الموضوع التاريخ / /

Static

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التاريخ / /

Particle الجزئ

Rigid Body الجسم المثالي

Quantity	unit by (FPS)		unit by (SI)
Force	1 lb	=	4.45 N
Mass	1 slug	=	14.59 Kg
Length	1 ft	=	0.305 m

G = giga = 10^9

M = mega = 10^6

m = milli = 10^{-3}

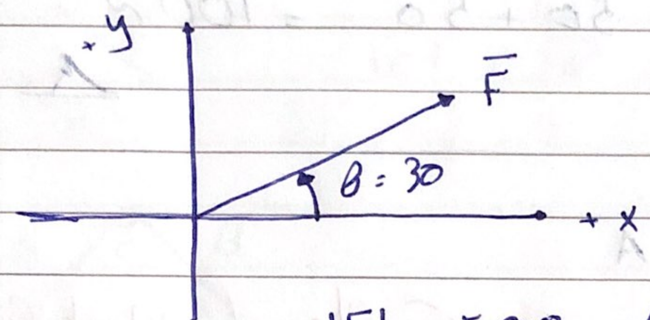
μ = micro

Force Vector

2.1 Scalar and vectors

Scalar ↓ Magnitude ↓ like Mass

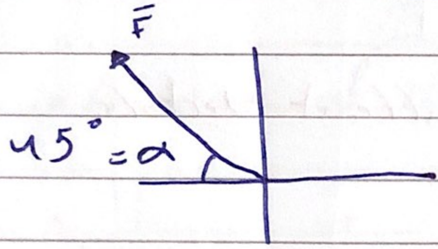
Vectors ↓ Magnitude and Direction ↓ like Force



$|F| = 500 \ N$

$Dir = \theta \ C.C.W$

$\theta = 30 \ \measuredangle$

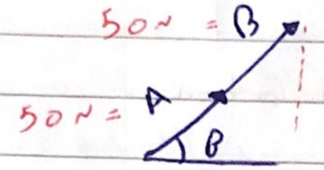


$|F| = 20 \ N$

$Dir = \theta = 45° \ \measuredangle$

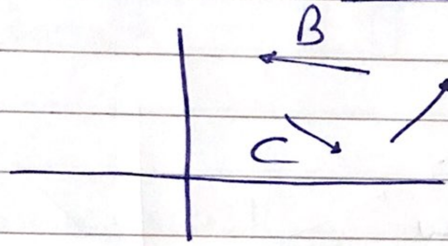
2.2 Vector operation

Addition of vectors.



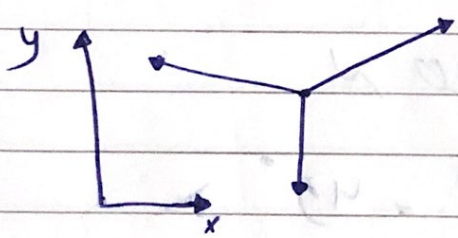
Collinear Vectors

$$|\bar{C}| = \bar{A} + \bar{B} = 50 + 50 = 100\,N$$



Coplanar Vectors

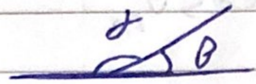
2-D



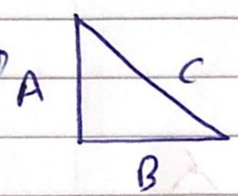
Concurrent Vectors

Graphical
Cartesion

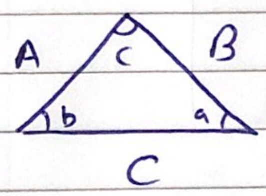
Note:

① 

$\theta + \alpha = 180$

② 

$|C| = \sqrt{A^2 + B^2}$

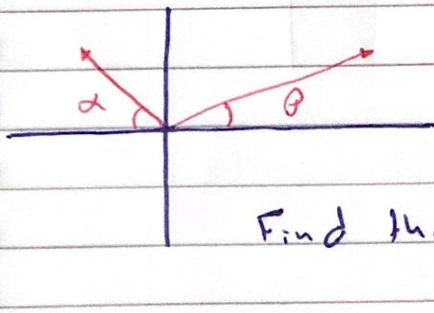
③ 

Sin Law: $\frac{A}{\sin a} = \frac{B}{\sin b} = \frac{C}{\sin c}$

Cos Law: $\sqrt{A^2 + B^2 - 2AB\cos c}$

• Addition of vectors $\Rightarrow$ to find Resultant

Magnitude Direction



Find the Resultant?

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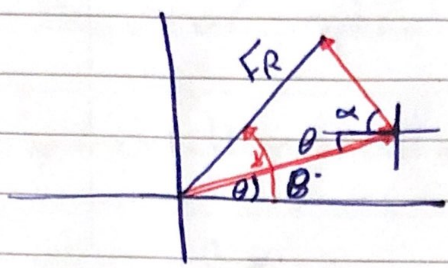
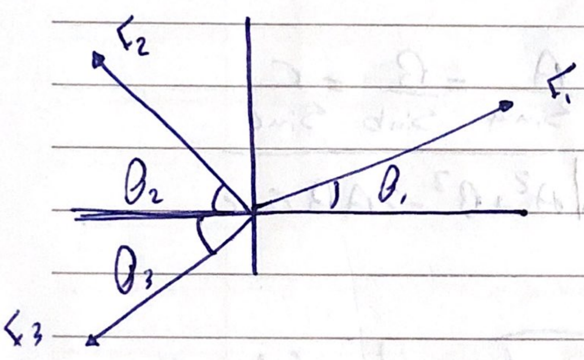


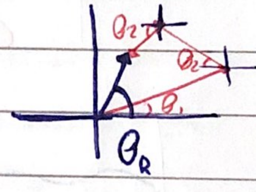
Cos Law: $F_R = \sqrt{F_1^2 + F_2^2 - F_1 F_2 \cos\theta_{F_R}}$

Sin Law: $\dfrac{F_R}{\sin\theta_{F_R}} = \dfrac{F_2}{\sin\gamma}$

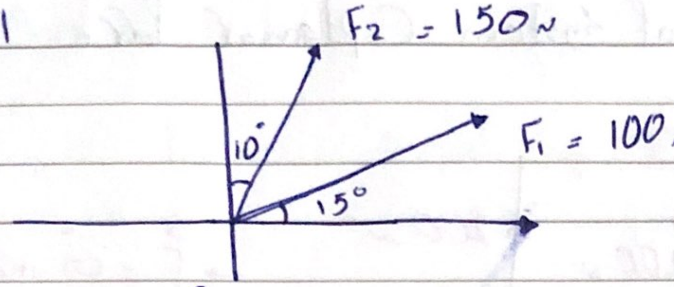
Direction $= \theta + \gamma = B^\circ$



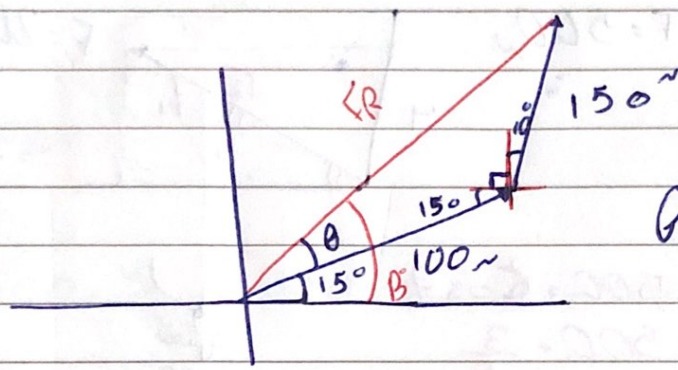
$\Longrightarrow$ Resultant



Ex 2.1



Find the Resultant ?



$\theta_R = 10 + 90 + 15$
$= 115°$

$$F_R = \sqrt{(100)^2 + (150)^2 - 2 \cdot 100 \cdot 150 \cdot \cos 115}$$
$$= \underline{\underline{212.55N}}$$

by Sin Law : $\dfrac{F_R}{\sin 115°} = \dfrac{F_2}{\sin \theta}$

$$\frac{212.5}{\sin 115} = \frac{150}{\sin \theta}$$

$$\therefore \theta = 39.76°$$

But $\beta = \theta + 15° = \underline{\underline{54°\ \measuredangle}}$

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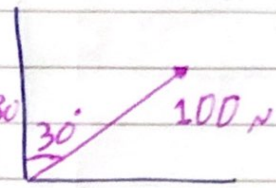
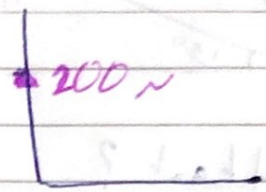
2.4 : addition of system Coplanar force

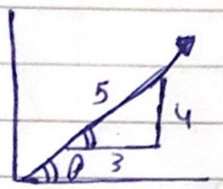
$F_x = 100 \sin 30$

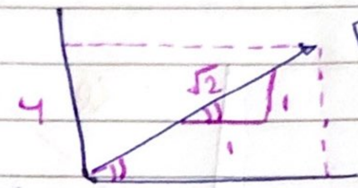
$F_y = 100 \cos 30$





$\rightarrow \vec{F} = 0\hat{i} + 200\hat{j}$



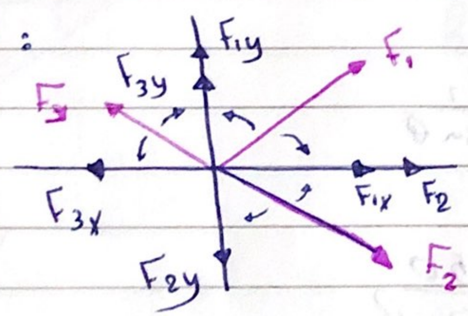


$\hookrightarrow F_x = 500 \cdot \cos\theta$
$= 500 \cdot \frac{3}{5}$

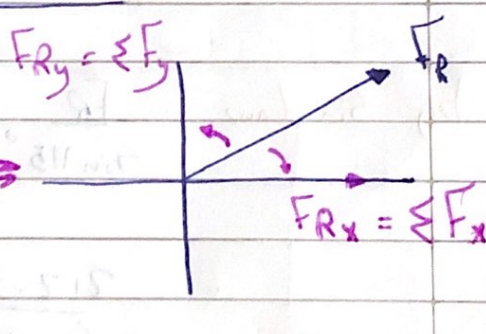
نفس هاي الطريقة

$\hookrightarrow F_y = 500 \cdot \sin\theta$
$= 500 \cdot \frac{4}{5}$

Ex :



$\Longrightarrow$



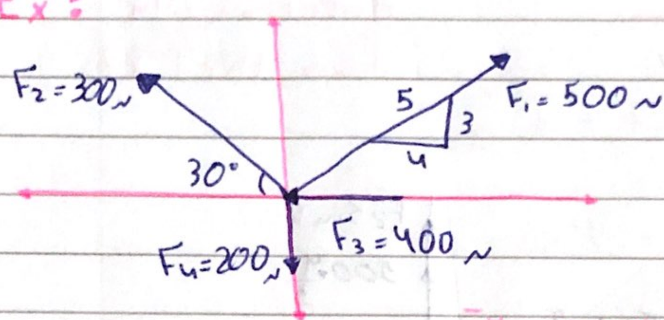
$\rightarrow \vec{F}_R = \sum F_x \hat{i} + \sum F_y \hat{j}$ = Cartesian vector

$\rightarrow$ magnitude : $|F_R| = \sqrt{(\sum F_x)^2 + (\sum F_y)^2}$

↳ Direction : $\tan\theta = \frac{F_y}{F_x}$

$\therefore \theta = \tan^{-1}\left(\frac{F_y}{F_x}\right)$

Ex :



-x بالاتجاه

* $F_{Rx} = 500 \cdot \frac{4}{5} - 300 \cdot \cos 30 - 400 = -259.8\,N$ ←

* $F_{Ry} = 500 \cdot \frac{3}{5} + 300 \sin 30 - 200 = 250\,N$ ↑

↳ $\vec{F_R} = -259.8\,\hat{i} + 250\,\hat{j}$

↳ $|F_R| = \sqrt{(-259.8)^2 + (250)^2} = 360.5\,N$

* Direction = $\tan\theta = \frac{250}{259.8}$ $\therefore \theta = 44°$

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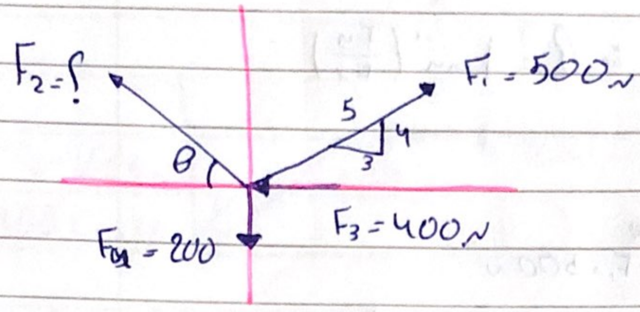
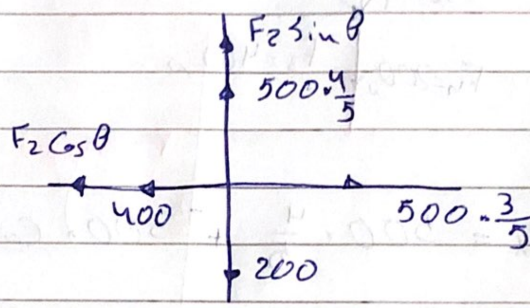
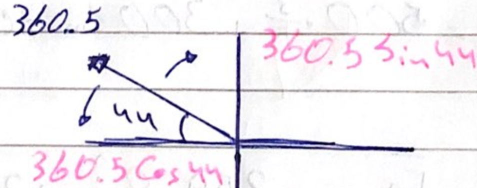
*** Ex:-**

- find F_2 and θ if Resultant = 360.5 N and the direction = 44° from the $-x$?







