محاضرة / -1-
التاريخ /

الكورس الاول
السعـر /

Engineering Mechanics

الميكانيك الهندسي

لطلبة الدراسات الاولية

المرحلة الاولى
قسم الهندسة الموارد المائية

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2018 - 2019

Al-Mustansiriyah University
College of Engineering
Water Resources Dept.
Engineering Mechanics Lect.

التاريخ: 8-11-2018

مدرس المادة: د. ختام عبد الحسين سعيد
Lecturer: Dr. Khitam

1. INTRODUCTION

First we define (Mechanics)

Mechanics: is that branch of physical science which considers the motion of bodies.

- In engineering mechanic attention is directed primarily with external effects of a system of forces acting on a rigid body.

- can be defined (the force) as the action of one body on another body which charges or tends to change the motion of the body acted on.

2. Force Vectors

2.1 Scalars and vectors Quantities

Saclar: is a quantity that characterized by a positive or negative number. For example: mass, length

Vector: is a quantity that has both magnitude and direction
For example; force, velocity

- A vector is represented graphically by an arrow. the length of arrow represent the magnitude, and the angle between the arrow line of action and a reference axis represents the direction.

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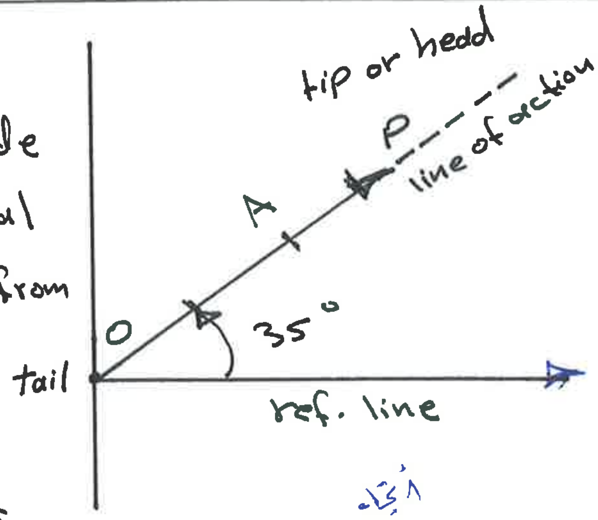
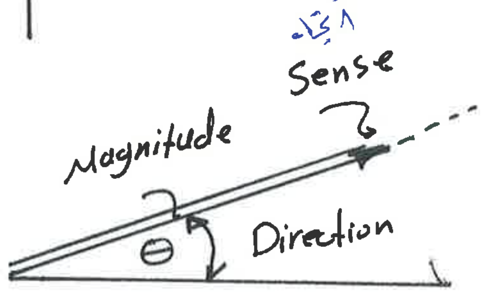
From the fig. shown:



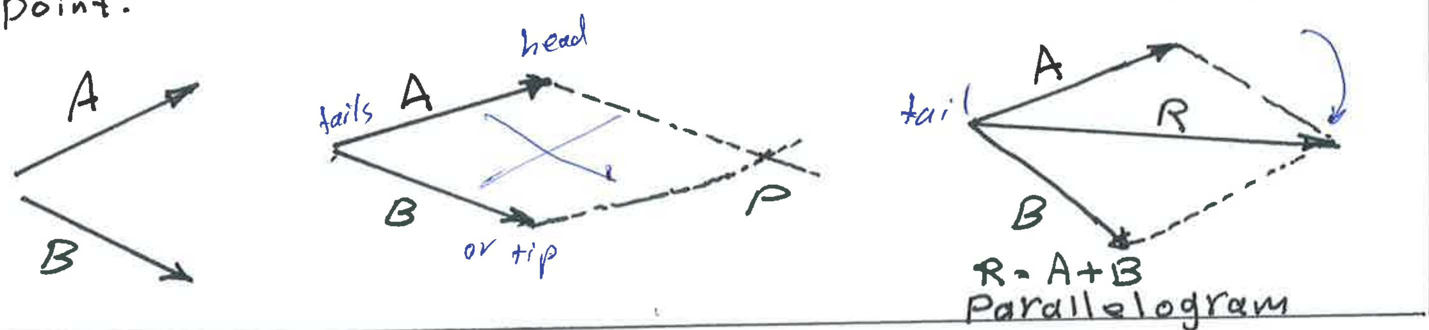
The vector (A) has a magnitude of (3) units and a direction equal (35°) measured counterclockwise from the reference line (horizontal here)

point (O) called tail (ذيل) and point (P) called tip (رأس) (or head)



Vector addition :-

- If we have a two vectors A and B. These two vectors can be added to form a resultant vector $R = A + B$ by using the parallelogram (متوازي اضلاع) law.
- To do this A and B are joined together by their tails. Parallel lines drawn from the head of each vector intersect at a common point to form a parallelogram.
- The resultant R is the diagonal of the parallelogram which extends from the tail of A & B to the intersection point.



