = K_a K_b K_c K_d \sigma_e^*$

$$K_d = \frac{1}{K_f}$$

From $q = \frac{K_f - 1}{K_t - 1} \Rightarrow 0.9 = \frac{K_f - 1}{1.35 - 1}$

$\Rightarrow \boxed{\cancel{K_f = 0.9}}$

$\cancel{K_d = \frac{1}{0.9} = 1.0989}$ $\quad K_f = 1.315 = 1/K_d$

$\therefore \sigma_e^* = 0.5(\sigma_{ut}) = (0.5)(600) = 300 N/mm^2$

$\therefore \sigma_e = (0.78)(0.85)(0.897)\left(\cancel{1.0989}\right)\left(\frac{1}{1.315}\right)(300)$

$$\boxed{\sigma_e = 135.676 N/mm^2}$$

From soderberg's eqn

$$\frac{\sigma_m}{\sigma_y} + \frac{\sigma_v}{\sigma_e} \le \frac{1}{f}$$

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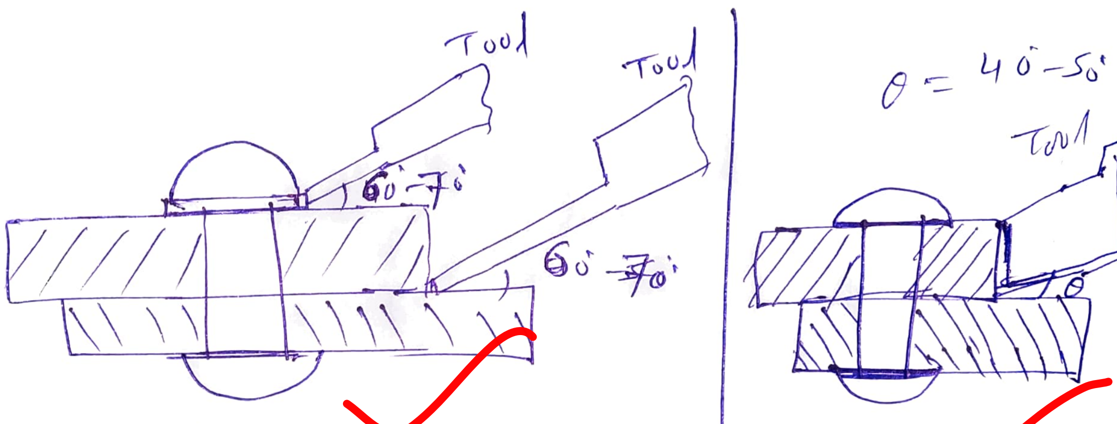
$$\frac{50929.58}{(d^3)(380)} + \frac{(95492.97)}{(d^3)(135.675)} \leq \left(\frac{1}{2}\right)$$

$$\Rightarrow \quad d \geq 11.8698$$

$$\boxed{d \simeq 12\,mm} \text{ (Ans)}$$

<u>Que (4)(b)</u> $\Rightarrow$ <u>Ans(i)</u> $\Rightarrow$

Caulking and Fullering.



Caulking   Fullering.

Caulking and fullering are the methods to make riveted joints tight and leakproof in case of Boiler and structural joints.

<u>Caulking</u> $\Rightarrow$ In this method a tool with edge thickness smaller than workpiece thickness is used at an angle 60 - 70° and with hammer force is applied and ~~workpie~~ plate edges or at tool edge.

6 Fullering ⇒ In fullering operation angle of inclination is smaller than caulking (30° - 50°) and tool of size equal to workpiece thickness is used and it is hammered at the edge of joint between plates. This is used to produce Leak proof joint.

Ans (ii) ⇒ Given ⇒ $\phi = 20°$ (Full depth involute)

$N_1 = 300$ rpm ; $P = 50$ kW

$Z_1 = 30$, $Z_2 = 60$, $Z_3 = 25$, $Z_4 = 50$

$m_1 = m_2 = m_3 = m_4 = 8$ mm $= m$

Gear (2-3) are compound gears.

(1) ← view [① driver]

$D_1 = m Z_1 = 8(30) = 240$ mm

$D_2 = m Z_2 = 8(60) = 480$ mm

$D_3 = m Z_3 = 8(25) = 200$ mm

$D_4 = m Z_4 = 8(50) = 400$ mm.

$$\boxed{N_2 = N_3}$$

$$T_1 = \frac{60 P}{2\pi N_1} = \frac{60 \times 50 \times 10^6}{2\pi(300)} = 159154.9.43 \text{ N-mm}$$

$$F_{t1} = \frac{2 T_1}{D_1} = \frac{2(159154.9.43)}{240}$$

$$\boxed{F_{t1} = 13262.91 \text{ N} = 13.263 \text{ kN}}$$ (Ans)

$F_{r1} = F_{t1} \tan\phi = 13.263 \times \tan 20°$

$\boxed{F_{r1} = 4.827 \text{ kN}}$ (Ans)

From $N_1 T_1 = N_2 T_2 \Rightarrow T_2 = \frac{N_1 T_1}{N_2}$

$$T_2 = \frac{Z_2 T_1}{Z_1} = \left(\frac{60}{30} \times T_1\right)$$

$[N_1 Z_1 = N_2 Z_2]$

$T_2 = 2T_1 = 2(159154.943) = 318309.886 \text{ N-mm}$

$$F_{t2} = \frac{2T_2}{D_2} = \frac{2 \times 318309.8}{480}$$

$$\boxed{F_{t2} = 1326.291 \text{ N} = 1.3263 \text{ kN}}$$

$$\boxed{F_{r2} = F_{t2} \tan\phi = 1.3263 \tan 20^\circ = 0.4827 \text{ kN}}$$

(Ans)

Now $T_2 = T_3 = 318309.886 \text{ N-mm}$

$$F_{t3} = \frac{2T_3}{D_3} = \frac{2 \times 318309.86}{200}$$

$$\boxed{F_{t3} = 3183.099 \text{ N} = 3.1831 \text{ kN}}$$

(Ans)

$$\boxed{F_{r3} = F_{t3} \tan\phi = 3.1831 (\tan 20^\circ) = 1.1586 \text{ kN}}$$