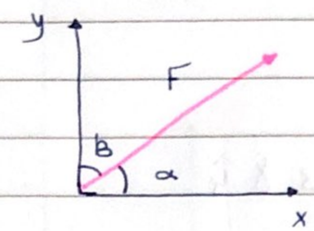
F_x :

$$-360.5\cos 44 = 300 - 400 - F_2\cos\theta$$

F_y : $360.5\sin = F_2\sin\theta + 400 - 200$

التاريخ / /　　　　　　　　　　　　　　　　　　　　الموضوع

2-5 Cartesin vector (3-D)



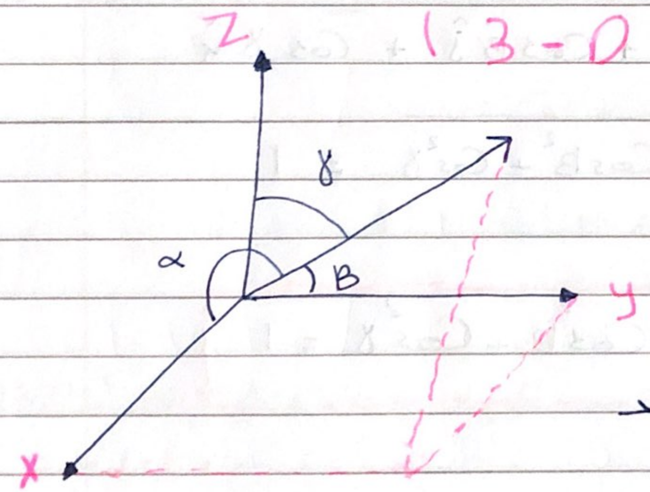
→ مراجعة (2-D)

$$\bar{F} = F_x \hat{i} + F_y \hat{j}$$

$$|F| = \sqrt{F_x^2 + F_y^2}$$

$$\tan \alpha = \frac{f_x}{f_y}$$

(3-D)



- يوجد ثلاث محاور

→ B, α, γ : Direction Angales with axis

$$\cos \alpha = \frac{F_x}{F}$$

$$\cos B = \frac{F_y}{F}$$

$$\cos \gamma = \frac{F_z}{F}$$

الموضوع التاريخ / /

→ Cartisin Vector :

$\bar{F} = F_x\hat{i} + F_y\hat{j} + F_z\hat{k}$

$= F\cos\alpha\,\hat{i} + F\cos B\,\hat{j} + F\cos\gamma\,\hat{k}$

→ $|F| = \sqrt{F_x^2 + F_y^2 + F_z^2}$

$\bar{U}$: unit Vector

$\bar{U} = \cos\alpha\,\hat{i} + \cos B\,\hat{j} + \cos\gamma\,\hat{k}$

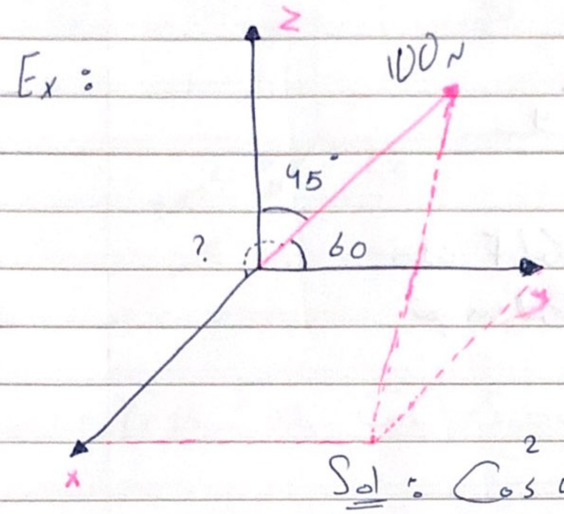
$|\bar{U}| = \sqrt{\cos^2\alpha + \cos B^2 + \cos^2\gamma} = 1$

$$\boxed{\therefore \cos^2\alpha + \cos^2 B + \cos^2\gamma = 1}$$

← يستخدم في حال اعطاء زاويتين

$$\boxed{U = \frac{\bar{F}}{|F|}}$$

Ex :



Q : Express F as Cartion Vector.

$$\bar{F} = F_x\hat{i} + F_y\hat{j} + F_z\hat{k}$$

Sol : $\cos^2\alpha + \cos^2 60 + \cos^2 45 = 1$

$$\therefore \cos\alpha = \sqrt{1 - \cos^2 60 - \cos^2 45}$$

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

$$\alpha = \mp 60 \text{ or } 120$$

لـ بختار الزاوية حسب مايلي : ١) الخط المتقطع مع (+) نأخذ الزاوية الصغيرة
2) // // // (-) // = الكبيرة

$$\bar{F} = 100\cos 60 + 100\cos 60 + 100\cos 45$$

$$\bar{U} = \cos 60\,\hat{i} + \cos 60\,\hat{j} + \cos 45\,\hat{k}$$

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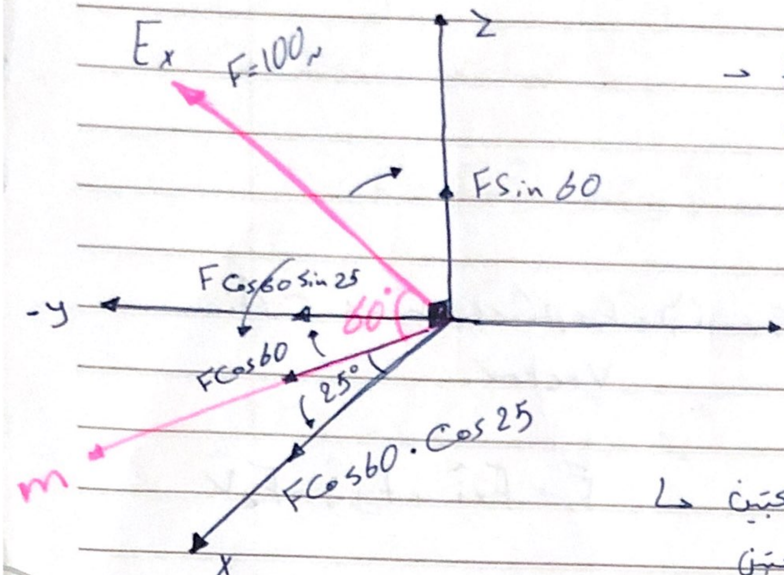
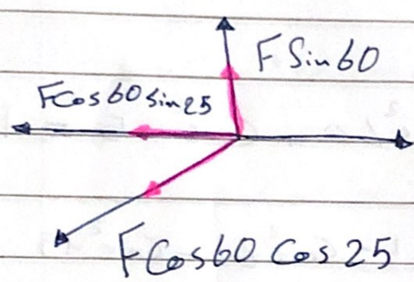


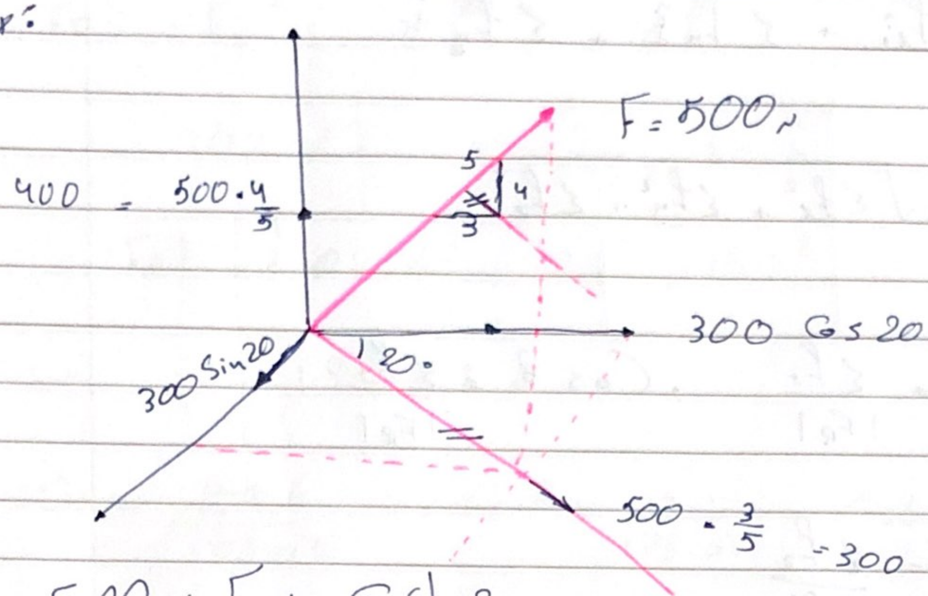
→ F as Cartesian vector and find its direction.

حللنا F لمركبتين
ثم m لمركبتين



$$\therefore \vec{F} = 100\cos 60^\circ \cos 25^\circ \,\hat{i} - 100\cos 60^\circ \sin 25^\circ \,\hat{j} + 100\sin 60^\circ$$

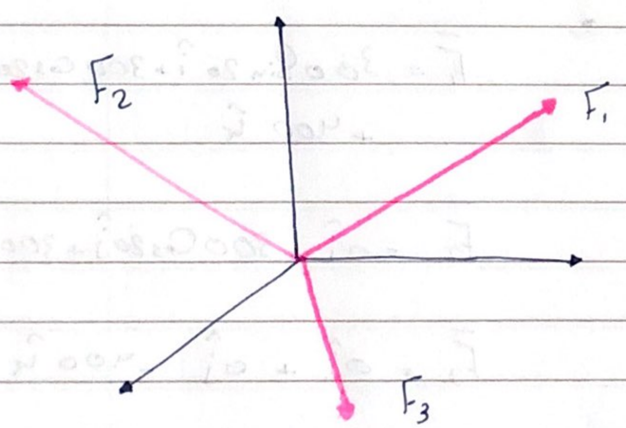
Ex:



→ Express F as Cartesian.

$$F = 300 \sin 20\,\hat{i} + 300 \cos 20\,\hat{j} + 400\,\hat{k}$$

2.6 Addition of Cartesian Vector (3-D)



1. Express each force as Cartesian vectors.

$$\bar{F}_1 = F_{1x}\,\hat{i} + F_{1y}\,\hat{j} + F_{1z}\,\hat{k}$$

$$\bar{F}_2 = F_{2x}\,\hat{i} + F_{2y}\,\hat{j} + F_{2z}\,\hat{k}$$

$$\bar{F}_3 = F_{3x}\,\hat{i} + F_{3y}\,\hat{j} + F_{3z}\,\hat{k}$$

التاريخ / /   الموضوع

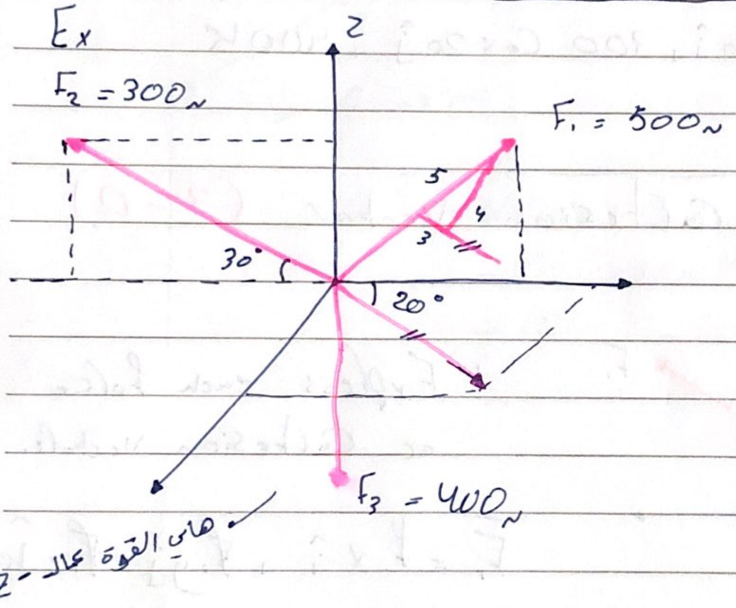
$\rightarrow \bar{F}_R = \sum f_x \hat{i} + \sum f_y \hat{j} + \sum f_z \hat{k}$

$\rightarrow |F_R| = \sqrt{\sum f_x^2 + \sum f_y^2 + \sum f_z^2}$

$\cos\alpha = \frac{\sum f_x}{|F_R|}$, $\cos\beta = \frac{\sum f_y}{|F_R|}$

$\cos\gamma = \frac{\sum f_z}{|F_R|}$

Ex



$\rightarrow$ Find the resultant

$\bar{F}_1 = 300 \sin 20\,\hat{i} + 300 \cos 20\,\hat{j} + 400\,\hat{k}$

$\bar{F}_2 = 0\hat{i} - 300 \cos 20\,\hat{j} + 300 \sin 30\,\hat{k}$

$\bar{F}_3 = 0\hat{i} + 0\hat{j} - 400\,\hat{k}$

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$$\bar{F}_R = \Sigma f_x \hat{i} + \Sigma f_y \hat{j} + \Sigma f_z \hat{k}$$

$$= 102.6\hat{i} - 22.1\hat{j} + 150\hat{k}$$

$$\rightarrow |F_R| = \sqrt{102.6^2 + 22.1^2 + 150^2}$$

$$= 183.07\ N$$

$$\cos\alpha = \frac{102.6}{183.07}, \quad \cos\beta = \frac{-22.1}{183.07}, \quad \cos\gamma = \frac{150}{183.07}$$

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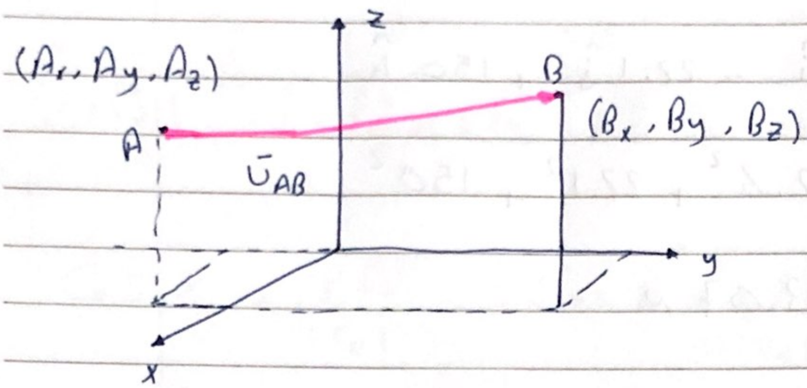
2.7 Position Vector ($\bar{r}$)



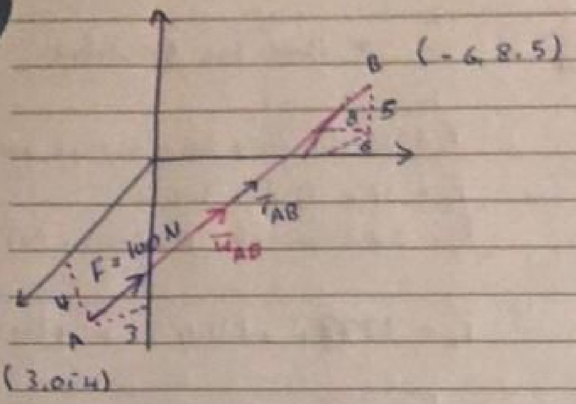
$$\bar{r}_{AB} = (B_x - A_x)\hat{i} + (B_y - A_y)\hat{j} + (B_z - A_z)\hat{k}$$

$$\bar{r}_{AB} = \Delta x\,\hat{i} + \Delta y\,\hat{j} + \Delta z\,\hat{k}$$

$$|\bar{r}_{AB}| = \sqrt{\Delta x^2 + \Delta y^2 + \Delta z^2}$$

$$\bar{U}_{AB} = \frac{\bar{r}_{AB}}{|\bar{r}_{AB}|} = \frac{\Delta x\,\hat{i} + \Delta y\,\hat{j} + \Delta z\,\hat{k}}{|\bar{r}_{AB}|}$$

$$= \cos\alpha\,\hat{i} + \cos\beta\,\hat{i} + \cos\gamma\,\hat{k}$$



① * Find the unite vector $\bar{u}_{AB}$

$$\bar u_{AB} = \frac{\bar r_{AB}}{|r_{AB}|}$$

$$\bar r_{AB} = (-6-3)\hat i + (8-0)\hat j + (5-(-4))\hat k$$

$$= -9\hat i + 8\hat j + 9\hat k$$

$$|r_{AB}| = \sqrt{(9)^2 + (8)^2 + (9)^2} = 15.03$$

$$\bar u_{AB} = \frac{-9\hat i + 8\hat j + 9\hat k}{15.03}$$

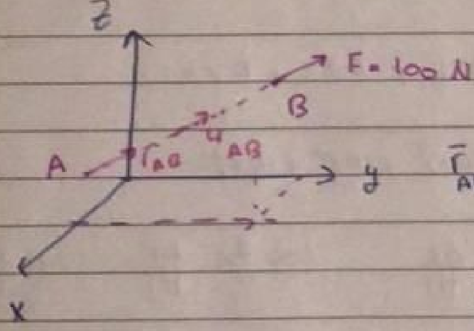
$$\bar u_{AB} = .59\hat i + .53\hat j + .59\hat k$$