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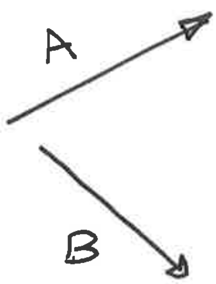
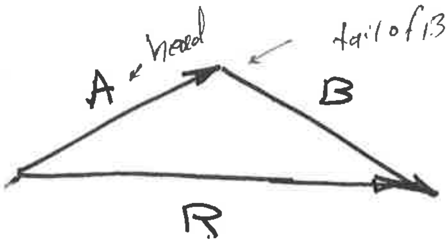
- we can also added B to A using the triangle construction which a special case of parallelogram law.
- connect the head of A to the tail of B. The resultant extends from the tail of A to the head of B

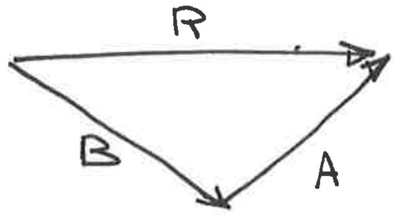
Or, head of A to tail of B





$R = A + B$

Triangle rule



$R = B + A$

Triangle rule

As a special case, if A & B are collinear (على خط واحد / كولينير) (the both have the same line of action), R determined by scalar addition.

$R = A + B$

(Addition of collinear Vectors)

3- Force system :-

is a number of forces acting in a given situation and can be classified according to the arrangement of the lines of action of the forces on the system such as:

the force may be:

in the same plant
- Coplanar or non-Coplanar متحد المستوى
- Concurrent or non. Concurrent متقاطع او متلاقية كونكرنت
- parallel or non. parallel
- Collinear or non. Collinear

3.1 The Resultant of a force system:

- force system which can replace the original system without changing its external effect on a rigid body.

- if the force system acting on a body has resultant equal to zero, the body is in equilibrium and the problem is one of statics

- when the resultant is different from zero, the problem is one of dynamics

- It can describe the effect of force external on a rigid body as:

1. Its magnitude مقدارها
2. its direction (sense and slope) الميل
3. its location of any point on its line of action

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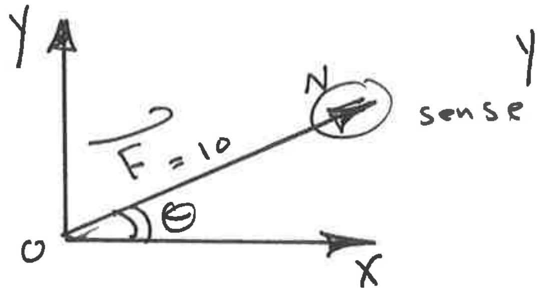
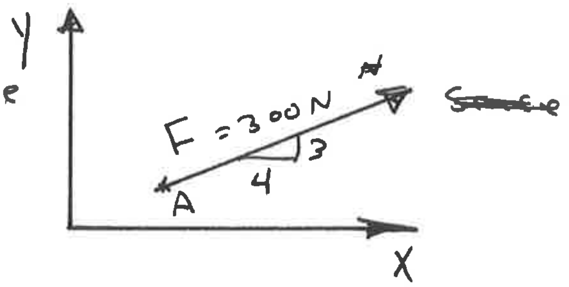




$|F|$ = magnitude
θ = slope
O = point of application

3-2 Composition and Resolution of forces :-

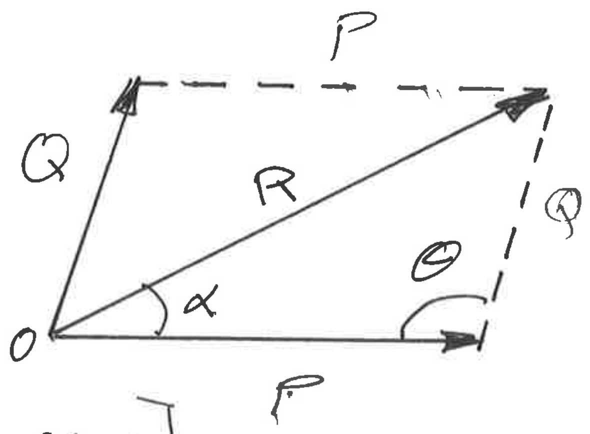
التركيب او تحليل

Composition :- is the process of replacing a force system by its resultant.