(Ans)

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$$\boxed{F_{t3} = F_{t4} = 3.1831 \text{ kN}}$$

Ans

(both are messing gears)

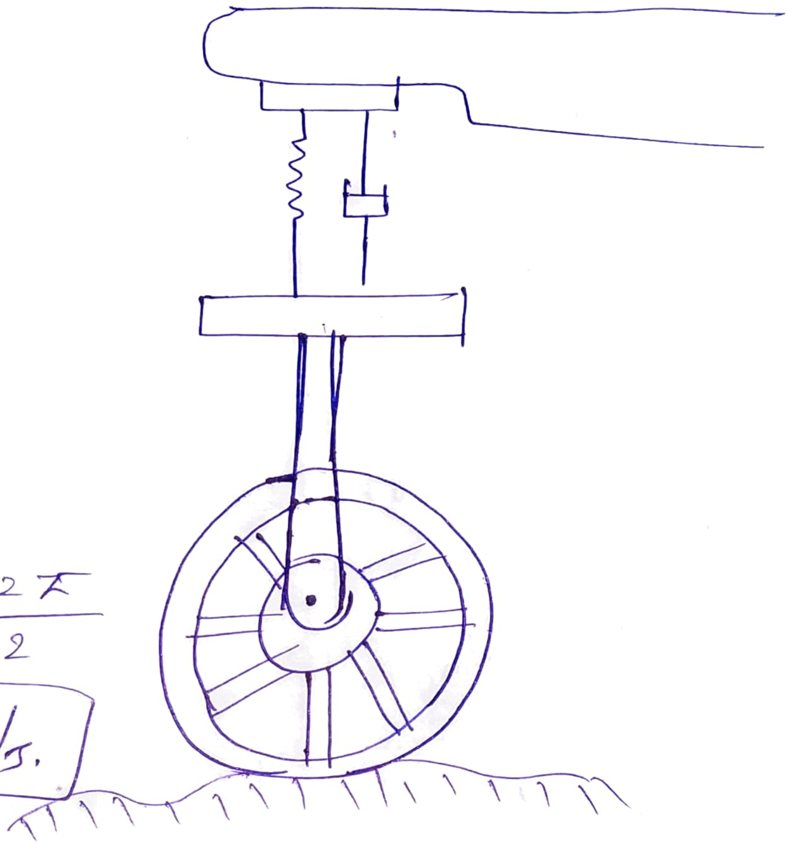
$$\boxed{F_{r3} = F_{r4} = 1.1586 \text{ kN}}$$

(Ans)

Que (4) (C) ⇒ Given ⇒ underdamped shock absorber ($\zeta < 1$)

$m = 200$ kg.

equivalent system



$n = 1.5$ rev.

$x_1 = x_1$

$x_{1.5} = \frac{x_1}{4}$

$T_d = 2$ s.

$\omega_d = \frac{2\pi}{T_d} = \frac{2\pi}{2}$

$\boxed{\omega_d = 3.14 \text{ rad/s.}}$

$\omega_d = \sqrt{1-\zeta^2}\ \omega_n = 3.14$ rad/s.

From $\frac{x_1}{x_{1.5}} = e^{n\delta} \Rightarrow 4 = e^{1.5\delta}$

$\Rightarrow \ln(4) = 1.5\delta = \frac{(1.5)(2\pi\zeta)}{\sqrt{1-\zeta^2}}$

$\Rightarrow \boxed{\zeta = 0.1455}$

$\zeta = \frac{c}{c_c} \Rightarrow \boxed{0.1455 = \frac{c}{2\sqrt{km}}}$

From $(\sqrt{1-\zeta^2})\ \omega_n = 3.14$ rad/s

$$\left\{\sqrt{(1-0.1455^2)}\right\}\omega_n = 3.14$$

$$\Rightarrow \quad \omega_n = 3.1738 \ rad/s = \sqrt{\frac{k}{m}}$$

$$\Rightarrow \quad 3.1738 = \sqrt{\frac{k}{200}}$$

$$\Rightarrow \quad \boxed{k = 2014.5689 \ N/m}$$

(Ans)

From $0.1455 = \dfrac{c}{2\sqrt{2014.5689 \times 200}}$

$$\Rightarrow \quad \boxed{c = 130.6123 \ N\text{-}s/m}$$

(Ans)

From underdamped oscillation,

$$x = x_1 e^{-\zeta \omega_n t}\left[\sin(\omega_d t + \phi)\right]$$

~~x =~~ let $\phi = 0$ (here)

$$x = x_1 e^{-\zeta\omega_n t} \left(\sin(\omega_d t)\right)$$

$$x = x_1 e^{-(0.1455 \times 3.1738 t)} \times \sin(3.14t)$$

$$\Rightarrow \quad \boxed{x = x_1 \left(e^{-0.4618t}\right) \sin(3.14t)}$$

velocity

$$= \dot{x} = x_1 \left\{ (-0.4618)\, e^{-0.4618t} \times \sin(3.14t) + \left(e^{-0.4618t}\right) \times (3.14) \cos(3.14t) \right\}$$

$\dot{x} = x_1 e^{-0.4618t} [3.14 \cos(3.14t) - (0.4618)\sin(3.14t)]$

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at $t = 0$, $x = 250\ mm = 0.250\ m$

$\dot{x} = (0.250)(e^0)[3.14(1) - 0]$

$\dot{x} = (0.250)(3.14) = 0.785\ m/s.$

$\boxed{\dot{x} = \text{velocity} = 785\ mm/s.}$

(Ans)

---

que (5) (a) ⇒ Given $d = 0.1542\ nm$

$d = 0.1542 \times 10^{-9}\ m$

d = interplaner spacing, a = Lattice parameter

(i) $(h\ k\ l) = (1\ 1\ 0)$

$2\theta = 45^\circ \Rightarrow \boxed{\theta = 22.5^\circ}$

⇒ $2d \sin\theta = d \Rightarrow \boxed{d = \frac{d}{2\sin\theta}}$

$\boxed{d = \frac{0.1542}{2 \times \sin 22.5} = 0.2015\ nm}$ (ans)

$d = \frac{a}{\sqrt{h^2 + k^2 + l^2}} \Rightarrow 0.2015 = \frac{a}{\sqrt{1^2 + 1^2 + 0^2}}$

$\Rightarrow \boxed{a = 0.2850\ nm}$ (ans.)