(2.8) Force Directed Along aline

② * Find the carhision vector

$$\bar F = F\bar u = F\frac{\bar r}{|r|}$$

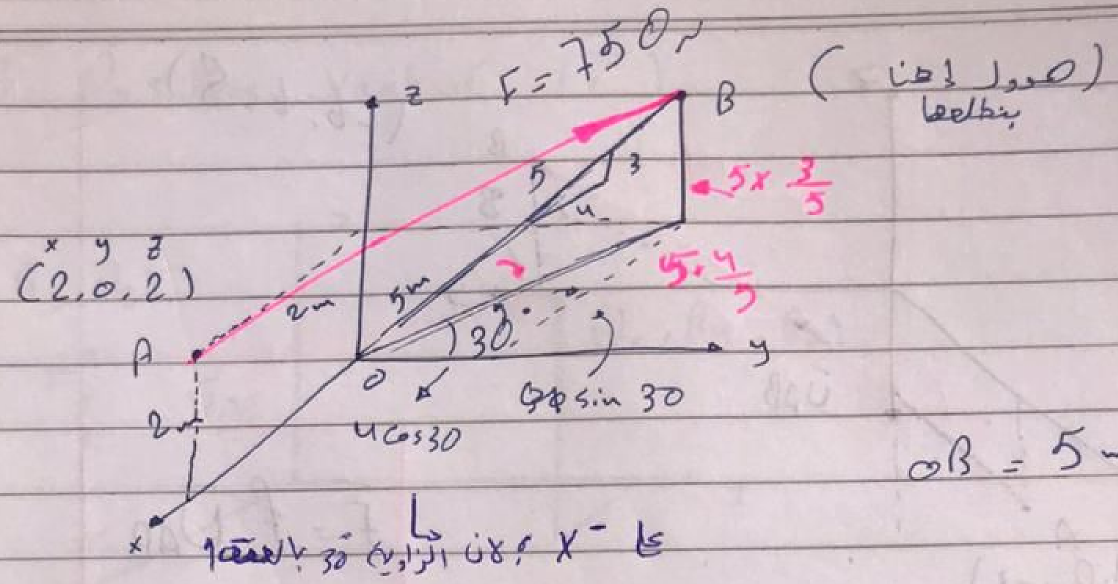
$$\bar F = 100\,(-.59\hat i + .53\hat j + .59\hat k)$$



$$\bar r_{AB} = u_{AB} = \frac{\bar r_{AB}}{r_{AB}}$$

$$F = F u_{AB}$$

Ex



$OB = 5\,m$

→ Express F as Cartesian vector and find its Direction

$$\bar{F} = f\,\bar{U}_{AB}$$

$$= f\,\frac{\bar{r}_{AB}}{r_{AB}} \quad \rightarrow \quad \bar{r}_{AB} = (-4\sin 30 - 2)\hat{i} + (4\cos 30 - 0)\hat{j} + (3-2)\hat{k}$$

$$= -4\hat{i} + 3.46\hat{j} + \hat{k}$$

$$\therefore |U_{AB}| = \sqrt{4^2 + 3.46^2 + 1^2}$$

$$= 5.38\,m$$

$$\bar{F} = 750\,\bar{U}_{AB}$$

$$= 750\left(\frac{-4\hat{i} + 3.46\hat{j} + \hat{k}}{5.38}\right)$$

$$\bar{F} = -557\hat{i} + 482\hat{j} + 139\hat{k}$$

الموضوع التاريخ / /

The Direction

$$\cos\alpha = \frac{-4}{5.38} \quad \alpha = \cos^{-1}\left(\frac{-4}{5.38}\right) = 130.02^\circ$$

$$\cos\beta = \frac{3.46}{5.38}$$

$$\cos\gamma = \frac{1}{5.38}$$

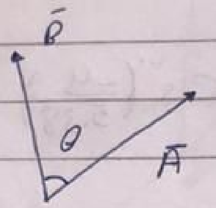
*Note:

$$r = \frac{r_x}{r}\hat{i} + \frac{r_y}{r}\hat{j} + \frac{r_z}{r} \qquad \hookrightarrow r_x = \Delta x$$

$$\bar{u} = \cos\alpha\,\hat{i} + \cos\beta\,\hat{j} + \cos\gamma\,\hat{k}$$

$$F = \frac{f_x}{f}\hat{i} + \frac{f_y}{f}\hat{j} + \frac{f_z}{f}\hat{k}$$

2.9 Dot product

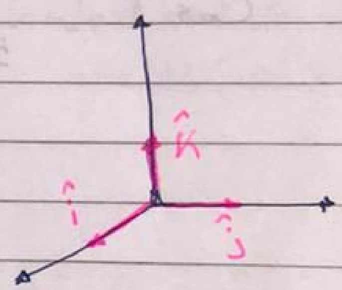


$\bar{A}.\bar{B} = |A||B| \cos\theta \rightarrow$ Scalar

$\rightarrow \cos\theta = \dfrac{\bar{A}.\bar{B}}{|A|\,|B|}$

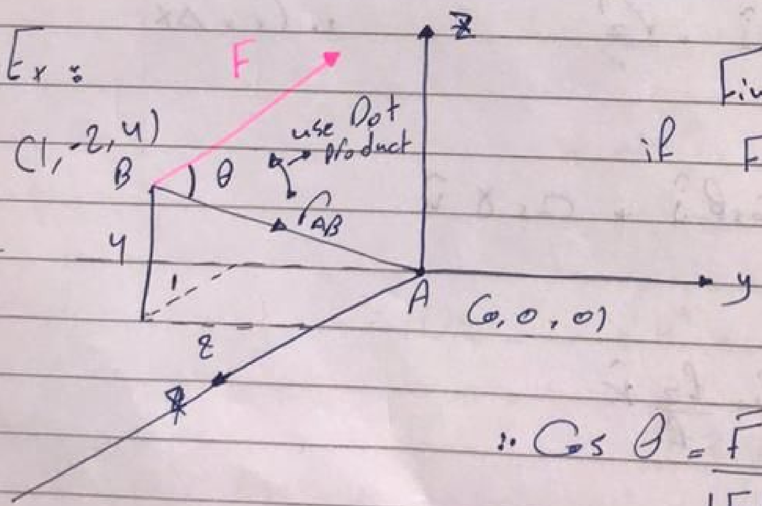
$\bar{A} = A_x \hat{i} + A_y \hat{j} + A_z \hat{k}$

$\bar{B} = B_x \hat{i} + B_y \hat{j} + B_z \hat{k}$



$\bar{A}.\bar{B} = A_x B_x + A_y B_y + A_z B_z$

Ex :



Find θ ?

if $F = -6\hat{i} + 3\hat{j} + 8\hat{k}$

$\therefore \cos\theta = \dfrac{F \,.\, r_{AB}}{|F|\,|r_{AB}|}$

$\to |f| = \sqrt{6^2 + 32 + 8^2} = 10.4$

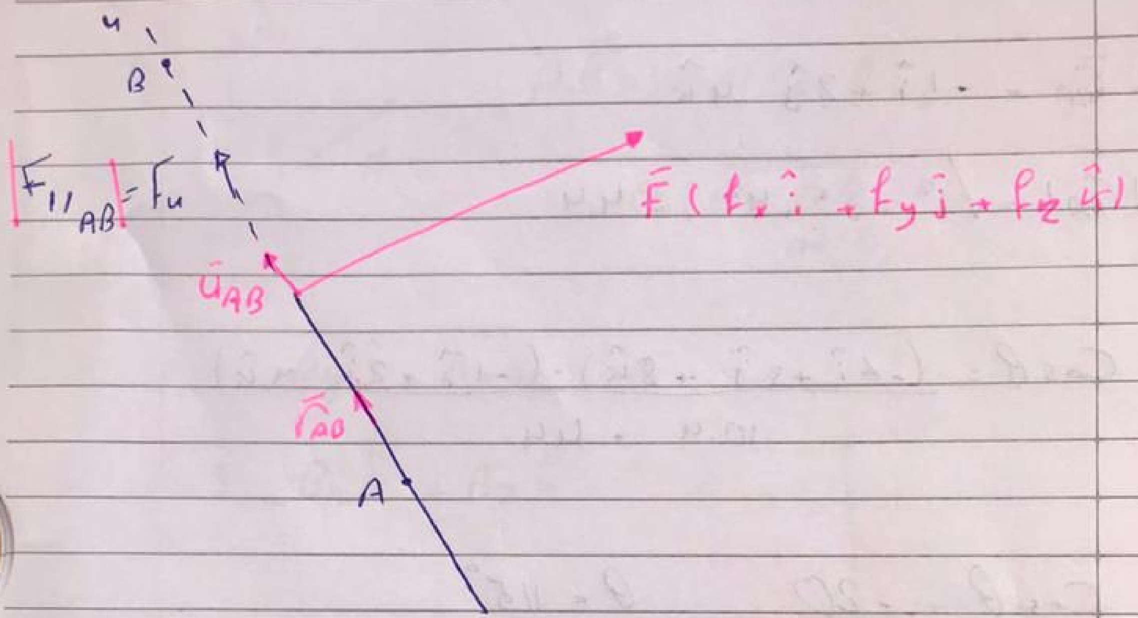
$\to \bar{r}_{BA} = -1\hat{i} + 2\hat{j} - 4\hat{k}$

$\to |r_{BA}| = \sqrt{1^2 + 2^2 + 4^2} = 4.4$

$\therefore \cos\theta = \dfrac{(-6\hat{i} + 3\hat{j} + 8\hat{k}) \cdot (-1\hat{i} + 2\hat{j} - 4\hat{k})}{10.4 \cdot 4.4}$

$\cos\theta = \dfrac{-20}{10.4 \cdot 4.4}$ $\quad \theta = 115^\circ$

- Dot product



- Component of a force parallel to a line

① $|F_{\parallel AB}| = \bar F \cdot \bar U_{AB} = \bar F \cdot \frac{\bar r_{AB}}{|r_{AB}|}$ → Magnitued

② The Component as Cartesian vector

$$\bar F_{\parallel AB} = |F_{\parallel AB}| \bar U_{AB}$$

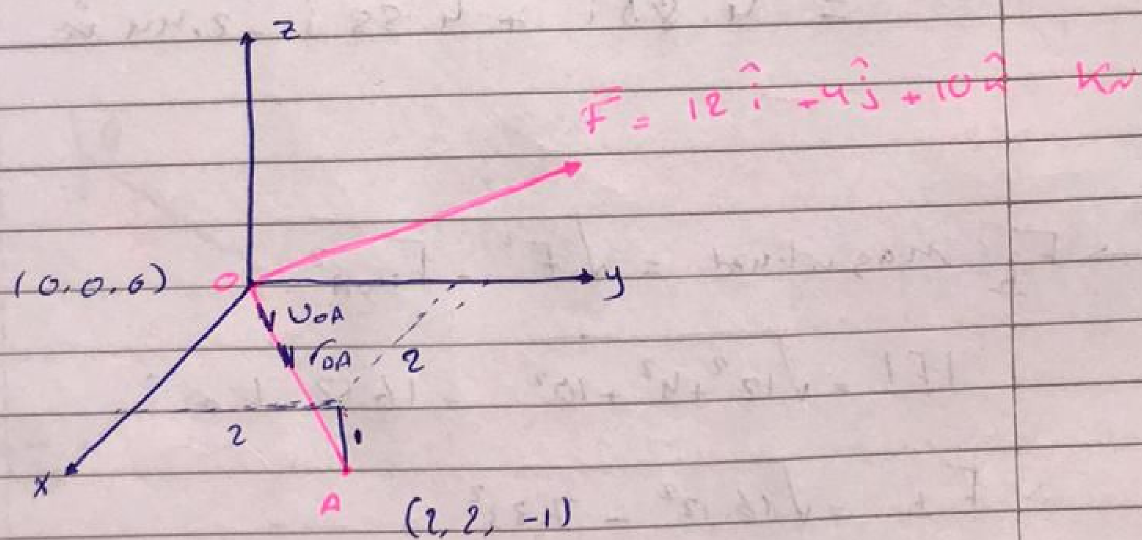
③ The Magnitude of the force ⊥ to line AB

$$|F_{\perp AB}| = \sqrt{|F|^2 - |F_{\parallel AB}|^2}$$

④ the perpendicular component on Cartesian vector

$$\bar{F}_{\perp AB} = \bar{F} - \bar{F}_{\parallel AB}$$

Ex:



- Determine the projection of F along the Rood (OA)

التاريخ / /

الموضوع

$\therefore \; |F_{\parallel OA}| = \bar{F}_{OA} \cdot \frac{\bar{r}_{OA}}{|r_{OA}|}$

$= \frac{(12\hat{i} + 4\hat{j} + 10\hat{k}) \cdot (2\hat{i} + 2\hat{j} - 1\hat{k})}{\sqrt{2^2 + 2^2 + 1}}$

$= 7.33 \text{ KN}$

$\rightarrow \bar{F}_{\parallel OA} = |F_{\parallel OA}| \; \bar{U}_{OA}$

$= 7.33 \left(\frac{2}{3}\hat{i} + \frac{2}{3}\hat{j} - \frac{1}{3}\hat{k} \right)$

$= 4.88\hat{i} + 4.88\hat{j} - 2.44\hat{k}$

as Cartesian vector

$\rightarrow F_{\perp}$ Magnitued $= \sqrt{F^2 - F_{\parallel OA}^2}$

$|F| = \sqrt{12^2 + 4^2 + 10^2} = 16.12 \text{ KN}$

$\therefore F_{\perp} = \sqrt{16.12^2 - 7.33^2} = \ldots$

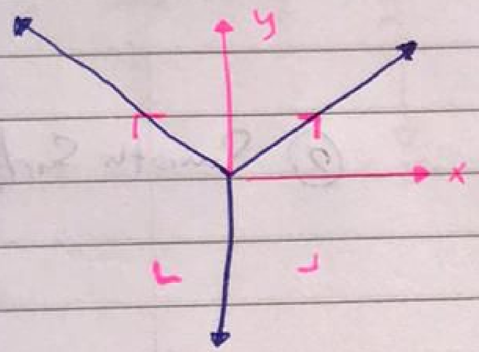
$\rightarrow \bar{F}_{\perp} = (12\hat{i} + 4\hat{j} + 10\hat{k}) - (4.88\hat{i} + 4.88\hat{j} - 2.44\hat{k})$

as Cartesian

Chapter 3

equilibrium of a particle

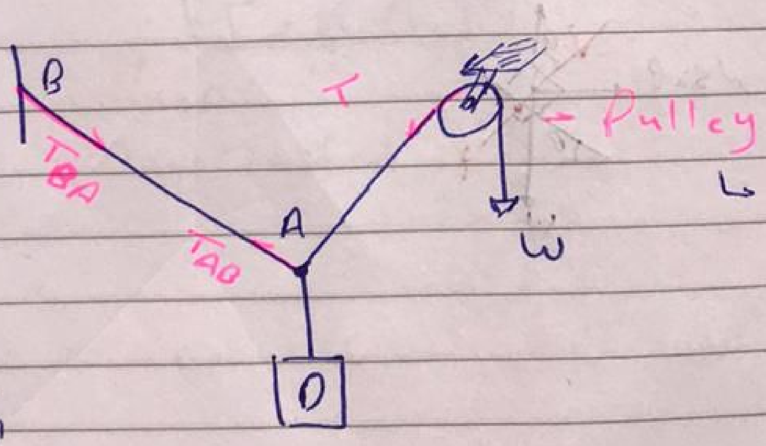
3.1 equilibrium of Coplanar force (2-D)



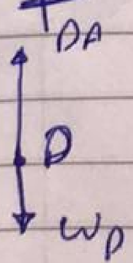
force equilibrium

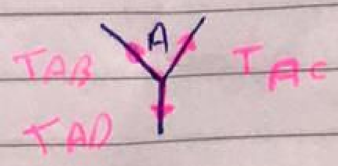
$$\Sigma \bar{F} = 0 \begin{cases} F_x = 0 \\ F_y = 0 \end{cases}$$