- The resultant of the two concurrent forces, ex: (P and Q) can be determined by means of the parallelogram Law.

$$R = (P^2 + Q^2 - 2PQ\cos\theta)^{1/2}$$

[cosine Law] زوايا المقابلة للمحصلة



The value of α can be determined as follows

$$\frac{\sin\alpha}{Q} = \frac{\sin\theta}{R} \quad \text{[the law of sines]}$$

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3.3 Resolution

تحليل

is the process of replacing a force by its components.

3.3.1 Resolving a force along rectangular components

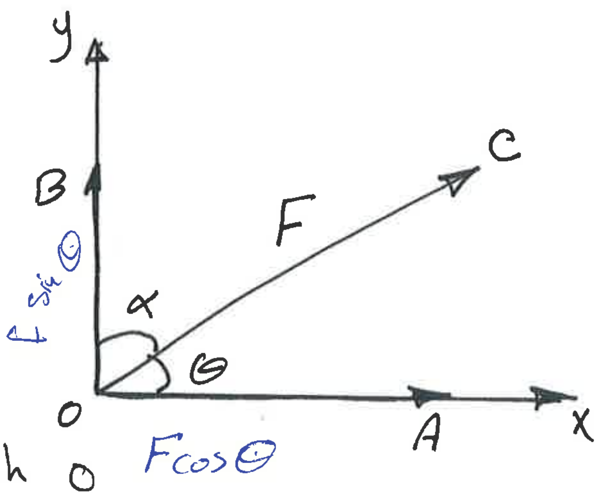
* For most purposes, rectangular which is perpendicular components of a force are more useful.

Ex:- $F_x = OA = F\cos\theta = (\frac{4}{5})F$

$F_x = 0.8F$ to the right through o

$F_y = OB = F\sin\theta = (\frac{3}{5})F$

$F_y = 0.6F$ upward through o



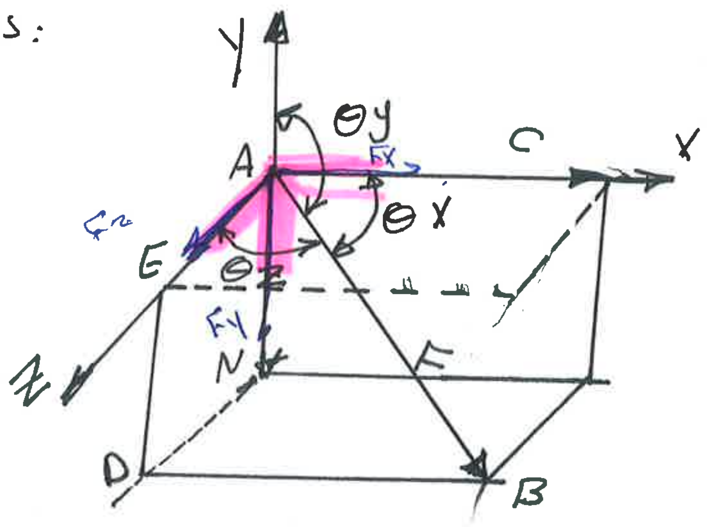
* While for a force in space (3 dimension), the resolution is as follows:

$F_x = AC = F\cos\theta_x$

$F_y = AN = F\cos\theta_y$

$F_z = AE = F\cos\theta_z$

the cosines of the angles θ_x, θ_y and θ_z are called direction cosines.



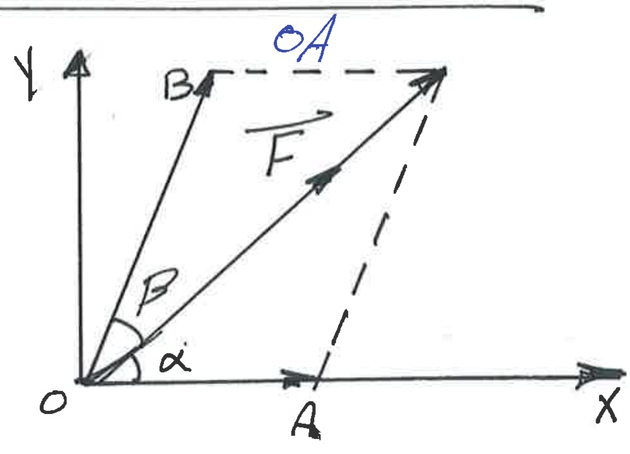
Notes:- * if the angle is grater than 90° the cosine is negative and the sense of the component is opposite the (+ve) direction of the axis $\theta_y > 90°$

* the three components always intersect at apoint on the line of action of the resultant force.

