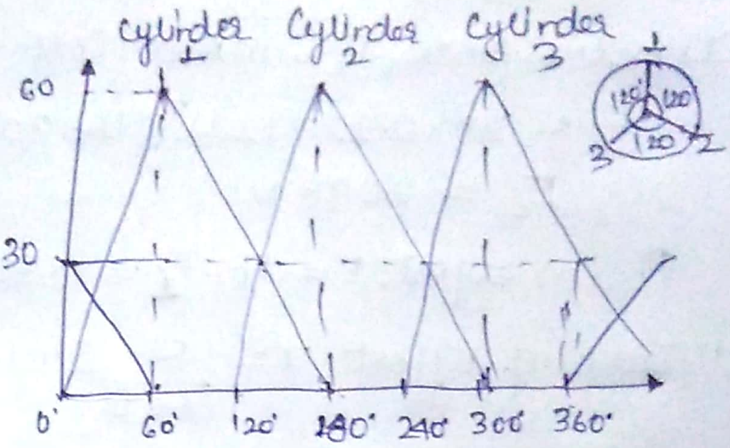
Ans.2 :-

(i) Work done/cycle

$= \text{Area of three } \Delta$

$= 3 \times \frac{1}{2} \times \pi \times 60 = 90\pi$



Mean Torque $= T_m$

$T_m = \frac{\text{Work done/cycle}}{\text{Angle turned}}$

$T_m = \frac{90\pi}{2\pi} = 45 \text{ N.m}$

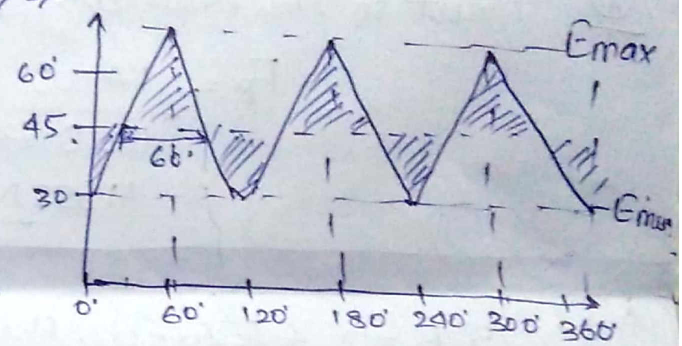
$P = T_m \times \omega = \cancel{45}^{15} \times \cancel{2} \times \pi \times \frac{400}{\cancel{60}/30} = 1885 \text{ W}.$

(ii) $\Delta E = I \omega^2 K.$

$\Delta E = E_{max} - E_{mean} =$

$\frac{1}{2} \times \frac{60 \times \pi}{180_3} \times (60 - 45^{\circ}).$

$= \frac{1}{2} \times \frac{\pi}{3} \times 15^{5} = 2.5\pi \text{ N.m}.$



$2.5\pi \text{ N.m} = m K^2 \omega^2 K.$

$K = \frac{2.5 \times \pi}{10 \times (0.088)^2 \times \left(\frac{2\pi \times 400}{60}\right)^2} = 0.0578 \text{ or } 5.78\%.$

Ans.3 :- radius, $r = \frac{440}{2} = 220 \text{mm}.$

Length of Connecting Rod $= 924 \text{mm}.$

$n = \frac{l}{r} = \frac{924}{220} = 4.2$

$N = 210 \text{ rpm}, \quad \omega = \frac{2\pi N}{60}$

$\omega = \frac{2\pi \times 210}{60} = 22 \text{ rad/s}.$

$\sin\beta = \frac{\sin\theta}{n} = \frac{\sin 30^{\circ}}{4.2} = 0.119$

$\beta = \sin^{-1}(0.119) = 6.837^{\circ}$

$F_P = (P_1 A_1 - P_2 A_2)$

$= \left\{ 500 \times 10^3 \times \frac{\pi}{4} \times 0.22^2 - 60 \times 10^3 \times \frac{\pi}{4}(0.22^2 - 0.04^2) \right\}$

$F_P = 19007 - 2206$

$= 16801 \text{ N}.$

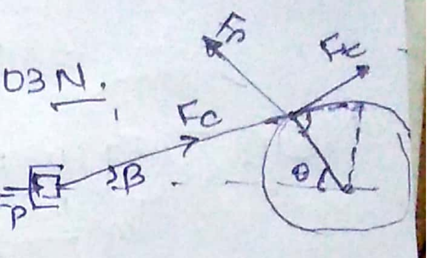
P.T.O

Continue Ans(3)