(ii) $(h\,k\,l) = (2\,0\,0)$

$2\theta = 65.1^\circ \Rightarrow \theta = 32.55^\circ$

$$d = \frac{\lambda}{2\sin\theta} = \frac{(0.1542)\,nm}{2\sin 32.55}$$

$$\boxed{d = 0.1433\ nm}$$

$$d = \frac{a}{\sqrt{h^2+k^2+l^2}} \Rightarrow 0.1433 = \frac{a}{\sqrt{2^2+0^2+0^2}}$$

$$\Rightarrow \boxed{a = 0.2866\ nm}$$

(iii) $(h\,k\,l) = (2\,1\,1)$

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$2\theta = 82.8^\circ \Rightarrow \boxed{\theta = 41.4^\circ}$

$$d = \frac{\lambda}{2\sin\theta} = \frac{(0.1542)\ nm}{2 \times \sin 41.4^\circ}$$

$$\boxed{d = 0.1165\ nm}$$

$$d = \frac{a}{\sqrt{h^2+k^2+l^2}} \Rightarrow (0.1165)\,nm = \frac{a}{\sqrt{2^2+1^2+1^2}}$$

$$\Rightarrow \boxed{a = 0.2854\ nm}$$

Que (5) (b) ⇒

defects in rolled products ⇒

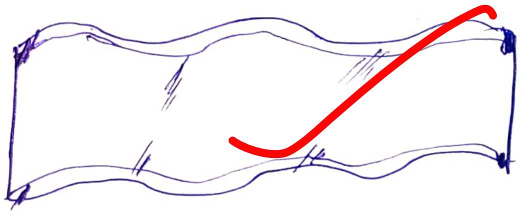
(1) surface defect ⇒

- It is rust, scale, pits on the surface of the rolled products.

- ~~It occurs due to~~
- It also includes scratches and cracks.
- It occurs due to inclusions and impurities in the metal
- To avoid this stock should be cleaned & lubricated.

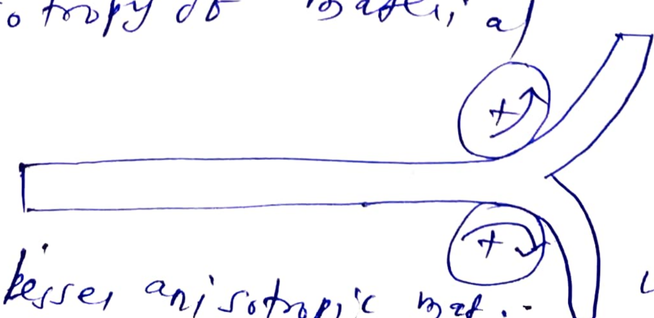
(2) wavy edges ⇒

- In this defects after rolling, strip is thinner along edges than centre.
- It occurs due to Roll bending.
- To avoid this Roll cambering should be done.



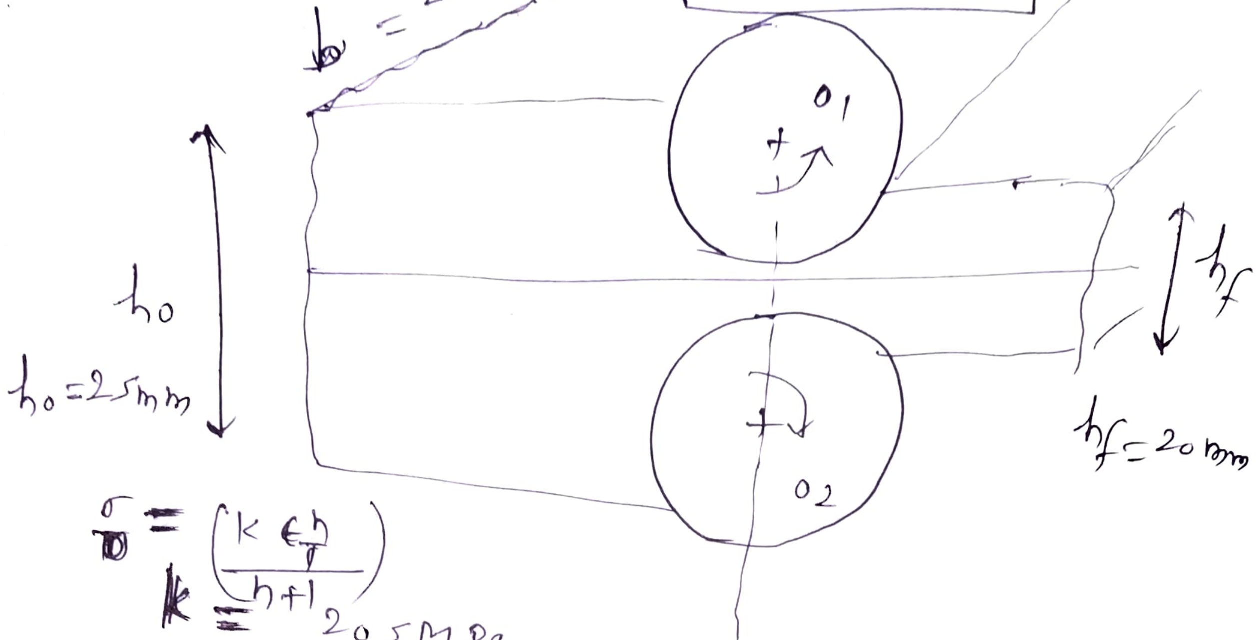
(3) Alligatoring ⇒

- In this defect rolled product bifurcates into two parts because of breaking of the edge.
- This occurs due to non uniform deformation and anisotropy of material



- To avoid this lesser anisotropic mat.. used.