3.3.2 Resolving aforce along non-rectangular components

① by graphically

② by using law of sines



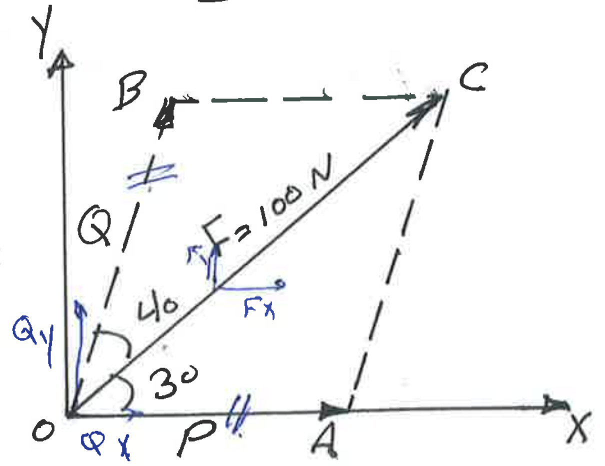
$$\frac{OA}{\sin\beta} = \frac{F}{\sin(180-\alpha-\beta)}$$

Ex:- Resolve the 100N force along OA and OB

① $\frac{P(OA)}{\sin 40} = \frac{100}{\sin(180-30-40)}$

$\therefore P = 100 \frac{\sin 40}{\sin 110} = 100 \times \frac{0.6427}{0.9396}$

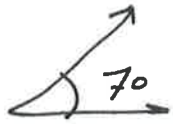
$P = 68.4 N \longrightarrow$ through O.



$$\frac{Q\ (OB)}{\sin 30} = \frac{100}{\sin(110)}$$

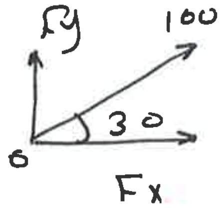
$\sin(180-30-40)$

$$\therefore Q = \frac{0.5 * 100}{0.9396} = 53.2\ N$$



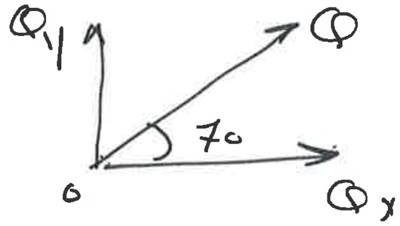
② $F_x = 100 \cos 30 = 86.6\ N \rightarrow$ through O

$F_y = 100 \sin 30 = 50\ N \uparrow$ " "



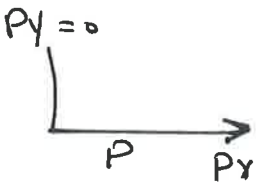
$Q_x = Q \cos 70 \rightarrow$

$Q_y = Q \sin 70 \uparrow$



$P_x = P = 68.4\ N$

$P_y = F_y = 50$



$F_y = Q \sin(40+30)$

$50 = Q \sin 70 \longrightarrow Q = \frac{50}{\sin 70} = 53.2\ N$

$F_x = Q \cos 70 + P$

$86.6 = 53.2 \cos 70 + P$

$\therefore P = 68.4\ N \longrightarrow$

or $100 \cos 30 = OA + OB \cos 70$

$\therefore OA = 86.6 - 0.342\, OB$

$OB \sin 70 = 100 \sin 30$

$\therefore OB = \frac{50}{0.939} = 53.2\ N$

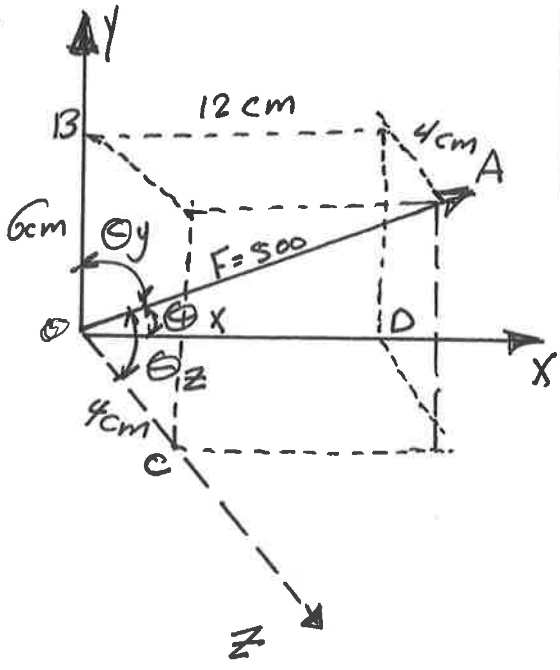
or $\overrightarrow{OB} = \overrightarrow{53.2}\ N$ through O.