Inertia force, $F_i = m r \omega^2 \left(\cos\theta + \frac{\cos 2\theta}{n} \right)$

$F_i = 20 \times 0.22 \times (122)^2 \left(\cos 30^\circ + \frac{\cos 60^\circ}{4.2} \right)$

$F_i = 2098\ N$



Piston effort, $F = F_p - F_i = 16801 - 2098 = 14703\ N.$

(i) Turning Effort, $T = \frac{F}{\cos\beta} \sin(\theta+\beta) \times r$

$$T = \frac{14703}{\cos 6.837} \sin(30^\circ + 6.837^\circ) \times 0.22$$

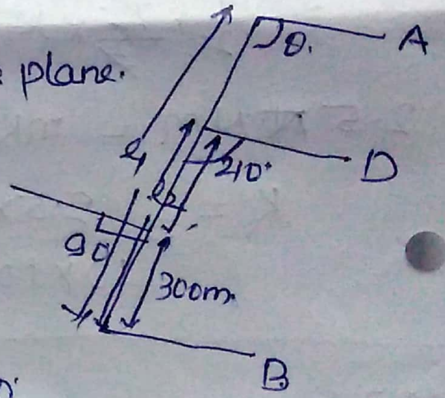
$= 1953\ N.m$

(ii) Thrust on the bearings, $F_b = \frac{F}{\cos\beta} \cos(\theta+\beta)$

$$F_b = \frac{14703}{\cos 6.837^\circ} \times \cos(30^\circ + 6.837^\circ)$$

$= 11852\ N.$

Ans.4 $\Sigma F_x = 0$ & $\Sigma F_y = 0$, Plane B is reference plane.



$m_A r_A \sin\theta_A + m_B r_B \sin\theta_B + m_C r_C \sin\theta_C + m_D r_D \sin\theta_D = 0^\circ$

$m(0.360)\sin\theta + \cancel{25}(0.48)\sin 0^\circ + 25(0.240)\sin 90^\circ + 20(0.300)\sin 210^\circ = 0$ —— (i)

similarly, $\Sigma F_y = 0$.

$m(0.360)\cos\theta + 15(0.48)\cos 0^\circ + 25(0.240)\cos 90^\circ + 20(0.300)\cos 210^\circ = 0.$ —— (ii)

θ & m are unknown, Two unknown & two equation,

from solving (i) & (ii) we get $m = 10.02\ kg$ & $\theta = 236.26$

Take Moment about B. $\Sigma M_x = 0$ & $\Sigma M_y = 0$, $M_x = m r l \sin\theta$, $M_y = m r l \cos\theta$

$10 \times (0.360) l_1 \cos(236) + 15(0.48)\cos(0^\circ) \times (0) + 25(0.240) \times (0.3)\cos 90^\circ + 20(0.300) l_2 \cos 210^\circ = 0$ —— (iii)

$10 \times (0.360) l_1 \sin(236) + 15(0.48)\sin(0) \times 0 + 25(0.240) \times 0.3 \sin 90^\circ + 20(0.3)\sin 210^\circ \times l_2 = 0$ —— (iv)

P.T.O.

continue ans (4).

$$-2.984\,l_1 + 1.8 - 3l_2 = 0 \quad \text{— (iv)}$$
$$-2.01\,l_1 - 3\sqrt{3}\,l_2 = 0 \quad \text{— (v)}$$

Solve (iv) 4 V, and get value of l_1 & l_2.

$l_1 = 989$ mm towards right
$l_2 = 382.6$ mm towards left.