case (5) (c) Answer ⇒ $\boxed{R = 300mm}$ $\boxed{N = 100 rpm}$



$\sigma_o = \left(\frac{K \epsilon_T^n}{n+1}\right)$

$K = 205 MPa, \quad n = 0.2$

$\epsilon_T = \ln\left(\frac{h_o}{h_f}\right) = \ln\left(\frac{25}{20}\right) = 0.2231$

$\Rightarrow \quad \sigma_o = \frac{(205)(0.2231)^{0.2}}{1.2} = \frac{151.864}{1.2} MPa$

$\boxed{\sigma_o = 126.55 MPa}$

$\Delta h = h_o - h_f = (25 - 20) = 5mm$

$L_p = \sqrt{R \Delta h} = \sqrt{(300)(5)} = 38.73 mm$

$b = 225 mm$

arm length $= a = 0.5 L_p = (0.5)(38.73)$

(Hot rolling)

$\boxed{a = 19.365 mm}$

(1) Guest and Tresca's theory

$\sigma_o' = \frac{2\sigma_o}{2} = \sigma_o = 126.55 MPa$

$F = \sigma_o' (L_p b) = (126.55)(38.73 \times 225)$

$F = 1102788.34\,N = 1.1028 \times 10^{6}\,N$

Torque $= T = F \times a =$

$\Rightarrow T = 1.1028 \times 10^{6} \times 19.365 \times 10^{-3}$

$T = 21355.72\ N\text{-}m$

Power $= 2\,T\omega = 2 \times \left(\frac{2\pi N T}{60}\right)$

$P = 2\left(\frac{2\pi(100)(21355.72)}{60}\right)$

$\boxed{P = 2 \times 223.637\ kW}$ $\boxed{P = 447.274\ kW}$

(2) von-Mise's theory.

$\sigma_0' = 2\sigma_0/\sqrt{3} = \frac{2(126.55)}{\sqrt{3}} = 146.13\ MPa$

$F = (\sigma_0')(Lp)\,b = (146.13)(38.73 \times 225)$

$F = 1.2734 \times 10^{6}\,N$

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Torque $= T = F(a) = 1.2734 \times 10^{6} \times 19.365 \times 10^{-3}$

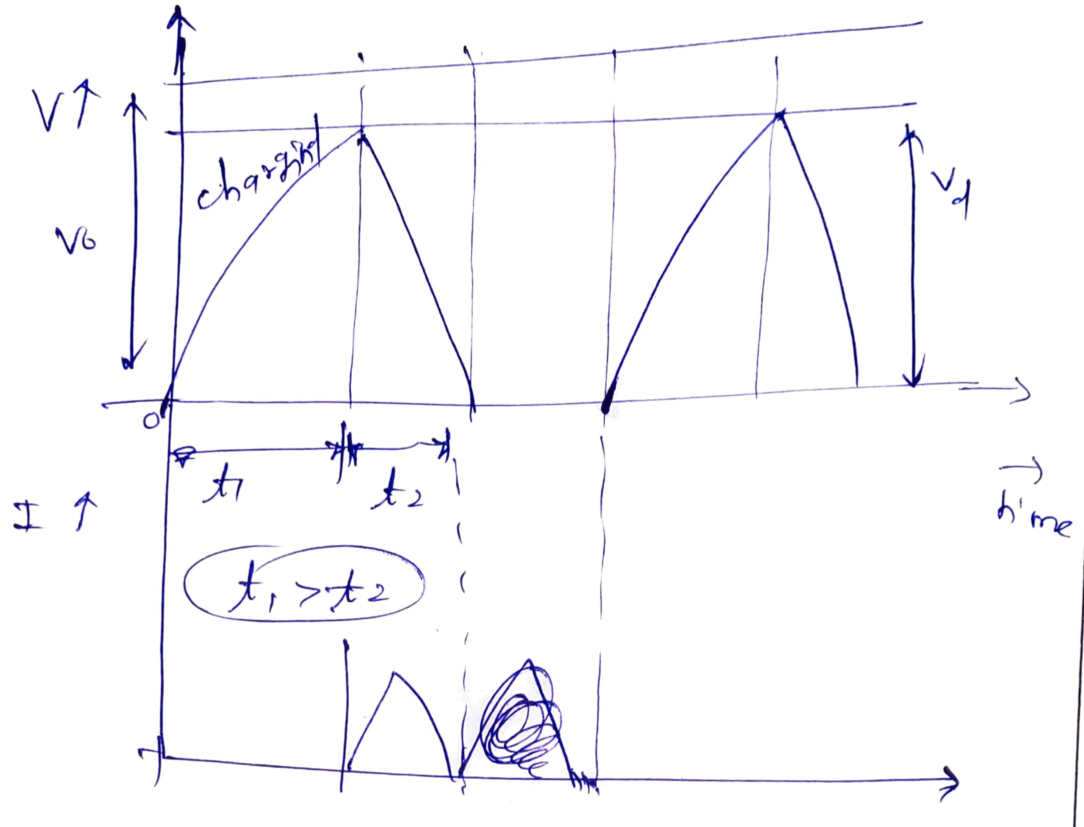
$\boxed{T = 24576.62\ N\text{-}m}$

Power $= P = 2\left(\frac{2\pi N T}{60}\right) = 2\left(\frac{2\pi(100)(24576.62)}{60}\right)$

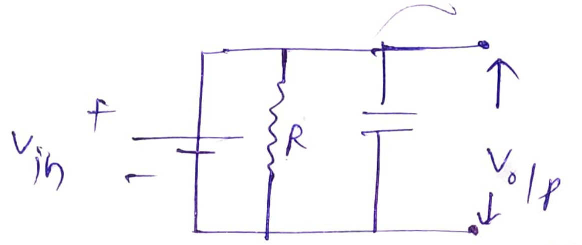
$\boxed{P = 2 \times 257.365\ kW}$ $\boxed{P = 514.73\ kW}$

Ans (5) (d) $\Rightarrow$ EDM

To prove $\Rightarrow$ using RC circuit with a constant DC source, for maximum power delivery the discharging voltage should be 72% of supply voltage.



time(t)



let V_0 = charging voltage = supply voltage

V_d = discharging voltage.

t_1 = charging time and t_2 = discharging time.