$OA = 86.6 - 0.342 * 53.2$
$= 68.4\ N$

or $\overrightarrow{OA} = \overrightarrow{68.4}\ N$ through O

* For three dimensions a force can be resolved in either of the following methods:

Ex: 2 Resolve the 500 N force into its rectangular components.



① use direction Cosines

length of $OA = \sqrt{4^2+6^2+12^2}$
$= 14\ cm$

$\cos \Theta_x = \frac{12}{14}$

$\cos \Theta_y = \frac{6}{14}$

$\cos \Theta_z = \frac{4}{14}$

$F_x = F\cos\theta_x$

$F_x = \frac{12}{14} * \overrightarrow{500i} \Longrightarrow 428.5\,\overrightarrow{i}$

$F_z = \frac{4}{14} * \overrightarrow{500k} \longrightarrow 142.9 \searrow$

$F_y = \frac{6}{14} * 500j \longrightarrow 214.3 \uparrow$

$\overrightarrow{F} = 500\left(\frac{12}{14}\overrightarrow{i} + \frac{6}{14}\overrightarrow{j} + \frac{4}{14}\overrightarrow{k}\right)$

③ use scale factor

long of OA $= \sqrt{4^2+6^2+12^2} = 14$

the scale of R is

$\frac{500}{14} = 35.7\ N/cm$

$F_x = \frac{500}{14} * 12 \longrightarrow$ through O $= 428.5N$

$F_y = \frac{500}{14} * 6 \uparrow$ through O $= 214.3N$

$F_z = \frac{500}{14} * 4 \searrow$ through O $= 142.9N$

$\overrightarrow{F_x} = \frac{500}{14} * \overrightarrow{12i} = \overrightarrow{428.5i}$

$\overrightarrow{F_y} = \frac{500}{14} * \overrightarrow{6j} = \overrightarrow{214.3j}$

$\overrightarrow{F_z} = \frac{500}{14} * \overrightarrow{4k} = \overrightarrow{142.9k}$

$\therefore \overrightarrow{F} = 428.5i + 241.3j + 142.9k$

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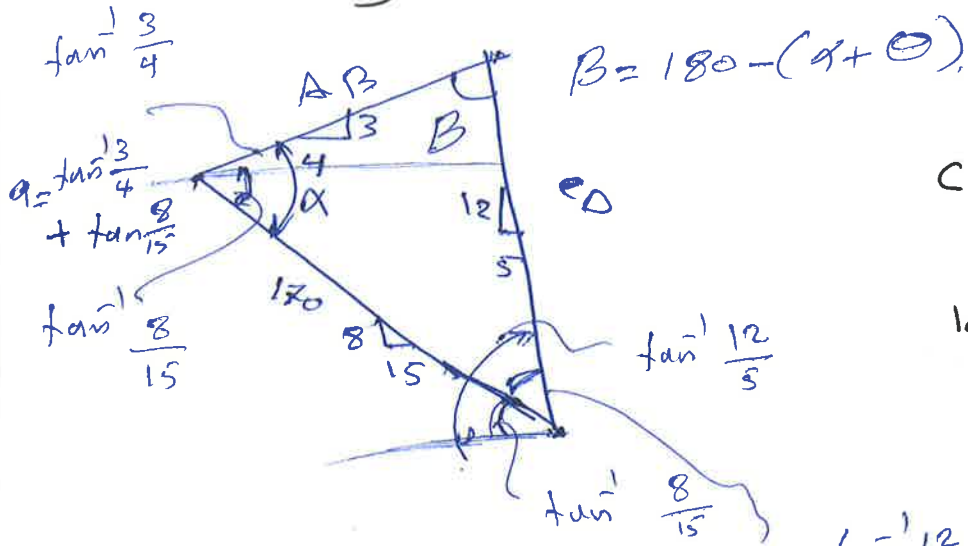
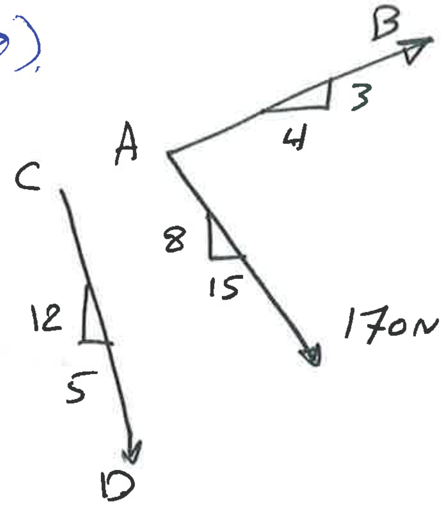
H.W Resolve 170 N force into two component one along AB and the other parallel to CD