Ans. 1
1.1 – d
1.2 – a
1.3 – d
1.4 – a
1.5 – a

Ans.5 $f = \frac{\omega}{2\pi}$, $\omega = 2\pi f$

$\omega = \sqrt{\frac{K}{m}}$.

$$2\pi \times 3.56 = \sqrt{\frac{K_o}{m_o}} \quad \text{— (i)}$$

$$2\pi \times 2.9 = \sqrt{\frac{K_o}{m_o+5}} \quad \text{— (ii)}$$

divide (i) by (ii).

$$\frac{\cancel{2\pi}\times 3.56}{\cancel{2\pi}\times 2.9} = \sqrt{\frac{\cancel{K_o}}{m_o}} \times \sqrt{\frac{m_o+5}{\cancel{K_o}}}$$

Square on both sides

$$\left(\frac{3.56}{2.9}\right)^2 = \frac{m_o+5}{m_o} = 1+\frac{5}{m_o}$$

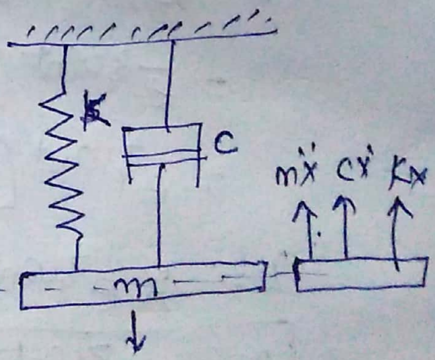
$$1.507 = 1 + \frac{5}{m_o}, \quad m_o = 9.86 \text{ Kg} \simeq 10 \text{ Kg}$$

Put the value of m_o in eq^n (i) & solve for K_o

$K_o = 4.93$ KN/m $\simeq 5$ N/mm Ans.

Ans 6:-

$$m\ddot{x} + c\dot{x} + Kx = 0$$
$$\ddot{x} + \frac{c}{m}\dot{x} + \frac{K}{m}x = 0$$
$$\text{9}\quad \frac{d^2x}{dt^2} + \frac{c}{m}\cdot\frac{dx}{dt} + \frac{K}{m}x = 0 \quad \text{— (i)}$$



It is 2nd order differential equation, its sol^n will be $x = Ae^{\alpha_1 t} + Be^{\alpha_2 t}$.

A.E of eq^n (i). $D^2 + \frac{c}{m}\cdot D + \frac{K}{m} = 0$. roots are α_1, α_2

$$\alpha_{1,2} = -\frac{c}{2m} \pm \sqrt{\left(\frac{c}{2m}\right)^2 - \left(\frac{S}{m}\right)}$$

Put $\sqrt{\dfrac{\left(\frac{c}{2m}\right)^2}{\frac{s}{m}}} = \xi$ (damping factor or ratio)

$$\frac{c}{2m\omega_n} = \xi \, . \quad , \frac{c}{2m} = \xi . \omega_n .$$

$$\frac{\frac{c}{2m}}{\sqrt{\frac{s}{m}}} = \xi$$

$$\alpha_{1,2} = -\left(\frac{c}{2m}\right) \pm \sqrt{\left(\frac{c}{2m}\right)^2 - \left(\frac{s}{m}\right)^2}$$

$$= -\xi . \omega_n \pm \sqrt{\xi^2 . \omega_n^2 - \omega_n^2} .$$

$$\alpha_{1,2} = (-\xi \pm \sqrt{\xi^2 - 1}) . \omega_n .$$

Now if $\xi < 1$, the system is underdamped then

$$\alpha_{1,2} = \left[-\xi \pm i\sqrt{1-\xi^2}\right] \omega_n .$$

$$x = A e^{-\xi \omega_n t} \left[A e^{i\sqrt{1-\xi^2} . \omega_n t} + B e^{-i\sqrt{1-\xi^2} . \omega_n t}\right]$$

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

$$x = e^{-\xi \omega_n t} \left[A e^{i\omega_d t} + B e^{-i\omega_d t}\right]$$

$$x = e^{-\xi \omega_n t} \left[A(\cos \omega_d t + i \sin \omega_d t) + B (\cos \omega_d t - i \sin \omega_d t)\right]$$

$$= e^{-\xi \omega_n t} \left[(A+B) \cos \omega_d t + i \sin \omega_d t \, (A-B)\right]$$

$$= e^{-\xi \omega_n t} \left[C \cos \omega_d t + D \sin \omega_d t\right]$$

$A+B = X \sin\phi = C$

$i(A-B) = X \cos\phi = D$

$$x = X e^{-\xi \omega_n t} \left[\sin\phi \cos \omega_d t + \cos\phi \sin \omega_d t\right]$$

$$\boxed{x = X e^{-\xi \omega_n t} \sin(\omega_d t + \phi).}$$