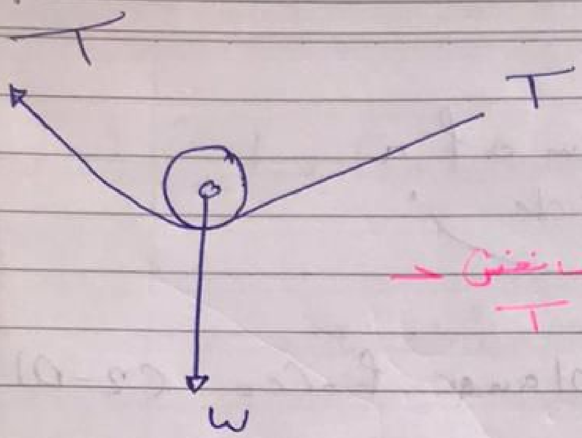
3.2 Free Body Diagram (F.B.D)



↳ frictionless







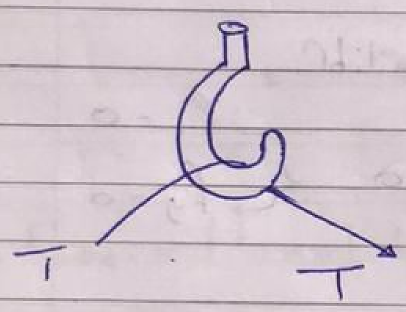
ماسك نفسي ← T

① Cable + Pulley

↓

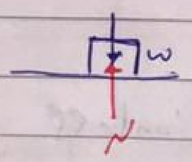
Tension

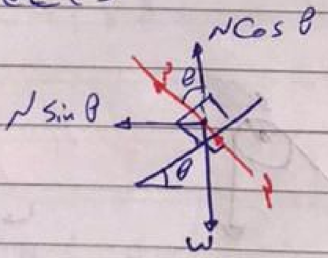
(T)



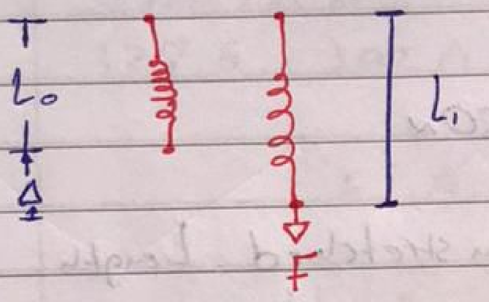
② Smooth Surface

→ Smooth Surfaces





3. Spring (T or Compression) → F



L_o: unstretched length
or
initial Length of undeformed

Δ: Stretch or deformation

L': final Length

$\Delta = L' - L_o$

$$\boxed{F = K\Delta}$$

Stiffness
Spring Constant

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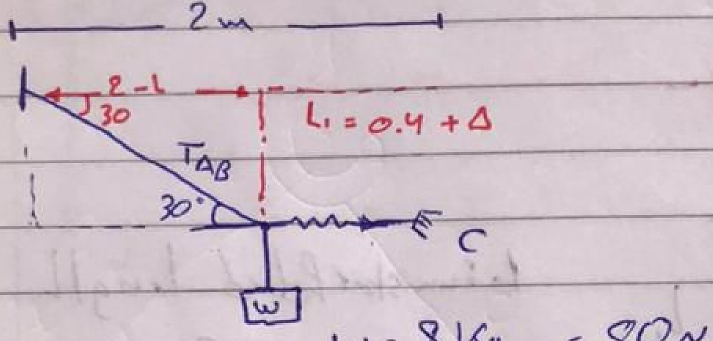
Ex : 3.2



$w = 8\,Kg = 80N$

- find length AB if the unstretched Length of the spring $AC = \underline{0.4}$ m
  L_0

$$\begin{bmatrix} \Sigma F_x = 0 \\ \Sigma F_y = 0 \end{bmatrix} \Rightarrow \begin{matrix} T_{AB} \\ F_{AC} \end{matrix}$$

$F_{AC} = K\,\Delta$

$\rightarrow L' = L_0 + \Delta$

$\overset{+}{\rightarrow}$ $\Sigma F_x = 0$

$\hookrightarrow F_{AC} - T_{AB}\cos 30 = 0$

$+\uparrow$ $\Sigma F_y = 0$

$\hookrightarrow -80 + T_{AB}\sin 30 = 0$

$\therefore T_{AB} = 160_N$

$\Rightarrow \quad F_{AC} - 160 \cos 30 = 0$

$\therefore \quad F_{AC} = 138.5\ N$

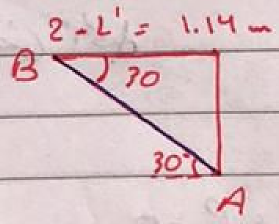
$F_{AC} = K\,\Delta$

$138.5 = 300\,\Delta$

$\therefore \quad \Delta = 0.46\ m$

$L' = L_o + \Delta$

$0.4 + 0.46 = 0.86\ m$



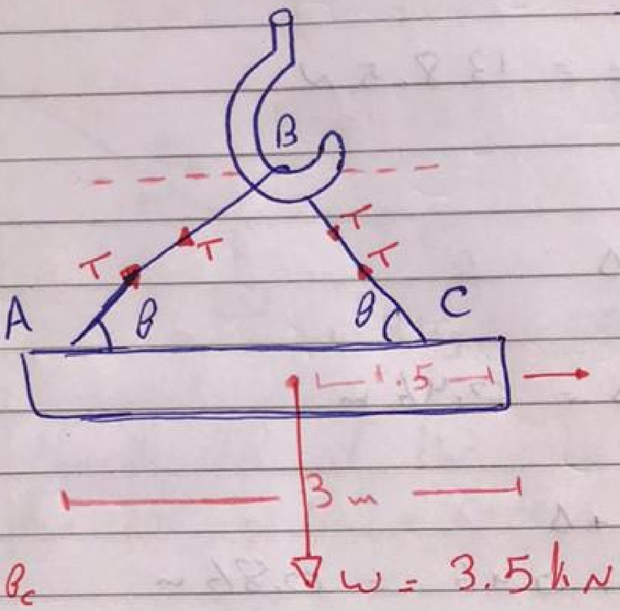
$L_{AB} \cos 30 = 1.14$

$$L_{AB} = \frac{1.14}{\cos 30} = 1.32\ m$$

التاريخ / /

الموضوع

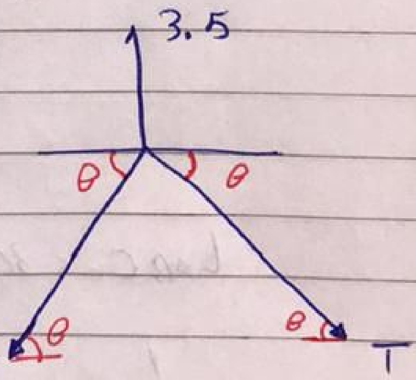
Ex :



Find the Lenght of Ac if the Cable Ac Can Supert Tension = 7KN?

→ $\theta_A = \theta_C$

← T هي نفسها لأنو نفس الحبل



$\Sigma F_x = 0$

↳ $T\cos\theta + T\cos\theta = 0$

$\Sigma F_y = 0$

↳ $3.5 - T\sin\theta - T\sin\theta = 0$

$2T\sin\theta = 3.5$

$\theta = \sin^{-1}\left(\frac{3.5}{2T}\right)$

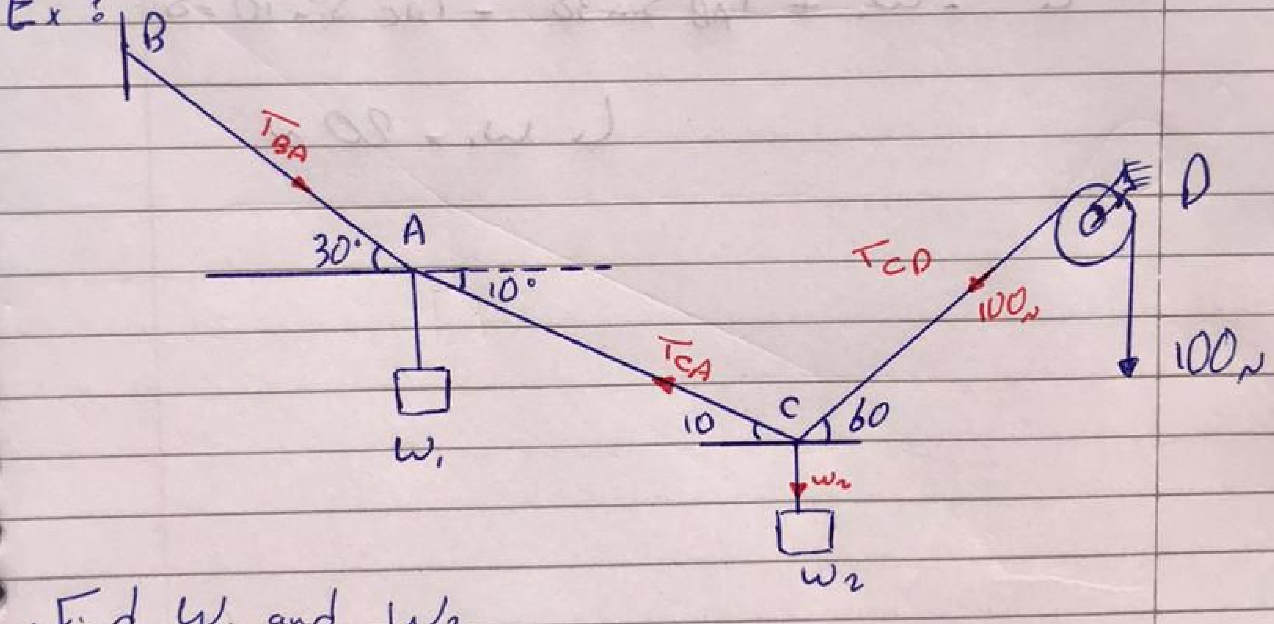
↳ but $T = 7$ kN

$\therefore \theta = 14.48°$

→ but $L_{AB} = \dfrac{1.5}{\cos 14.48} = 1.55 \text{ m}$

→ $L_{AC} = 2 L_{AB} = 2 \times 1.55 \text{ m}$
$= 3.1 \text{ m}$

Ex:



→ Find W_1 and W_2

C

$\xrightarrow{+} \Sigma F_x = 0$

↳ $100 \cos 60 - T_{CA} \cos 10 = 0$

↳ $\therefore T_{CA} = 50.77 \text{ N}$

$+\uparrow \Sigma F_y = 0$

↳ $100 \sin 60 + T_{CA} \sin 10 - W_2 = 0$

↳ $\therefore W_2 = 95 \text{ N}$

الموضوع التاريخ / /

(4)

$\xrightarrow{+} \sum F_x = 0$

$\hookrightarrow 50.77 \cos 10 - T_{AB} \cos 30 = 0$

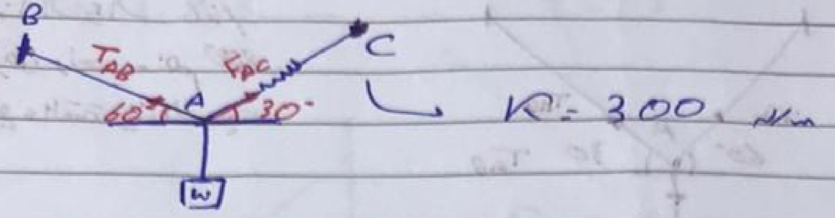
$\hookrightarrow T_{AB} = 57.7 \, N$

$+\uparrow \sum F_y = 0$

$\hookrightarrow -W_1 + T_{AB} \sin 30 - T_{AC} \sin 10 = 0$

$\hookrightarrow W_1 = 20 \, N$

Ex :



- Find W = ? if the stretch in spring = 0.1 m ?

Δ

$F_{AC} = K\Delta$

$300 * 0.1 =$

$\sum F_x = 0 \rightarrow -T_{AB}\cos 60° + F_{AC}\cos 30° = 0$

$\therefore T_{AB} =$

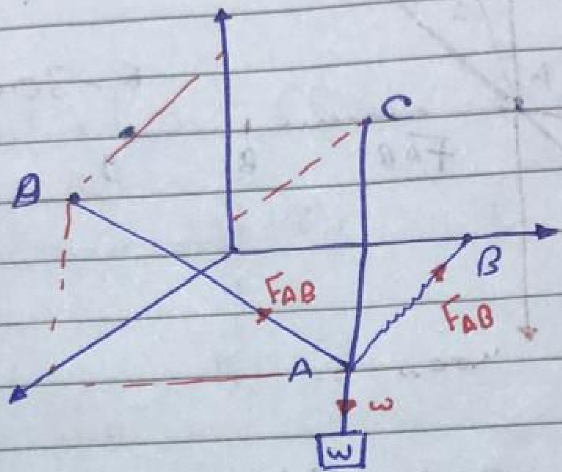
$\sum F_y = 0 \rightarrow T_{AB}\sin 60° + F_{AC}\sin 30 - W = 0$

$\therefore W =$

الموضوع

التاريخ / /

3.4 equilibrium in 3-D



unknown

$$\sum \bar{F} = 0 \begin{cases} \sum F_x = 0 \\ \sum F_y = 0 \\ \sum F_z = 0 \end{cases}$$

$T_{AB} = T_{AB}\hat{i} + T_{AB}\hat{j} + T_{AB}\hat{k}$

$$\bar{F} = F\bar{U} = F\frac{\bar{r}}{|r|}$$

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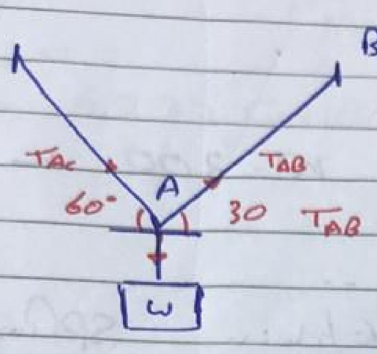
Ex :



- بهذا السؤال لازم
أفرض واحد منهم 200
و بطلع علاقة بين الاثنين

→ What is the Max W if the cables can support 200 N

$\Sigma F_x = 0 \rightarrow T_{AB} \cos 30 - T_{AC} \cos 60 = 0$

$\therefore T_{AB} = .57\, T_{AC}$

$\Rightarrow$ Assuem $T_{AC} = 200\,N$

$\therefore T_{AB} = .57 \cdot 200$
$= 114\,N$

$\Sigma F_y = 0 \rightarrow 114 \sin 30 + 200 \sin 60 - W = 0$

$\therefore W =$ ______

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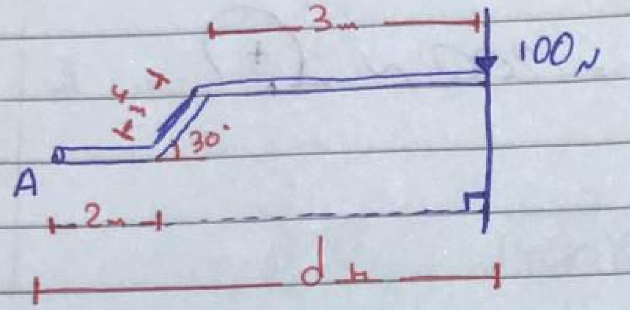
Chapter 4

Force System Resultant

→ 4.1 Moment of a force (Scalar formulation) صيغة

2-0



$M_A = ?$

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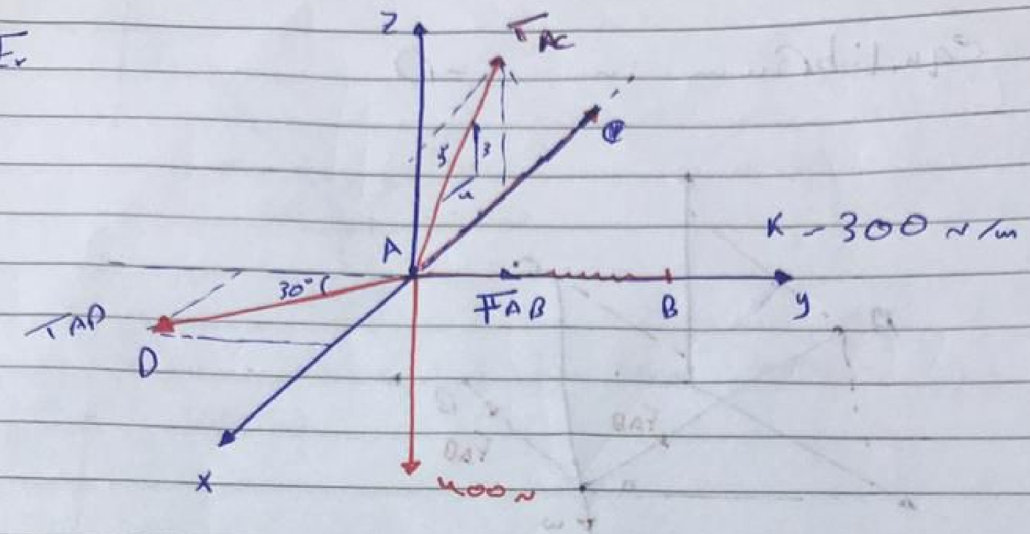
التاريخ / /

Ex



- Find Force in each Cables and the Stretch in the Spring?