$$V_d = V_0(1 - e^{-t/RC})$$

Energy supplied to spark $= \frac{1}{2} C V_d^2$

$$E = \frac{1}{2} C \{V_0(1 - e^{-t/RC})\}^2$$

$$E = \frac{1}{2} C V_0^2 (1 - e^{-t/RC})^2$$

Power supplied $= P = \dfrac{E}{t_1 + t_2} = \dfrac{E}{t_1}$

$$P = \frac{\frac{1}{2} C V_0^2 \left(1 - e^{-\frac{t_1}{RC}}\right)^2}{t_1} \quad \text{(since } t_1 > t_2\text{)}$$

$$P = \frac{1}{2}\,\frac{C\,V_0^2\,(R)}{(R)\,t_1}\left(1-e^{-\frac{t_1}{RC}}\right)^2$$

$$P = \frac{1}{2}\,\frac{V_0^2}{R}\left(\frac{RC}{t_1}\right)\left(1-e^{-t_1/RC}\right)^2$$

let $t_1/RC = x$

$$P = \frac{1}{2}\,\frac{V_0^2}{R\,x}\left(1-e^{-x}\right)^2$$

For max. power

$$\frac{dP}{dx} = 0$$

$$\Rightarrow \left(\frac{1}{2}\,\frac{V_0^2}{R}\right)\left\{\left(\frac{-1}{x^2}\right)\left(1-e^{-x}\right)^2 + \frac{2\left(1-e^{-x}\right)\times\left(e^{-x}\right)}{x}\right\} = 0$$

$$\Rightarrow \frac{\left(1-e^{-x}\right)^{\cancel{2}}}{x^{\cancel{2}}} = \frac{2\,e^{-x}}{\cancel{x}}\,\cancel{\left(1-e^{-x}\right)}$$

$$\Rightarrow \left(1-e^{-x}\right) = 2\,x\,e^{-x}$$

$$\Rightarrow \boxed{x = 1.26}$$

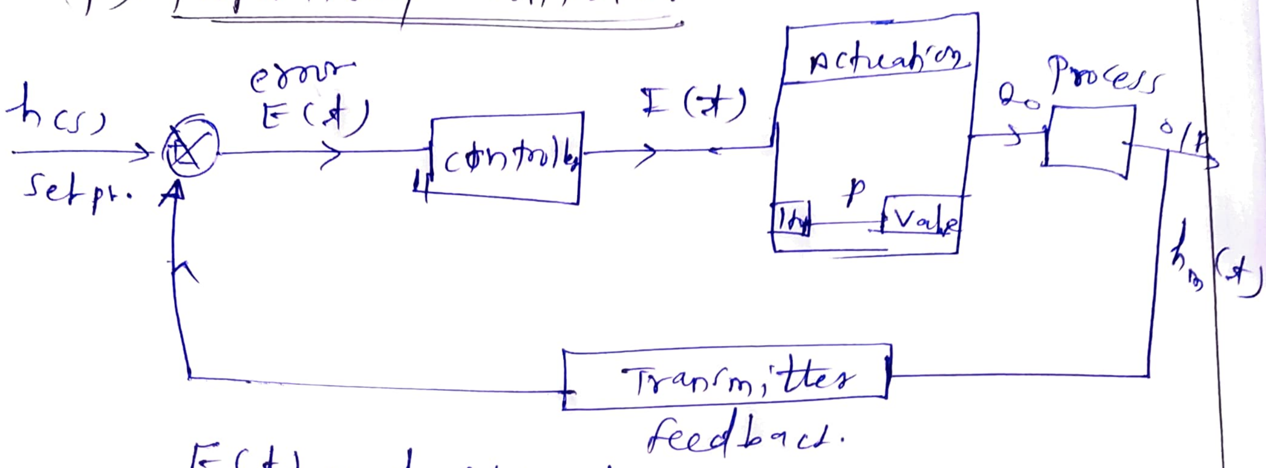
$$\Rightarrow \text{So}\quad V_d = V_0\left(1-e^{-x}\right) = V_0\left(1-e^{-1.26}\right)$$

$$\boxed{V_d = 0.72\,V_0}$$

$$\boxed{V_d = 72\%\text{ of }V_0}$$

ans (5)(e) ⇒

(1) Proportional Controller ⇒

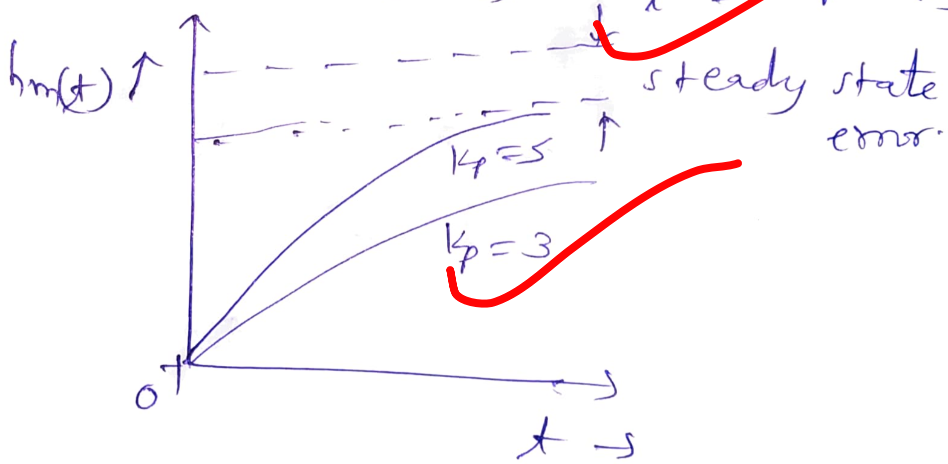


$E(t) = h_s(t) - h_m(t)$

$I(t) = \Delta I(t) + I_0$

In this change in current delivered by Controller is directly proportional to change in error

$\Delta I(t) \propto E(t) \Rightarrow \Delta I_t = K_p E(t)$



adv ⇒ (1) simple to design and implement

(2) For higher value of K_p, speed of response increases

disad ⇒ - If K_p increased, steady state error reduced but not eliminated completely.