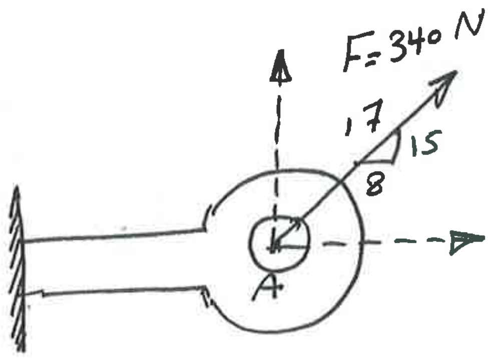
$B = 180 - (\alpha + \theta)$



$\theta = \tan^{-1}\frac{12}{5} - \tan^{-1}\frac{8}{15}$

The problems

1.1 Determine a pair of horizontal and vertical components.



Solu:

$F_h = 340 \times \frac{8}{17} = 160$ N to the right through A

$F_v = 340 \times \frac{15}{17} = 300$ N upward through A.

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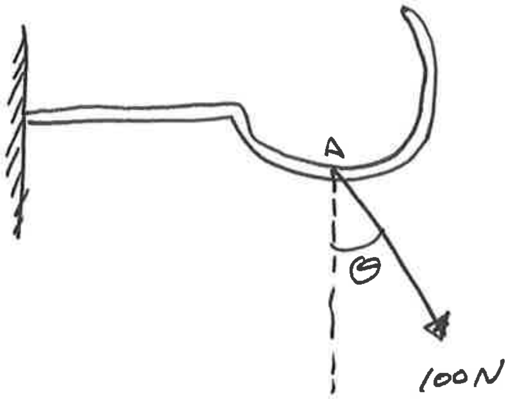
1-3 Resolve the 100 N force into horizontal and vertical components if the values of θ are as following: $\theta = 22^\circ$, $\theta = 132^\circ$

ⓐ for $\theta = 22^\circ$



$F_h = F \sin \theta$

$= 100 \sin(22^\circ) = 37.46\ N$ through A

$F_v = F \cos \theta$

$= 100 \cos 22^\circ$

$92.718\ N \downarrow$ through A

ⓑ for $\theta = 132^\circ$

$F_v = 100 \cos 132^\circ$

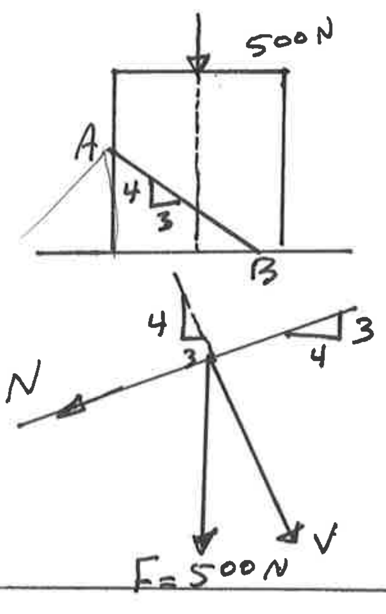
$= 100(-0.6691) = -66.91$

$= 66.91\ N$ upward through A

$F_h = 100 \sin \theta$

$= 100(0.7431) = 74.31\ N \longrightarrow$ through A.

1.4 Resolve the 500 N force into two components a vertical component parallel to AB and normal component perpendicular to AB



$V = F \cos \theta = 500 \times \frac{4}{5} = 400\ N \searrow$

$N = F \sin \theta = 500 \times \frac{3}{5} = 300\ N \swarrow$

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1-5 Resolve the force of fig. into two non-rectangular component, one along AB and the other horizontal.

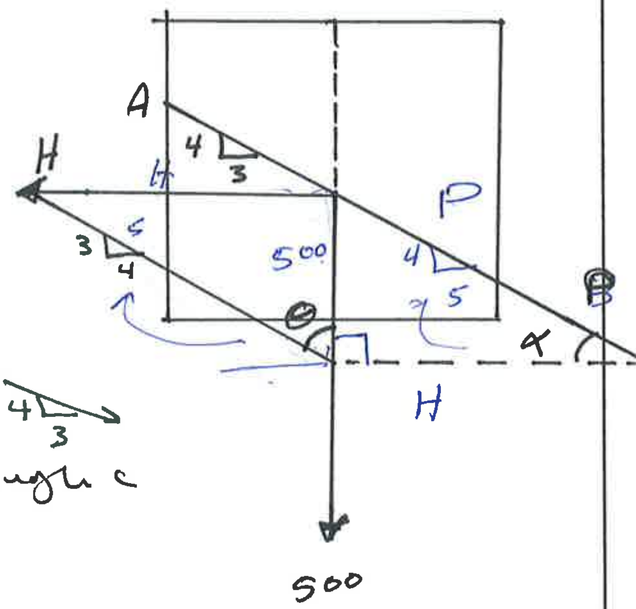
Solu:

$$\frac{H}{\sin\theta} = \frac{500}{\sin\alpha}$$

$$\frac{H}{\frac{3}{5}} = \frac{500}{\frac{4}{5}} \Longrightarrow \boxed{H = 375}$$

$$\frac{P}{\sin 90} = \frac{500}{\underbrace{\frac{4}{5}}_{\sin\alpha}} \Longrightarrow \boxed{P = 625}$$

through c



1.6 The horizontal component of the force F in fig. is 60N to the right through O. Determine the vertical component and the magnitude of F.

Solu:

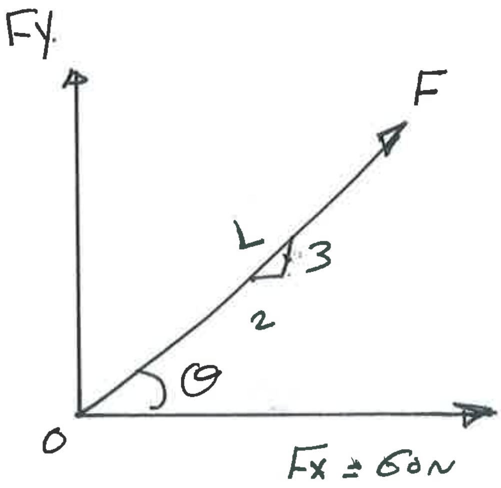
$$L = \sqrt{(3)^2 + (2)^2} = \sqrt{13}$$

$$F_x = F\cos\theta$$

$$60 = F * \frac{2}{\sqrt{13}} \Longrightarrow F = 108.17\ N$$

$$F_y = F\sin\theta$$

$$F_y = 108.17 * \frac{3}{\sqrt{13}} = 90\ N \uparrow$$ through O



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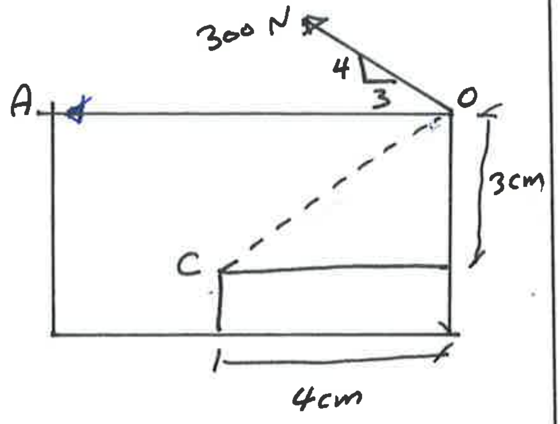
1.8 The 300 N force in fig. acts on the box B. Resolve this force into two components, one along AO and the other through point C.