$\Sigma F_x = 0$

$\hookrightarrow \quad T_{AD} \sin 30 - T_{AC} \cdot \frac{4}{5} = 0$

$\therefore T_{AD} = 1066.66\,N$

$\Sigma F_y = 0 \qquad -T_{AD} \cos 30 + F_{AB} = 0$

$\hookrightarrow$

$\therefore F_{AB} = 923.75\,N$

$\Sigma F_z = 0$

$\hookrightarrow \frac{3}{5} \cdot T_{AC} - 400 = 0$

$F_{AB} = K \cdot \Delta \qquad T_{AC} = 666.66\,N$

$\Delta = \frac{923.75}{300} = 3.08\,m$

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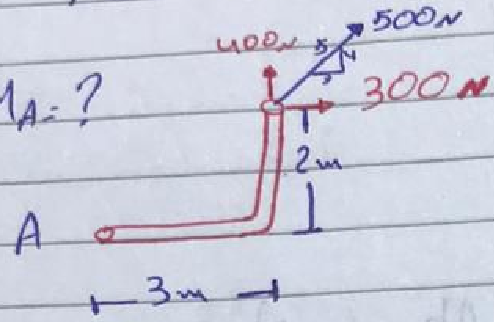
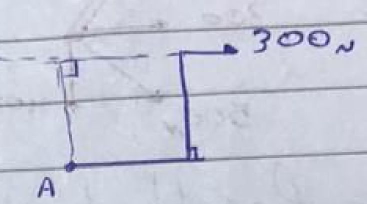
→ 4.4 Principal of a Moment

Moment of a force = Σ Moments of its Components

Ex: $M_A = ?$



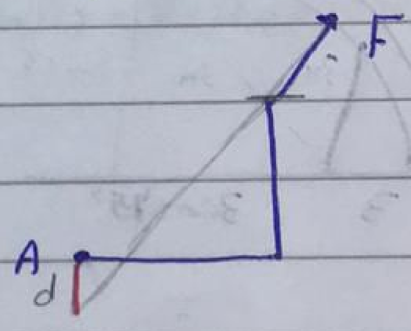


$$\Sigma M_A = +(400)(3) - (300)(2) = +600 \ N.m$$

(+)

→ Find the Perpendicular distance Between the Point and the force

$M = F d_\perp$ → $d_\perp = \frac{M}{F} = \frac{600}{500}$



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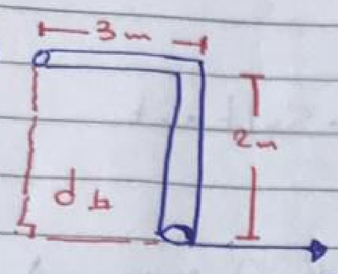
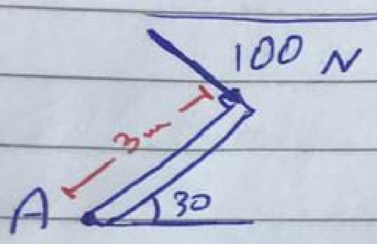
Ex:



$M_A = ?$

$M_A = 100 \cdot 2 = 200\ N.m$ (+)

Ex:



$M_A = ?$

$M_A = 100 \cdot 3 = -300\ N.m$ (-)

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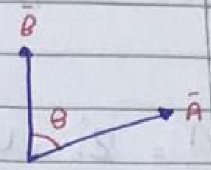
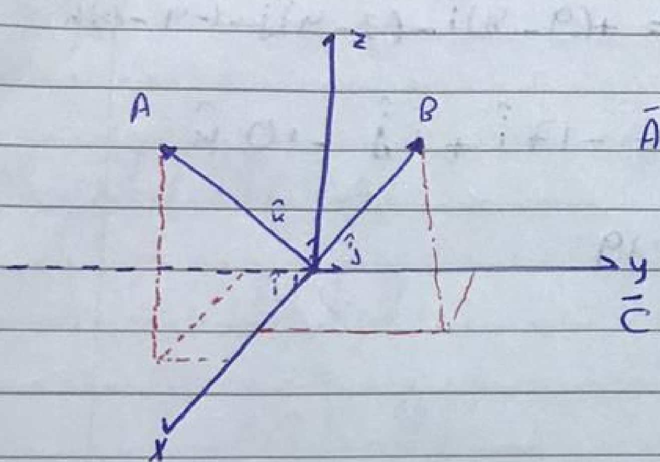
الموضوع

4.2 Cross Product $\longrightarrow$ Vector

$\bar{A} \times \bar{B} = |A||B| \sin\theta$



$\bar{A} = A_x\hat{i} + A_y\hat{j} + A_z\hat{k}$
$\bar{B} = B_x\hat{i} + B_y\hat{j} + B_z\hat{k}$



$$\bar{A}\times\bar{B} = \begin{vmatrix} \overset{+}{\hat{i}} & \overset{-}{\hat{j}} & \overset{+}{\hat{k}} \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix}$$

$$\bar{C} = +\begin{vmatrix} A_y & A_z \\ B_y & B_z \end{vmatrix}\hat{i} - \begin{vmatrix} A_x & A_z \\ B_x & B_z \end{vmatrix}\hat{j} + \begin{vmatrix} A_x & A_y \\ B_x & B_y \end{vmatrix}\hat{k}$$

$$\bar{C} = +(A_yB_z - B_yA_z)\hat{i} - (A_xB_z - B_xA_z)\hat{j} + (A_xB_y - B_xA_y)\hat{k}$$

$$\bar{C} = C_x\hat{i} + C_y\hat{j} + C_z\hat{k}$$

$$|C| = \sqrt{C_x^2 + C_y^2 + C_z^2}$$

$$\cos\alpha = \frac{C_x}{|C|}, \quad \cos\beta = \frac{C_y}{|C|}, \quad \cos\gamma = \frac{C_z}{|C|}$$

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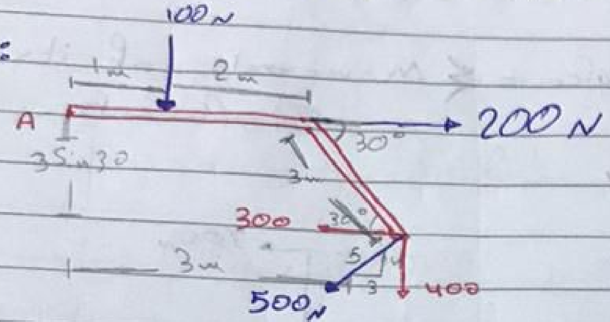
الموضوع

* Resultant Moment $= \sum M = \sum F_i d_i$

Ex:

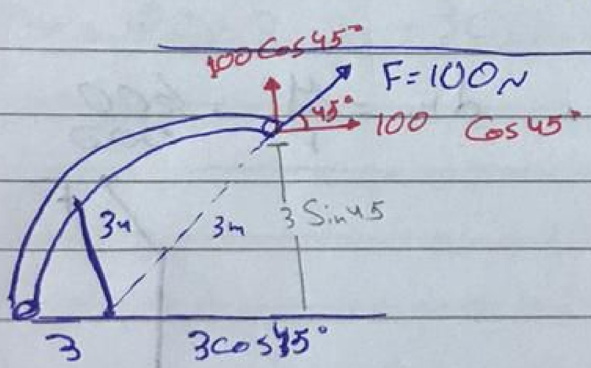


→ Find the Resultant Moment About $\underline{A}$

$$\sum M = -(100)(1) + (200)(0) - (300)(3\sin 30) - (400)(3 + 3\cos 30)$$

$= - \_\_\_\_$ N.m (−)

Ex



$M_A = ?$

$$\sum M_A = -(100\cos 45)(3\sin 45) + 100\sin 45(3 + 3\cos 45)$$

$\therefore M_A = 212.1$ (+)

212.1 (+)

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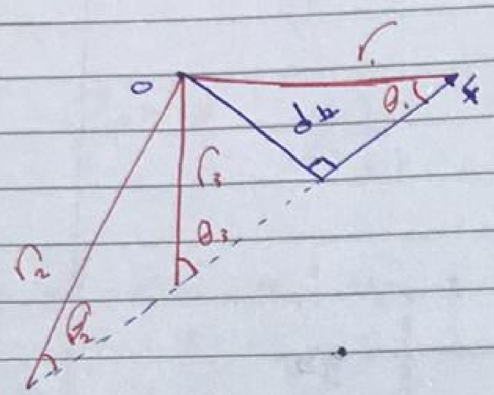
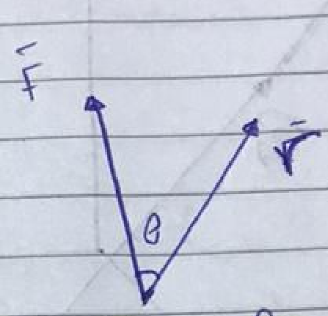
التاريخ / /

4.3 Moment of force [vector formulation]





$$\bar{r} \times \bar{F} = rF\sin\theta = \bar{M}_o$$

$$M_o = Fd = Fr_1\sin\theta_1 = Fr_2\sin\theta_2 = Fr_3\sin\theta_3$$

but $\bar{r}\times\bar{F} \neq \bar{F}\times\bar{r}$

$$\rightarrow \bar{M}_o = \bar{r}\times\bar{F} = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ r_x & r_y & r_z \\ F_x & F_y & F_z \end{vmatrix}$$

F = F as Cartesian vector

r = Any position vect from O to any on the line o force

$$\bar{M}_o = M_x\hat{i} + M_y\hat{j} + M_z\hat{k}$$

$$|M_o| = \sqrt{M_x^2 + M_y^2 + M_z^2}$$

$$\cos\alpha = \frac{M_x}{|M_o|}, \quad \cos\beta = \frac{M_y}{|M_o|}, \quad \cos\gamma = \frac{M_z}{|M_o|}$$

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$$\boxed{\bar{A} \times \bar{B} \neq \bar{B} \times \bar{A}}$$ Note

Ex: $\bar{A} = 2\hat{i} + 4\hat{j} - 3\hat{k}$ find $\bar{B} \times \bar{A}$

$\bar{B} = -1\hat{i} + 3\hat{j} + 2\hat{k}$

$$\bar{B} \times \bar{A} = \begin{array}{c} \begin{array}{ccc} \hat{i} & \hat{j} & \hat{k} \end{array} \\ \begin{vmatrix} -1 & 3 & 2 \\ 2 & 4 & -3 \end{vmatrix} \end{array} = +(-9-8)\hat{i} - (3-4)\hat{j} + (-4-6)\hat{k}$$

$$= -17\hat{i} + 1\hat{j} - 10\hat{k}$$

$$|C| = \sqrt{(17)^2 + (1)^2 + 10^2} = 19$$

as a Direction

$\cos\alpha = \frac{-17}{19}$, $\cos\beta = \frac{-1}{19}$, $\cos\gamma = \frac{-10}{19}$

الموضوع التاريخ / /

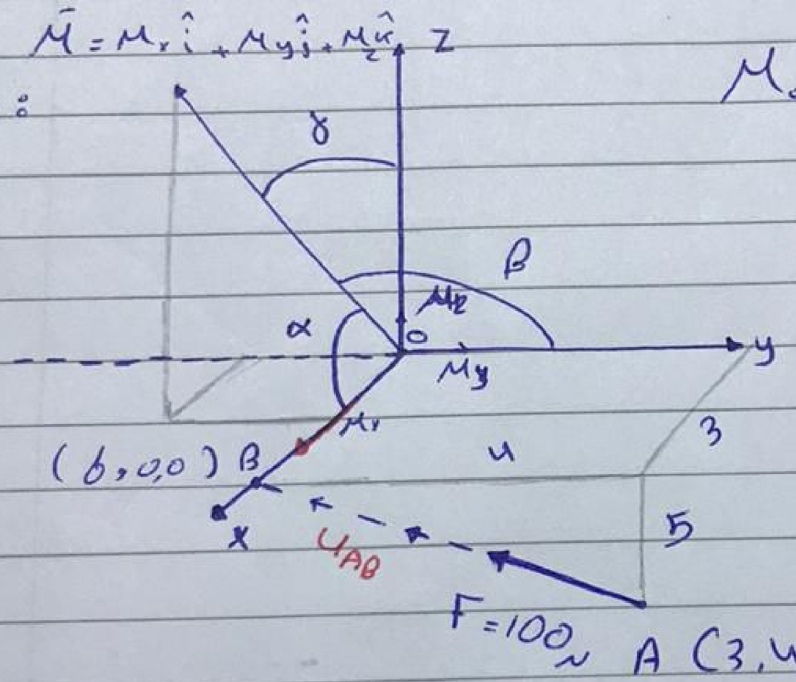
$$\cos\alpha = \frac{-59}{(62.2)} , \quad \cos\beta = \frac{17}{(62.2)}$$

$$\cos\gamma = \frac{-10}{(62.2)} \rightarrow \text{Direction}$$

$\bar{M} = M_x\hat{i} + M_y\hat{j} + M_z\hat{k}$

Ex:

$M_o = ?$



$$M_o = \bar{r} \times \bar{F}$$

r_{oB} or r_{oA}

Take This

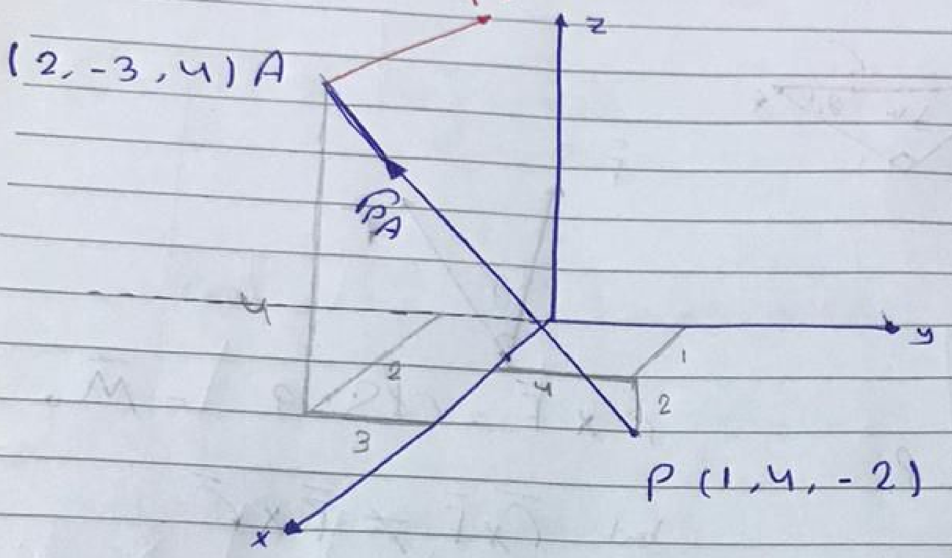
$$\bar{F} = \frac{(3\hat{i} - 4\hat{j} + 5\hat{k})}{\sqrt{3^2 + 4^2 + 5^2}} \cdot 100$$

$$M_o = r_{oB} \cdot \bar{F}$$

$r_{oB} = 6\hat{i} + 0\hat{j} + 0\hat{k}$

Ex : Find M_o

$\bar{F} = -2\hat{i} + 4\hat{j} + 5\hat{k}$ KN



$\bar{r} = (2-1)\hat{i} + (-3-4)\hat{j} + (4+2)\hat{k}$

$\bar{r} = 1\hat{i} - 7\hat{j} + 6\hat{k}$

$$\bar{M}_P = \bar{r} \times \bar{F} = \begin{array}{ccc} + & - & + \\ \hat{i} & \hat{j} & \hat{k} \end{array} \begin{vmatrix} 1 & -7 & 6 \\ -2 & 4 & 5 \end{vmatrix}$$

$$\bar{M}_P = (-35-24)\hat{i} - (5+12)\hat{j} + (4-14)\hat{k}$$
$$= -59\hat{i} - 17\hat{j} - 10\hat{k}$$

$\bar{M}_P$ as Cartesian vector

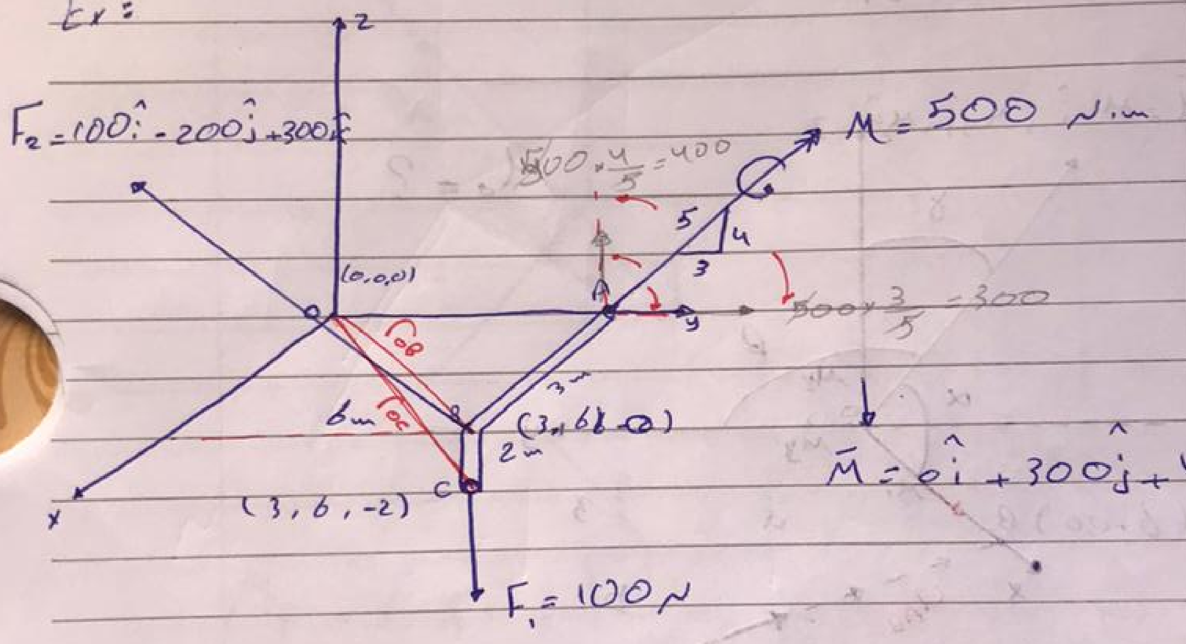
$$|M_P| = \sqrt{59^2 + 17^2 + 10^2} = 62.20 \text{ KN.m}$$

Magnitude

Resultent Moment (3-D)

$$\bar{M}_{oR} = \Sigma \bar{M}_o = \Sigma \bar{r} \times \bar{F}$$

Ex:



$$\bar{M} = 0\hat{i} + 300\hat{j} + 400\hat{k}$$

Resultent Moment

$$\bar{M}_{oF_1} = -600\hat{i} + 300\hat{j} + 0\hat{k} = \begin{array}{ccc} + & - & + \\ \hat{i} & \hat{j} & \hat{k} \end{array} \begin{vmatrix} 3 & 6 & -2 \\ 0 & 0 & -100 \end{vmatrix}$$

$$\bar{M}_{oF_2} = \begin{array}{ccc} + & - & + \\ \hat{i} & \hat{j} & \hat{k} \end{array} \begin{vmatrix} 3 & 6 & 0 \\ 100 & -200 & 300 \end{vmatrix} = 1800\hat{i} - 900\hat{j} - 1200\hat{k}$$

$$\bar{M}_{oR} = +1200\,\hat{i} - 300\,\hat{j} - 800\,\hat{k}$$

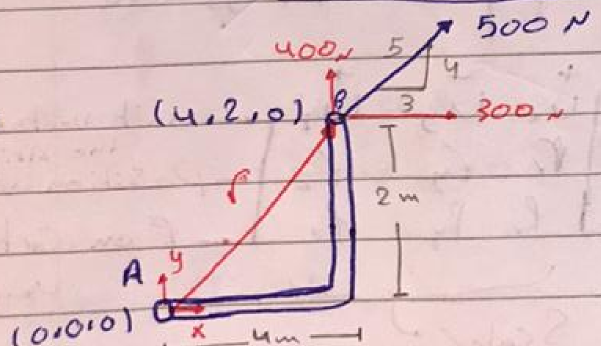
$$|M_{oR}| = \sqrt{1200^2 + 300^2 + 800^2} = 1529.7 \text{ N.m}$$

$$\cos\alpha = \frac{1200}{1529.7}$$

$$\cos\beta = \frac{-300}{1529.7}$$

$$\cos\gamma = -\frac{800}{1529.7}$$

Ex :



M_A ?

$$r_{AB} = 4\,\hat{i} + 2\,\hat{j} + 0\,\hat{k}$$

$$F = 300\,\hat{i} + 400\,\hat{j} + 0\,\hat{k}$$

$$\begin{array}{c} + \quad - \quad + \end{array}$$

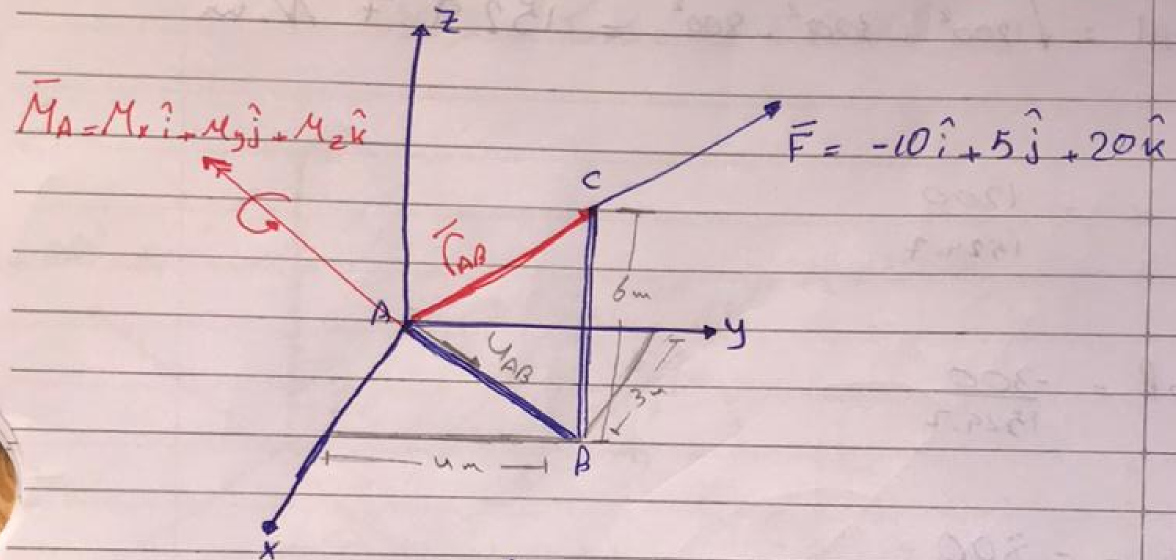
$$M_A = \begin{vmatrix} i & j & k \\ 4 & 2 & 0 \\ 300 & 400 & 0 \end{vmatrix}$$

$$M_A = 0\,\hat{i} + 0\,\hat{j} + 4 \cdot 400 - 300 \cdot 2\,\hat{k}$$

$$\sum M_A = 1000 \text{ N.m } (+)$$

التاريخ / /　　　　الموضوع

4.5 Moment of a Force about a Specific Axis (Line)



$$\bar{M}_A = \bar{r}_{AC} \times \bar{F} = \begin{vmatrix} \overset{+}{i} & \overset{-}{j} & \overset{+}{k} \\ r_x & r_y & r_z \\ f_x & f_y & f_z \end{vmatrix} = M_x\hat{i} + M_y\hat{j} + M\hat{k}$$

$$|M_{\parallel AB}| = M_A \cdot \bar{U}_{AB} = \underbrace{\begin{vmatrix} \overset{+}{u_x} & \overset{-}{u_y} & \overset{+}{u_z} \\ r_x & r_y & r_z \\ f_x & f_y & f_z \end{vmatrix}}_{\text{Scalar}}$$

← Unit vector of the Axis
← Position vector
← F on Cartesian Vector

- $\bar{M}_{\perp AB} = \bar{M}_A - \bar{M}_{\parallel AB}$
- $\bar{M}_{\parallel AB} = |M_{\parallel AB}| \cdot \bar{U}_{AB}$
- $|M_{\perp AB}| = \sqrt{M_A^2 - M_{\parallel AB}^2}$

التاريخ / /

الموضوع

$F = -10\hat{i} + 5\hat{j} + 20\hat{k}$

$\bar{r}_{AC} = 3\hat{i} + 4\hat{j} + 6\hat{k}$

$$M_A = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 3 & 4 & 6 \\ -10 & 5 & 20 \end{vmatrix} = -50\hat{i} - 120\hat{j} + 55\hat{k}$$

$|M_A| = \sqrt{50^2 + 120^2 + 55^2} = 141.1 \ N.m$

$$\bar{u}_{AB} = \frac{3\hat{i} + 4\hat{j} + 0\hat{k}}{\sqrt{3^2 + 4^2 + 0^2}} = 0.6\hat{i} + 0.8\hat{j} + 0\hat{k}$$

$$|M_{\parallel AB}| = \begin{vmatrix} 0.6 & 0.8 & 0 \\ 3 & 4 & 6 \\ -10 & 5 & 20 \end{vmatrix} = 0.6(4\times20 - 5\times6) - 0.8(3\times20 + 10\times6) + 0(3\times5 + 40)$$

$= -66 \ N.m$

$\bar{M}_{\parallel AB} = -66(0.6\hat{i} + 0.8\hat{j} + 0\hat{k})$

$= -39.6\hat{i} - 52.8\hat{j} + 0\hat{k}$

$M_{\perp AB} = \bar{M}_A - \bar{M}_{\parallel AB}$

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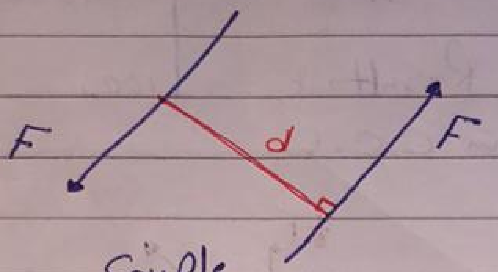
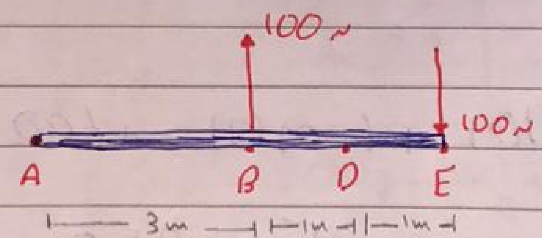
4.6 Moment of Couple : free vector

$M = F d_{\perp}$



2-D

$\Sigma F = 0$



$\circlearrowleft + \ \Sigma M_A = (100)(3) - (100)(5) = -200 \ N.m$

$\circlearrowleft + \ \Sigma M_B = -(100)(2) = -200 \ N.m$

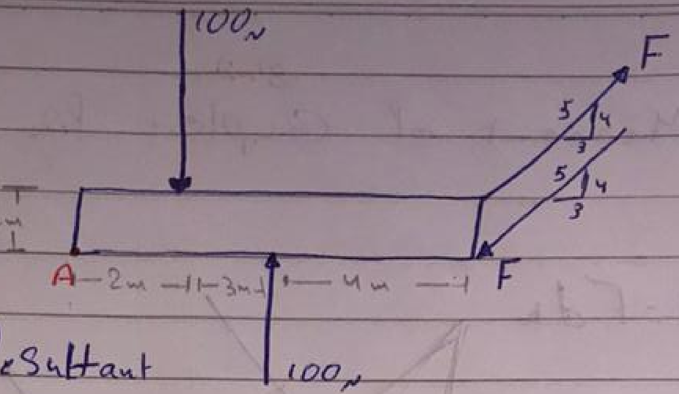
$\circlearrowleft + \ \Sigma M_D = -(100)(1) - (100)(1) = -200$

$\circlearrowleft + \ \Sigma M_E = -(100)(2) = -200 \ N.m$

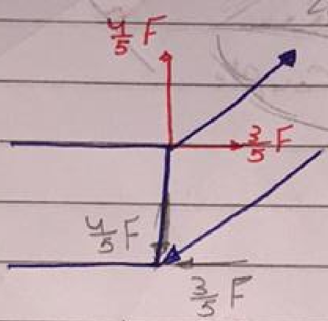
$M = F d_{\perp} = 100 \cdot 2$

↳ Distance between the Two force

Ex:



→ Find F = ? if the Resultant Moment = 600 N.m C.C.W.



$$\overset{+}{\circlearrowleft} \Sigma M = -\frac{3}{5}(F)(2) + (100)(3) = +600$$

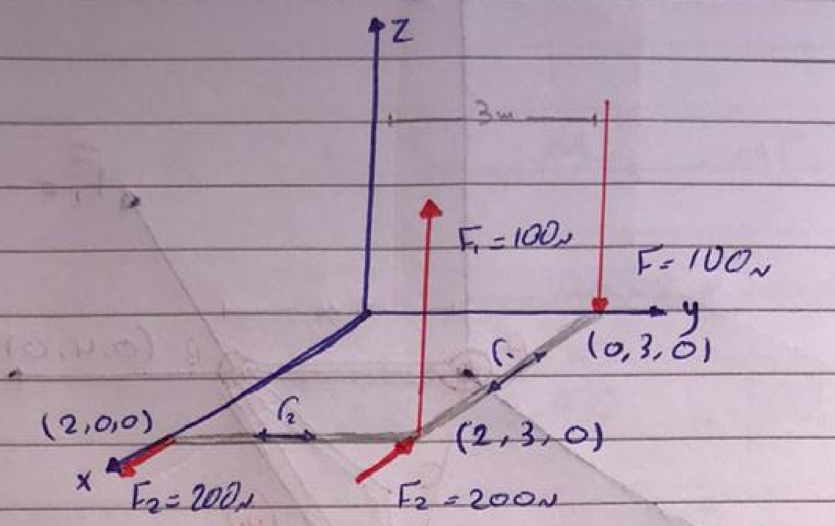
$$\therefore F = -250 \text{ N}$$

another sol: $\overset{+}{\circlearrowleft} \Sigma M_A = -(100)(2) + (100)(5) - (\frac{4}{5}F)(9) - (\frac{4}{5}F)(9) = 600$

$$F = -250 \text{ N}$$

الموضوع التاريخ / /

Ex:



- Find the Resultant Moment ?