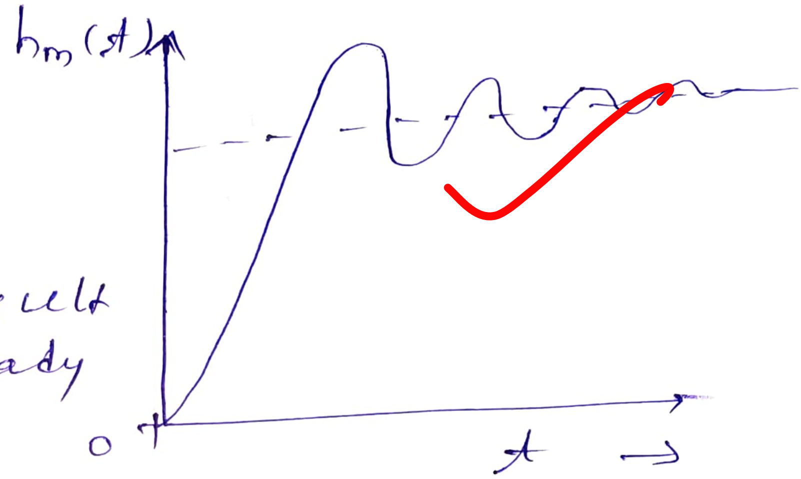
(2) Integral Controller ⇒

change in current delivered by controller is directly prop. to integration of change in error

$\Delta I(t) \propto \int E(t)\,dt.$

$\Rightarrow \quad \Delta I(t) = K_I \int E(t)\,dt$

↓ Integral gain.



Adv. ⇒

(1) It may result in "ZERO" steady state error.

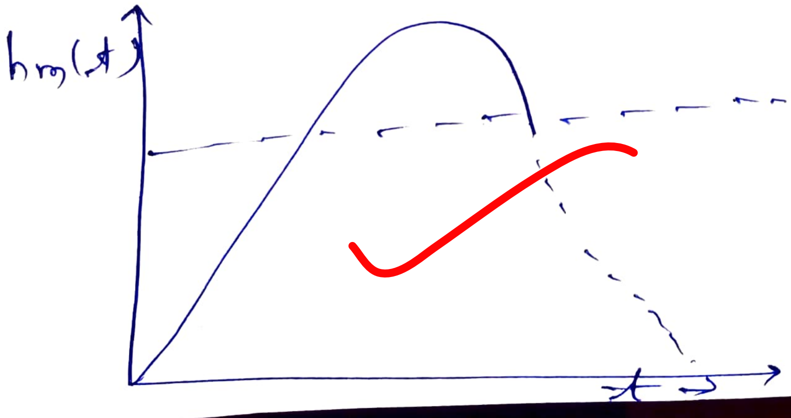
Disadv ⇒ (1) It works very slowly
(2) It may generate oscillating response

(3) Derivative controller ⇒

The change in current by controller is directly proportional to derivative of "change in error."

$\Delta I(t) \propto \frac{d}{dt}(E(t)) \Rightarrow \Delta I(t) = K_D \frac{dE(t)}{dt}$

↓ Derivative gain.



Adv ⇒ (1) It can increase speed of response

(2) It provided damping, so system stability can be increased.

Disadv ⇒ (1) For lower order system it may not result in "zero" steady state error.

Que (7) (a) ⇒

Ans (i)

$\sigma_{E_1} = 235$ MPa, | $\sigma_{E_2} = 250$ MPa

$\epsilon_{E_1} = 0.194$ | $\epsilon_{E_2} = 0.296$

$\sigma_T = k\,\epsilon_T^{\,n}$

$\sigma_{T_1} = \sigma_{E_1}(1 + \epsilon_{E_1}) = 235(1 + 0.194)$

$\sigma_{T_1} = 280.59$ MPa

$\epsilon_{T_1} = \ln(1 + \epsilon_{E_1}) = \ln(1 + 0.194)$

$\epsilon_{T_1} = 0.1773$

$\sigma_{T_2} = \sigma_{E_2}(1 + \epsilon_{E_2}) = 250(1 + 0.296)$

$\sigma_{T_2} = 324$ MPa

$\epsilon_{T_2} = \ln(1 + \epsilon_{E_2}) = \ln(1 + 0.296) = 0.2593$

$$n = \frac{\ln\left(\frac{\sigma_{T_1}}{\sigma_{T_2}}\right)}{\ln\left(\frac{\epsilon_{T_1}}{\epsilon_{T_2}}\right)} = \frac{\ln\left(\frac{280.59}{324}\right)}{\ln\left(\frac{0.1773}{0.2593}\right)}$$

$\boxed{n = 0.378}$

$\sigma_{T_1} = k\,\epsilon_{T_1}^{\,n} \Rightarrow 280.59 = k(0.1773)^{0.378}$

$$\boxed{K = 539.59\,MPa}$$

$$\therefore \quad \sigma_T = (539.59)\,\epsilon_T^{0.378}$$

For $\epsilon_E = 0.25$

$\epsilon_T = \ln(1+\epsilon_E)$

$\epsilon_T = \ln(1+0.25) = 0.2231$

$$\sigma_T = (539.59)\,(0.2231)^{0.378}$$

$\sigma_T = 306.05\,MPa = \sigma_E(1+\epsilon_E)$

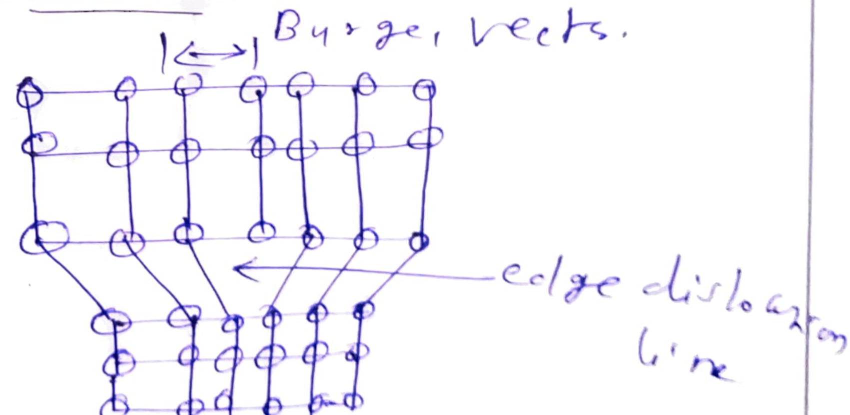
$\Rightarrow \quad 306.05 = \sigma_E(1+0.25)$

