Q1 Single equivalent couple acting on the system,

$M = M_1 + M_2$ (1)

Position vector of ED, $ED = (192\ mm)k$

Force vector, $F_1 = -(12,5N)i$

Couple made by the force F_1,

$M_1 = ED \times F_1$

$= (192\ mm)k \times [-(12.5)i]$

$= -(2400\ N\cdot mm)j$

Position vector of GF, $GF = -(160\ mm)i$

Position vector of BF,

$BF = -(160\ mm)i - (\frac{144}{2} mm)j + (\frac{192}{2} mm)k$

$= -(160\ mm)i - (72\ mm)j + (96\ mm)k$

Magnitude of BF,

$BF = \sqrt{160^2 + 72^2 + 96^2}$

$= 200mm$

Force vector of BF,

$F_2 = F_2 \left(\frac{BF}{BF}\right) = (50N) \times \left(\frac{-(160mm)i - (72mm)j + (96mm)k}{200mm}\right)$

$= (-40N)i - (18N)j + (24N)k$

Couple made by the force F_2

$M_2 = GF \times F_2$

$= -(160mm)i \times [(-40N)i - (18N)j + (24N)k]$

$= (2880N\text{-}mm)k + (3840N\text{-}mm)j$

From equation (1), we get equivalent couple,

$M = M_1 + M_2$

$= -(2400N\text{-}mm)j + (2880N\text{-}mm)k + (3840N\cdot mm)j$

$= (1440\ N\cdot mm)j + (2880\ N\cdot mm)k$

Magnitude of the equivalent couple,

$M = \sqrt{(1440)^2 + (2880)^2}$

$= 3219{,}937\ N\cdot mm$

$\boxed{= 3{,}219\ N\text{-}m}$

From the equivalent caple, we get Moment in x-direction,

$M_x = 0 N\text{-}m$

Moment in y-direction

$M_y = 1440 N\text{-}m$

$= 1{,}44 N\text{-}m$

Moment in z-direction

$M_z = 2880\ N.mm$

$= 2{,}88\ N.m$

The angle of equivalent moment with respect to x-axis,

$\theta_x = \cos^{-1}\left(\frac{M_x}{M}\right)$

$= \cos^{-1}\left(\frac{0}{3{,}219}\right) = \underline{\underline{90^\circ}}$

The angle of equivalent moment with respect to y-axis,

$\theta_y = \cos^{-1}\left(\frac{M_y}{M}\right)$

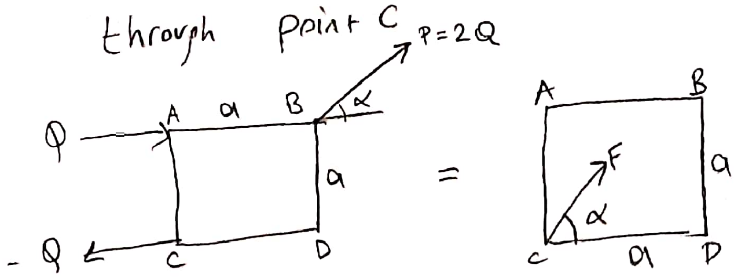
$= \cos^{-1}\left(\frac{1.44}{3{,}219}\right) = \underline{\underline{63{,}426^\circ}}$

The equivalent moment with respect to z-axis,

$\theta_z = \cos^{-1}\left(\frac{M_z}{M}\right)$

$= \cos^{-1}\left(\frac{2.88}{3{,}219}\right) = \underline{\underline{26{,}531^\circ}}$

Q2) If the line of action of the single equivalent force is to pass through point C



Let F be the single equivalent force which replaces the given force and couple.
For similar loadings, the single equivalent force is $F = \Sigma F$

$= Q - Q + P = 2Q(\cos\alpha\, i + \sin\alpha\, j)$

For similar loadings, sum of moments about C should be the same in both the cases.

$\Sigma M_C = M_C$

$-(Q)(a) - (P\cos\alpha)(a) + (P\sin\alpha)(a) = 0$

$-(Q)(a) - (P\cos\alpha)(a) + (P\sin\alpha)(a) = 0$

$2Q(\sin\alpha - \cos\alpha) = Q$

$\sin\alpha - \cos\alpha = 0.5$

$\sin\alpha = 0.5 + \cos\alpha$

Square on both sides of the above equation:

$\sin^2\alpha = (0.5 + \cos\alpha)^2$

$\sin^2\alpha = 0.25 + \cos^2\alpha + 2(0.5)\cos\alpha$

$\cos^2\alpha + \cos\alpha + 0.25 = 1 - \cos^2\alpha$

$2\cos^2\alpha + \cos\alpha - 0.75 = 0$

$$\cos\alpha = \frac{-1 \pm \sqrt{1^2 - 4(2)(-0.75)}}{2(2)}$$

$$= \frac{-1 \pm 2.646}{4}$$

$\cos\alpha = 0.4115$

$\alpha = \cos^{-1}(0.4115)$

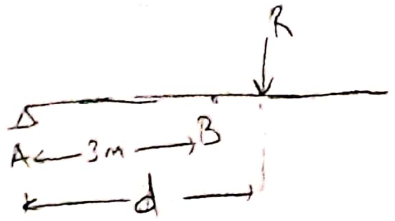
$\boxed{= 65.7^\circ}$

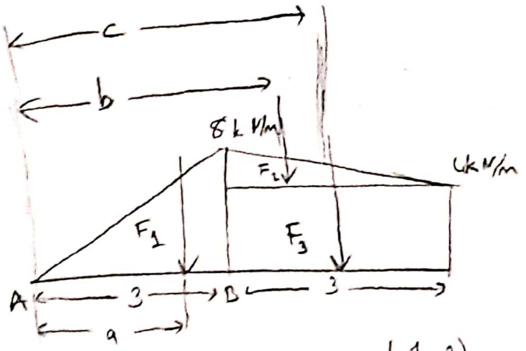
Q3

$$R = \underbrace{\frac{1}{2}\times 3\times 8}_{F_1} + \underbrace{\frac{1}{2}\times 3\times(8-4)}_{F_2} + \underbrace{4\times 3}_{F_3}$$

$$\boxed{R = 12 + 6 + 12 = 28\ kN/m}$$

resultant





$a = 3 - \left(\frac{1}{3}.3\right)$

$a = 2$

$b = 3 + \left(\frac{1}{3}.3\right)$

$b = 4$

$c = 3 + \left(\frac{1}{2}.3\right)$

$\boxed{c = \frac{9}{2} = 4.5}$

$+\circlearrowright M_A = F_1.a + F_2 b + F_3 c$

$= 12\times 2 + 6\times 4 + 12\times 4,5$

$= \boxed{102\ kN/m\ 2}$

$M_A = R\times d$

$102 = 28\times d \quad \boxed{d = 3,64\ m}$