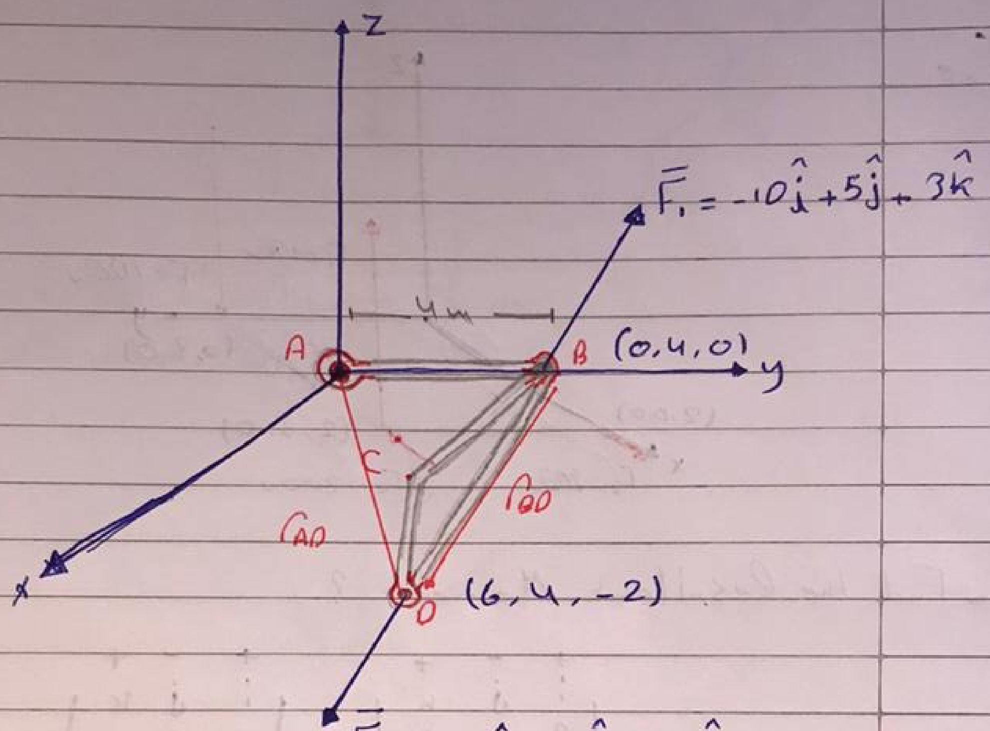
$$\Sigma M = \begin{array}{c} \begin{matrix} + & - & + \end{matrix} \\ \begin{vmatrix} i & j & k \\ 2 & 0 & 0 \\ 0 & 0 & 100 \end{vmatrix} \end{array} + \begin{array}{c} \begin{matrix} + & - & + \end{matrix} \\ \begin{vmatrix} i & j & k \\ 0 & 3 & 0 \\ -200 & 0 & 0 \end{vmatrix} \end{array}$$

$$= (0\hat{i} - 200\hat{j} + 0k) + (0\hat{i} + 0\hat{j} + -600\hat{k})$$

$$= -200\hat{j} - 600\hat{k}$$

7

Ex:



$\bar{F}_1 = 10\hat{i} - 5\hat{j} - 3\hat{k}$

$$\bar{M}_B = \begin{array}{c} \begin{matrix} + & - & + \end{matrix} \\ \begin{vmatrix} i & j & k \\ 6 & 0 & -2 \\ 10 & -5 & -3 \end{vmatrix} \end{array} = \bar{M}_A = \begin{array}{c} \begin{matrix} + & - & + \end{matrix} \\ \begin{vmatrix} i & j & k \\ -6 & 0 & 2 \\ -10 & 5 & 3 \end{vmatrix} \end{array}$$

$$\rightarrow \quad \sum \bar{M}_A = \bar{r}_{AB} \times \bar{F}_1 + \bar{r}_{AB} \times \bar{F}_2$$

$$= \begin{array}{c} \begin{matrix} + & - & + \end{matrix} \\ \begin{vmatrix} i & j & k \\ 0 & 4 & 0 \\ -10 & 5 & 3 \end{vmatrix} \end{array} + \begin{array}{c} \begin{matrix} + & - & + \end{matrix} \\ \begin{vmatrix} i & j & k \\ 6 & 4 & -2 \\ 10 & -5 & -3 \end{vmatrix} \end{array}$$

التاريخ / /

الموضوع

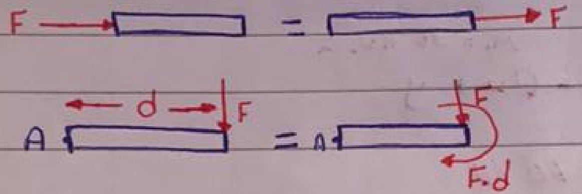
$$\# M_R = \Sigma M = 60 + M_{F_y} + M_{F_x}$$

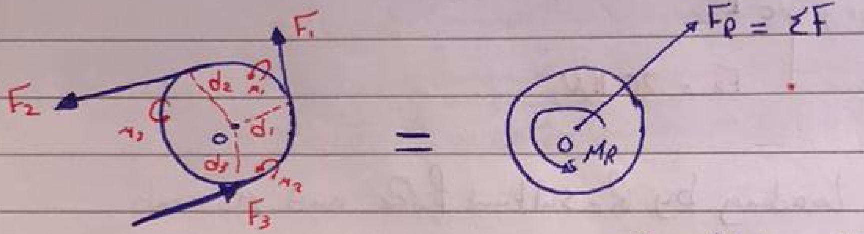
$$+ 40 \times 2 + 20 \cdot 4$$

$$+ \cancel{60} \; \cancel{-80}^{\,-20} \; - 80$$

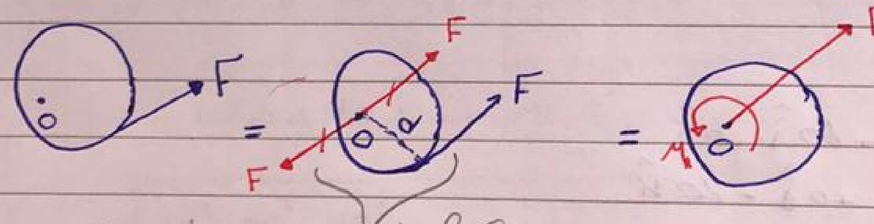
$$-100 \text{ kN.m}$$

4.7 Simplification of a Force and Couple System.

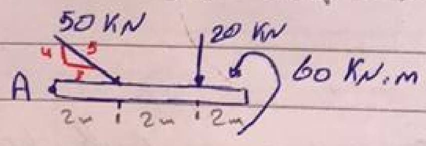




$M_R = \Sigma M + \Sigma F \cdot d$



Moment ضبط Couple force هدول



Ex :

→ Replace the Loading by Resultant Force and Moment of A :

F_R :-

$\overset{+}{\rightarrow} \Sigma F_x = 30\,KN \rightarrow$

$\Sigma F_y = -40 - 20 = -60\,KN \downarrow$

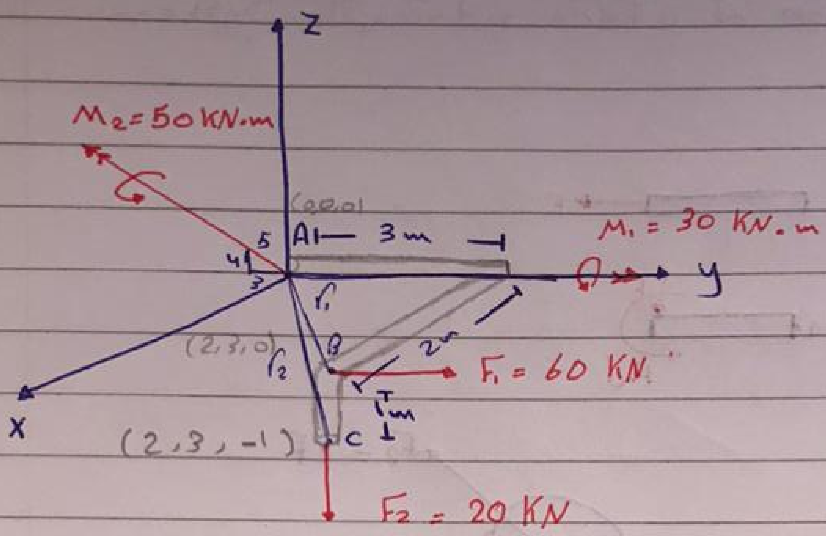
$M_R = \Sigma M_A = -40 \cdot 2 - 20 \cdot 4 + 60$

$= -100\,KN.m$

$F_R = \sqrt{30^2 + 60^2}$ $\quad \tan\theta^\circ = \frac{60}{30} = \theta = \_\_\_\_\_ \,^\circ$

الموضوع التاريخ / /

Ex :



→ Replace the Loading by Resultant force and Moment of A.

$\overline{F_R}$:-

$\overline{F_1} = 0\hat{i} + 60\hat{j} + 0\hat{k}$

$F_2 = 0\hat{i} + 0\hat{j} - 20\hat{k}$

$\overline{F_R} = 0\hat{i} + 60\hat{j} - 20\hat{k}$

$|F_R| = \sqrt{60^2 + 20^2} = 63.25$, $\cos\alpha = \frac{0}{63.25}$, $\cos\beta = \frac{60}{63.25}$

$\cos\gamma = \frac{-20}{63.25}$

الموضوع   التاريخ / /

$\bar{M}_R = \Sigma M_A + \Sigma \bar{r} \times \bar{F}$

$\bar{M}_1 = 0\hat{i} + 30\hat{j} + 0\hat{k}$

$M_2 = 30\hat{i} + 0\hat{j} + 40\hat{k}$

$\bar{M}F_1 = \bar{r}_1 \times \bar{F}_1$

$$\hookrightarrow \begin{array}{ccc} \overset{+}{\hat{i}} & \overset{-}{\vec{j}} & \overset{+}{k} \end{array} \begin{vmatrix} 2 & 3 & 0 \\ 0 & 60 & 0 \end{vmatrix} = 0\hat{i} + 0\hat{j} + 120\hat{k}$$

$$\bar{M}_{F_2} = \bar{r}_2 \times \bar{F} = \begin{array}{ccc} \overset{+}{i} & \overset{-}{j} & \hat{k} \end{array} \begin{vmatrix} 2 & 3 & -1 \\ 0 & \cancel{60} & -20 \end{vmatrix} = -60\hat{i} + 30 \times 2\hat{j} + 0\hat{k}$$

$\bar{M}R = \Sigma M_x \hat{i} + \Sigma M_y \hat{j} + \Sigma M_z \hat{k}$

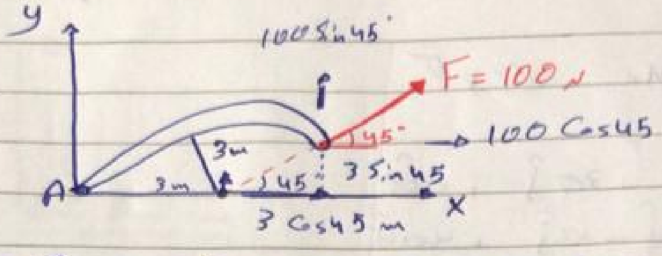
$\bar{M}_R = -30\hat{i} + 90\hat{j} + 180\hat{k}$

$|M_R| = \sqrt{30^2 + 90^2 + 160^2}$

$\cos\alpha = \dfrac{M_x}{|M_R|}$ ------

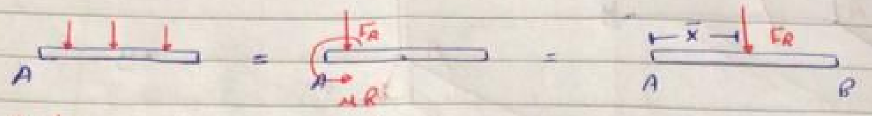
الموضوع ١   التاريخ / /

Ex:



$$\circlearrowleft \; \sum M_A = (100 \sin 45)(3 + 3\cos 45) - (100 \cos 45)(3 \sin 45)$$
$$= 212.1 \text{ N.m}$$

4.8 Further Simplification of a Force and Couple System

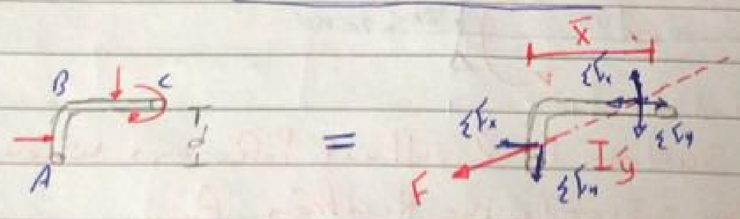


→ Replace the Loading by Resultant Force and Moment at A

$$\bar{x} = \frac{M_R}{F_R}$$

→ Replace the Loading by Resultant Force and where its line of action intersects the Beam force A

$$M_R = \bar{x} F_R$$

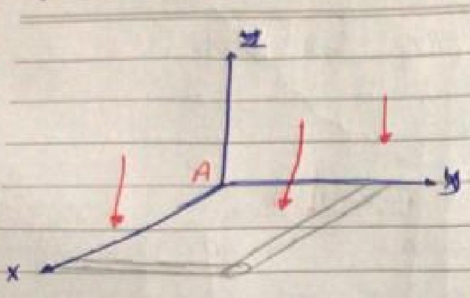


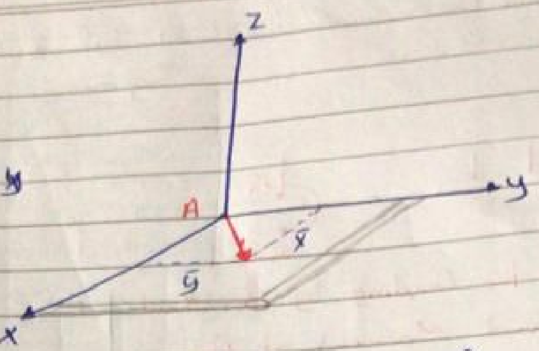
$\bar{y}$ → Put F_R on AB

$$\Sigma M_A = (\Sigma F_x)\bar{y}$$

From $\bar{x}$ → Put F_R on BC

$$\Sigma M_A = (\Sigma F_x)(L) - (\Sigma F_y)\bar{x}$$





$\bar{F_R} = \Sigma \bar{F}$

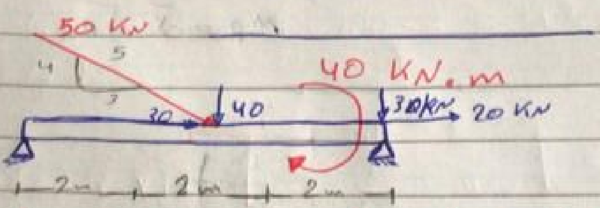
$\bar{r} = \bar{x}\hat{i} + \bar{y} + 0\hat{k}$