$\Rightarrow$

$$\boxed{\sigma_E = 244.84\,MPa}$$

Ans (ii) $\Rightarrow$

(b) ~~Screw~~ Edge dislocation $\Rightarrow$

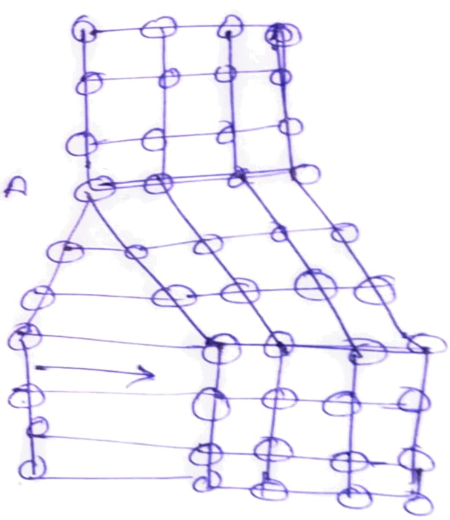


- burger vector is perpendicular to disolation line.

- In this an extra half plane of atom appear and edge of which terminates within the crystal.
- It is a linear defect that centers around the line that is defined along the end of the extra half plane of atoms.

- This is termed dislocation line, ~~which~~ in which b it is ⊥ to dislocation line.
- within the region around dislocation line, there is localized distortion.
- Atoms above dislocation line are squeezed together and those below are pulled apart.
- This is reflected in slight curvature for vertical planes of atoms as they bend around this extra half plane.
- The magnitude of this distortion decreases with away distance from dislocation line.
-

(a) <u>screw dislocation</u>



- This is formed by shear stress that is applied to produce the distortion.
- upper front region of crystal is shifted one atomic distance to right relative to bottom portion.
- The atomic distortion is linear and along dislocation line.

- In this dislocation path is spiral or helical path or ramp that is traced around the dislocation line by the atomic planes of atoms

Que 7 (b) $\Rightarrow$ Ans (i) $\Rightarrow$ $V_o = 60V$, $I_s = 750A$.

$$\frac{V_t}{V_{oc}} + \frac{I_t}{I_s} = 1$$

$$\Rightarrow \frac{V_t}{60} + \frac{I_t}{750} = 1 \quad \rightarrow (i)$$

$$V_a = (15 + 6L)$$

$$\because \boxed{V_t = V_a}$$

$$\Rightarrow \frac{(15+6L)}{60} + \frac{I_t}{750} = 1$$

$$\Rightarrow I_t = \left\{1 - \frac{(15+6L)}{60}\right\} \cdot 750$$

$$I_t = (45 - 6L)(12.5)$$

$$\boxed{I_t = 562.5 - 75L}$$

$$V_t = (15 + 6L)$$

Power = $P = I_t V_t = (562.5 - 75L) \times (15 + 6L)$

For maximum power,

$$\frac{dP}{dL} = 0$$

$$\Rightarrow (15+6L)(-75) + 6(562.5 - 75L) = 0$$

$$\Rightarrow \boxed{L = 2.5 \text{ mm}}$$

(1) optimum length of arc

$$\boxed{L_{opt} = 2.5\ mm}$$

(2) 10

$I_t = 562.5 - 75L = 562.5 - 75(2.5)$

$I_t = 375A$

$V_t = 15.76L = 15.76(2.5) = 30V$

$P_{max} = I_t V_t = (375 \times 30) = 11250\ W$

$$\boxed{P_{max} = 11.250\ kW}$$

Ans (ii) ⇒

(1) SPT ⇒

Job	PT (days)	cumulative PT	due date	Tardiness
3	3	3	20	
1	4	7	7	—
5	5	12	15	—
2	8	20	10	10
4	8	$\boxed{28}$ MST	18	10
Total		70 = JFT		20

Mean Job flow time $= \frac{70}{5} = 14$ days

Avg. tardiness per job $= \frac{20}{5} = 4$

No. of tardy jobs = 2

(2)

EDD Rule ⇒

Job	EDD	PT	cumulative PT	Tardiness
1	7	4	4	—
2	10	8	12	2
5	15	5	17	2
4	18	8	25	7
3	20	3	$\boxed{28}$ MST	8
Total			86 = JFT	19

10

Mean Job flow time = $\frac{86}{5} = 17.2$ days

Average tardiness per job = $\frac{19}{5} = 3.8$

No. of tardy jobs = 4

Que (7) (c) ⇒

$\boxed{\text{Soln}}$

	M I	M II
Tooling cost	100	210
setting cost	$\frac{60}{60} \times 20 = 20$	$\frac{240}{60} \times 20 = 80$
overhead cost	$(3 \times 20) = 60$	$10 \times 80 = 800$
Total Fixed cost	100 + 20 + 60 = 180	210 + 80 + 800 = 1090

variable cost	M-I	M-II
Machining labour cost	4	4
overhead cost	12	40
Total variable cost	16	44
No. of pieces produced per hour	20	60
variable cost per piece	$\left(\frac{16}{20}\right) = 0.80$	$\frac{44}{60} = 0.733$

10

Let x be Break Even pt.

$F_1 + xV_1 = F_2 + xV_2$

$\Rightarrow 180 + 0.8x = 1090 + 0.733x$

160

$\Rightarrow x = 13582.09 \simeq 13582$ pieces

(Ans ①)

(2) quantity produced < 13582
(M/C I preffered)

quantity produce more than 13582
(M/C II preffered)

Que (8) (a) ⇒

Ans (i)

$d = 0.6\,cm = 0.006\,m,$

$E = 200\,GPa = (200 \times 10^3)\,MPa$

$R = 120\,\Omega$

$P = 2200\,N$ (tension)

$\Delta R = 0.01\,\Omega$

g = Gauge factor = $\dfrac{\left(\frac{\Delta R}{R}\right)}{\left(\frac{\Delta l}{l}\right)}$

5

⇒ $g = \dfrac{\left(\frac{\Delta R}{R}\right)}{\left(\frac{4P}{\pi d^2 E}\right)}$

$g = \dfrac{\left\{\frac{(0.01)}{120}\right\}}{\frac{4 \times 2200}{\pi (0.006)^2 \times 200 \times 10^3}}$ 06^2

$\boxed{g = 2.1419 \times 10^{-7}}$

Ans (ii) ⇒

Que (8)(b) =)

Ans (ii) =)

$\alpha = 0.25$,

For May, $F = 600$ units,

$D = 560$ units.

(1) Forcast for June

$F_{june} = F_{may} + \alpha(D_{may} - F_{may})$

$F_{june} = 600 + 0.25(560 - 600)$

$F_{june} = 590$ units.

(2)

$D_{june} = 580$ units.

5

$F_{july} = F_{june} + \alpha(D_{june} - F_{june})$

$F_{july} = 590 + 0.25(580 - 590)$

$$\boxed{F_{july} = 587.5 \text{ units} \simeq 588 \text{ units.}}$$

(3)

$$F_{August} = \frac{F_{may} + F_{june} + F_{july}}{3}$$

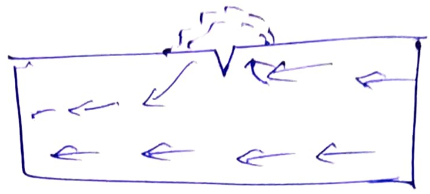
Demands

$$= \frac{600 + 590 + 588}{3}$$

$= 592.67 \simeq 593$ units.

Ans (i) =) Various methods of inspection of casting =)

(1) Magnetic particle inspection ⇒



- In this surface is covered with Fe_2O_3 Powder & then magnetic flux is passed through it.
- If there is any crack, void, discontinuity there will be flux leakage in that region.

(2) Liquid penetration inspection ⇒

- First sur. preparation is done to remove dirt, grease, oil
- Liquid, penetrant is now applied on mat. by spraying, brushing,
- wait for some time for liq. to settle in voids & excess penetrant should be removed.
- Then developer is applied to sample, which draws the penetrant trapped in flaws.

(3) Eddy current testing ⇒

- Electric currents are passed (AC) through a coil to set up mag. field. It induces eddy current in test object below coil.
- secondary magnetic field arises due to eddy current.
- If crack is present secondary mag field deviates.

(4) ultra sonic (~~Acoustic emission~~) ⇒

- High frequency sound waves are introduced into the materials. piezo electric crystals are used.
- From flaws these waves are reflected back.

(5) Infrared thermograpy. ⇒

- In this process thermal images are used to capture infrared radiations emitted by an object to locate any abnormal heat pattern or thermal anomaly which indicate possible fault, defects or inefficiencies within a system ~~etc~~.

(6) Acoustic emission ⇒

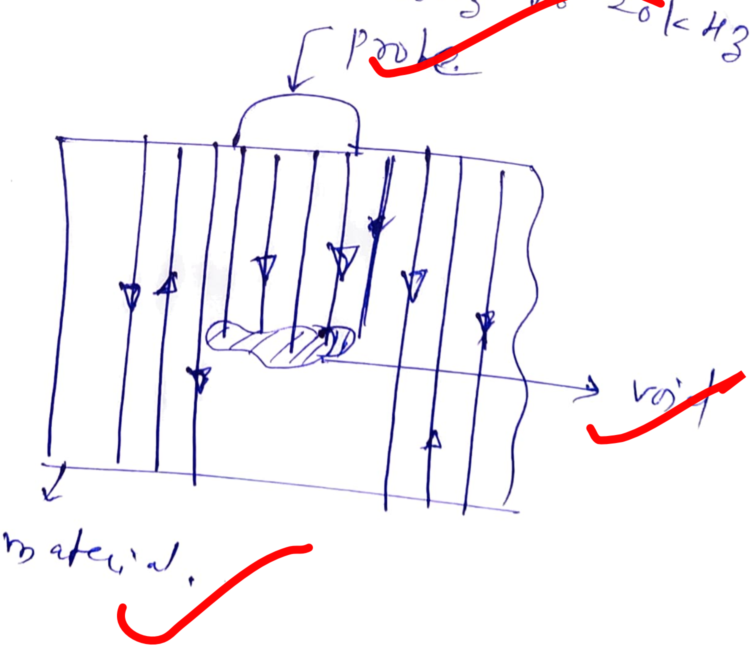
- In this transient elastic waves due to rapid release of strain energy caused by small deformation, corrosion or cracking within surface. using AE sensor
- Data is studies in waveform or signature form or in form of FTIR.

10

ans (8) (c) =)

ultrasonic testing of condition monitoring =)

- This method uses sound waves having frequencies in the mega cycle range. It can detect discontinuities oriented both in plane of normal to surface of component.
- Sound waves are passed through solid, reflected by any voids, crack present.
- This uses a ultrasonic transducer which changes high frequency electrical energy into sound wave. ~~(c)~~
- There are two probes one is transmitter probe, which changes the ultrasonic sound wave to electrical energy and other is receiver probe. This is connector to monitor.
- ultrasonic testing is used for internal defects.
- Audible sound waves are 20 Hz to 20 kHz frequencies.



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Working =)

- probe contains a piezoelectric crystal which transmits ultrasonic waves into material when an alternating potential difference is applied to it.
- When high frequency AC power is supplied to transmitter probe, it will pass ultrasonic wave through work piece.
- If the work is defect free, the wave will strike the bottom of work and return to receiver probe.
- The striking of waves at the bottom surface and top surface are indicated in the form of normal pip in monitor. If there is any defect in material, in between top and bottom surface, the wave is reflected back from that spot, and it is indicated as short pip in monitor.

Application =)

- It is used to detect internal flaws in most engineering metals and alloys.
- Bonds produced by welding, brazing, soldering can be examined.

- It is used in quality control testing in pressure vessels, machines, jet engines, .