$\Sigma M_A = \Sigma \bar{r} \times \bar{F}$

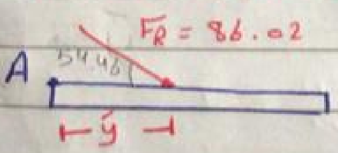
$M_A \Rightarrow \bar{r} \times \bar{F}$

$\Sigma M_A = M_x \hat{i} + M_y \hat{j} + M_z \hat{k}$

Ex:



• Replace Loading System by Resultant Force and when its lies of action intesects the Read from A

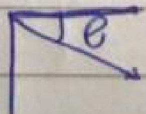


$\Sigma F_x = 30 + 20 = 50 \text{ kN} \rightarrow$

$\Sigma F_y = -40 - 30 = -70 \downarrow$

$F_R = \sqrt{(50)^2 + (70)^2} = 86.02 \text{ kN}$

$\tan\theta = \frac{70}{50} \rightarrow \theta = 54.46^\circ$



التاريخ / /　　　　الموضوع

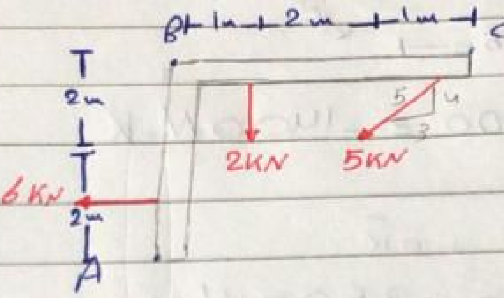
$M_A = \circlearrowleft + \sum M_A = -(40 \cdot 2) - 40 - (30 \cdot 6)$

$= -300$ KN.m

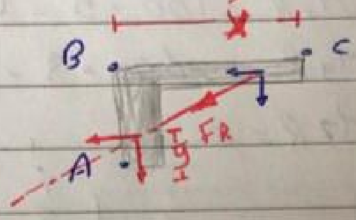
$-300 = -40\bar{X}$

$\bar{X} = \frac{30}{4}$ m

Ex:

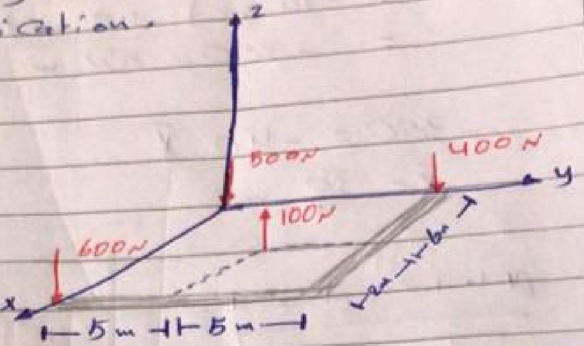


Replace the Loading by resultant force and where it's line of AB and BC from A.



$\Sigma F_x = 30$

Ex = Replace the loading by resultant force and find its point of application.



$\Sigma \bar{F} = -600 - 500 - 400 + 100 = -1400 \, N \cdot K$

$\to M_{AR} = -3500\hat{i} + 4200\hat{j} + 0\hat{k}$

$M_x R = 100 \cdot 5 - 400 \cdot 10 = -3500 \, N \cdot m$

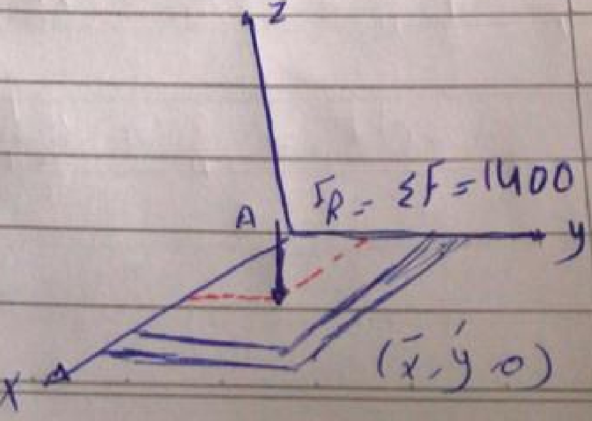
$M_y R = 600 \cdot 8 - 100 \cdot 6 = 4200 \, N \cdot m$

$M_z R = 0$

$$M_A = \bar{r} \times \bar{F} = \begin{vmatrix} \overset{+}{i} & \overset{-}{j} & \overset{+}{k} \\ \bar{x} & \bar{y} & 0 \\ 0 & 0 & -1400 \end{vmatrix} = -1400\bar{y}\hat{i} + 1400\bar{x}\hat{j} +$$

$-3500 = -1400\bar{y} \qquad \therefore \bar{y} = \frac{35}{14} \, m$

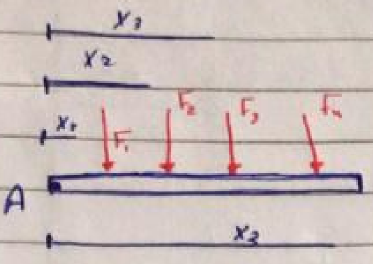
$4200 = 1400\bar{x} \qquad \therefore \bar{x} = \frac{42}{14} \, m$

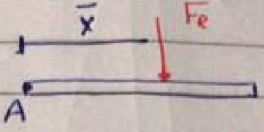


التاريخ / /

الموضوع :

4.9 Reductio of Distributed Load

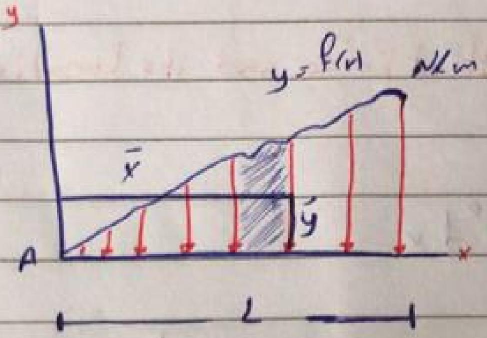


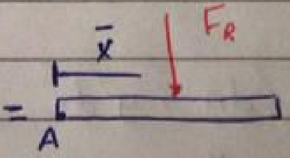


$$F_R = \sum F_i$$

$$\sum F_i x_i = \bar{x} F_e$$

$$\bar{x} = \frac{\sum F_i x_i}{\sum F_i}$$





$$dA = y\,dx = f(x)\,dx$$

$$F_R = \int_0^L dA = \boxed{\int_0^L f(x)\,dx}$$

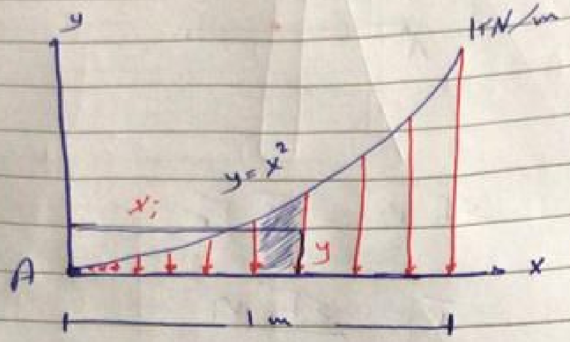
$$\int_0^L x_i f(x)\,dx = \bar{x} \int_0^L f(x)\,dx$$

الموضوع 7

التاريخ / /

$$\bar{x} = \frac{\int_0^1 x_i \, f_{(x)} \, dx}{\int_0^1 f_{(x)} \, dx}$$

Ex:



→ Determine the equivalent resultant force and its location from A.

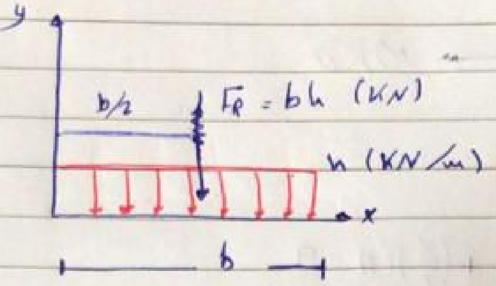
$$dA = y\,dx = x^2 dx$$

$$x_i = x$$

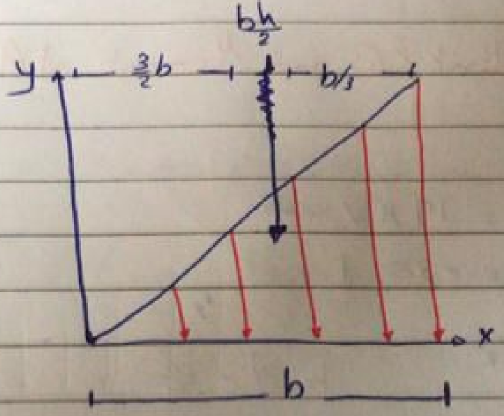
$$F_R = \int dA = \int_0^1 x^2 \, dx = \frac{x^3}{3}\Big]_0^1 = \frac{1}{3} \text{ kN}$$

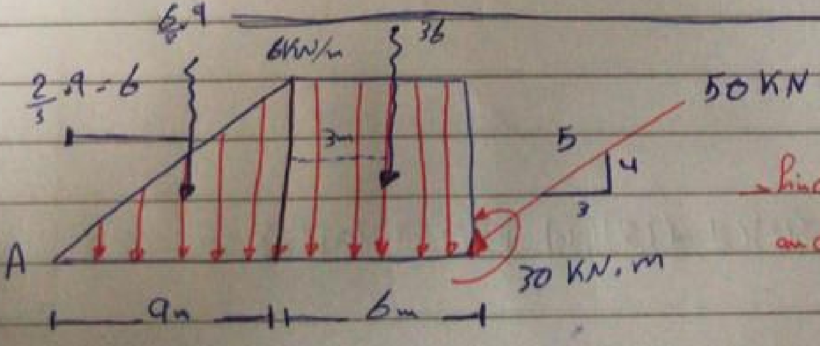
$$\int x_i \, dA = \int_0^1 x \, x^2 \, dx = \int_0^1 x^3 = \frac{x^4}{4}\Big]_0^1 = \frac{1}{4}$$

$$\bar{x} = \frac{\int x \, dA}{\int dA} = \frac{1/4}{1/3} = \frac{3}{4} = .75 \text{ m}$$



→ Uniform Distributed load.





→ Find the Resultant force and Moment at A.

F_R $\quad \Sigma F_x = 30 \leftarrow$

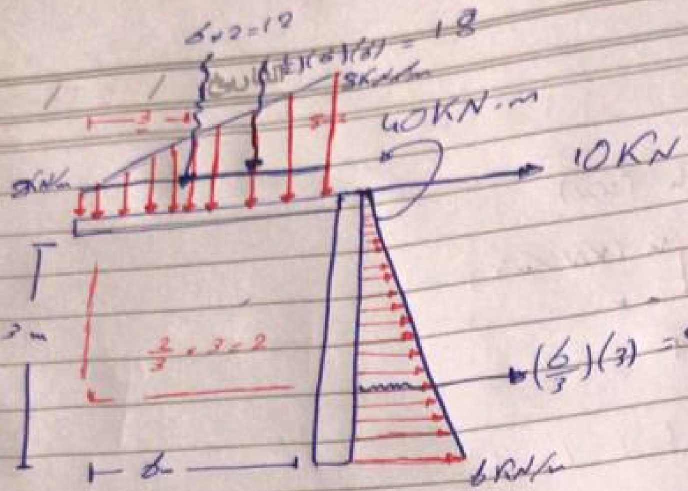
$\Sigma F_y = -27 - 36 - 40$

$F_R \sqrt{\;\;}$ "

$\tan\theta = \frac{\Sigma F_y}{\Sigma F_x}$

M_R

$\Sigma M_A = -(27)(6) - (36)(12) - (40)(15)$



→ Find the Resultant Force and Moment at A

F_R

$\Sigma F_x = 9 + 10 = 19\ KN \rightarrow$

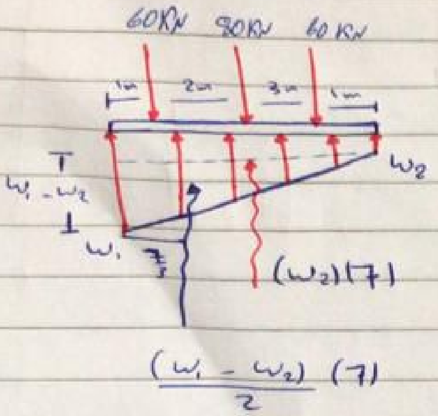
$\Sigma F_y = -12 - 18 = -30 \downarrow$

$F_R = \sqrt{19^2 + 30^2}$, $\tan\theta = \frac{30}{19}$

M_R

$\Sigma M_A = -(12)(3) - (18)(4) + 40 + (9)(2) =$

Ex :



→ Find w_1, w_2?

$\Sigma F_y = 0$

$$60 + 90 + 60 = (w_2)(7) + \frac{(w_1 - w_2)(7)}{2} \quad \ldots\ldots (1)$$

$$\circlearrowleft + \ \Sigma M = 0 \quad (60)(1) + (90)(3) + (60)(6) = (7w_2)(3.5) + \left(\frac{w_1 + w_2}{2}\right)7 \cdot \frac{7}{3}$$

(2)

← معادلتين بمجهولين اطلب بحلك كمل كالك

Ch 5 : Equilibrium of Rigid Body

2-P

5.1 Condition of equilibrium :

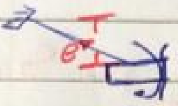
$\sum F_x = 0$

$\sum F_y = 0$

$\sum M = 0$

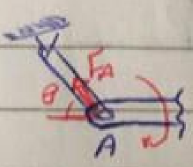
5.2 Free Body Diagram ⇒ Type of supports ⇒ Support Reaction

1. Cable (T)



→ one unknown

2. link (T or C)



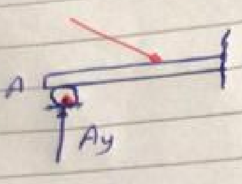
→ one unknown

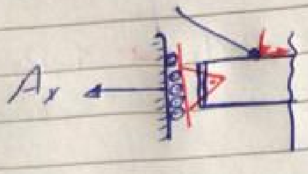
التاريخ / /

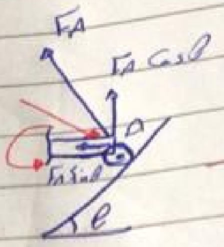
الموضوع 12

3. Roller (⊥ on the Surface)

→ 1 unknown

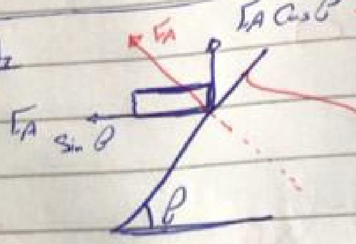






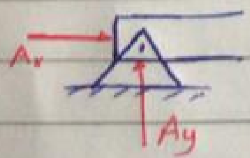
the Same

4. Smooth Surface ⊥



→ Smooth

5. Pin (Hing)



→ 2 unknowns

$F_A = \sqrt{A_x^2 + A_y^2}$

$\tan\theta = \frac{A_y}{A_x}$