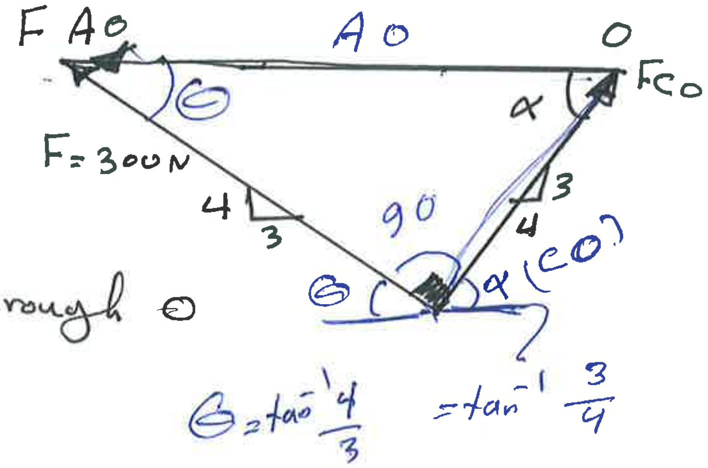


$$\theta = \tan^{-1}\frac{4}{3} = 53.13^\circ$$

$$\alpha = \tan^{-1}\frac{3}{4} = 36.869^\circ$$

$$\frac{F}{\sin\alpha} = \frac{F_{AO}}{\sin 90}$$

$$\frac{300}{\sin 36.869} = \frac{F_{AO}}{1}$$



$F_{AO} = 500\text{ N} \longleftarrow$ through O

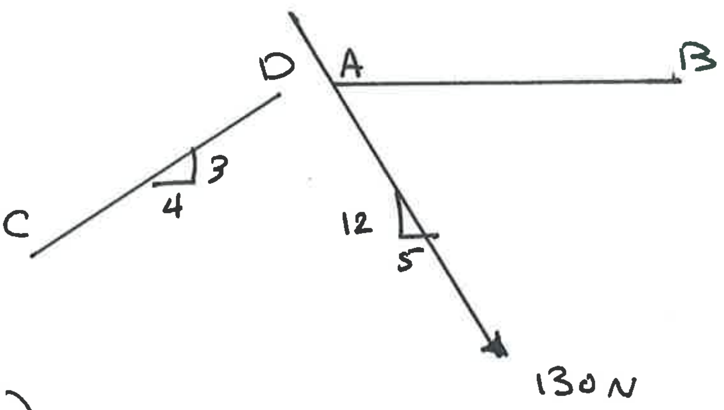
$$\frac{F}{\sin\alpha} = \frac{F_{CO}}{\sin\theta}$$

$$\frac{300}{\sin 36.869^\circ} = \frac{F_{CO}}{\sin 53.13}$$

$F_{CO} = 400\text{ N}$ ↗ (3, 4) through O.

1.9 Resolve the 130N force of fig. shown into two non-rectangular component one having a line of action along AB and the other parallel to CD

Solu :

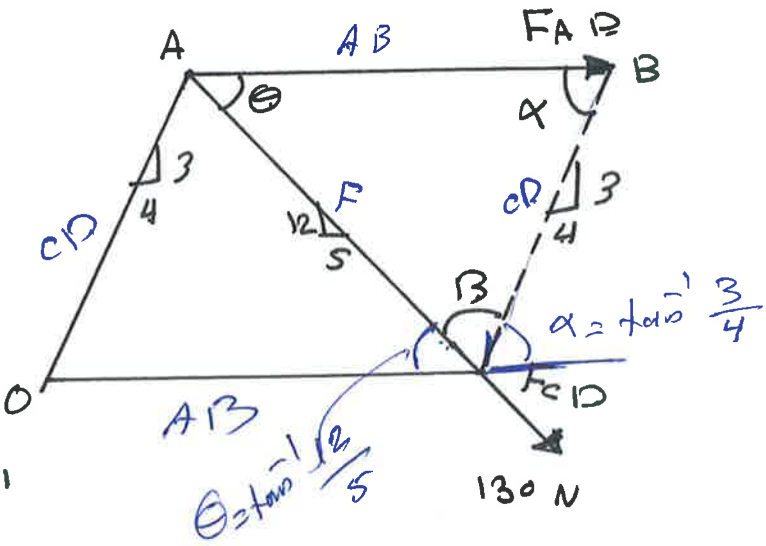


$\alpha = \tan^{-1}\frac{3}{4} = 36.869^\circ$

$\theta = \tan^{-1}\frac{12}{5} = 67.38^\circ$

$\beta = 180 - (36.869 + 67.38)$

$= 75.751^\circ$



$$\frac{F}{\sin\alpha} = \frac{F_{AB}}{\sin\beta}$$

$$\frac{130}{\sin 36.869} = \frac{F_{AB}}{\sin 75.751}$$

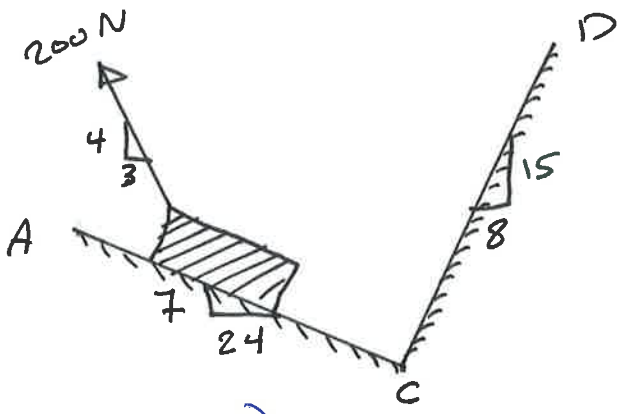
$F_{AB} = 210\ N \longrightarrow$

$F_{CD} = 200\ N \swarrow$

$$\frac{F_{CD}}{\sin\theta} = \frac{F}{\sin\alpha}$$

$F_{CD} = 200\ N \swarrow$

1.11 The 200 N force of fig acts on the Box B. Resolve the force into two component, one along AC and the other parallel to CD.



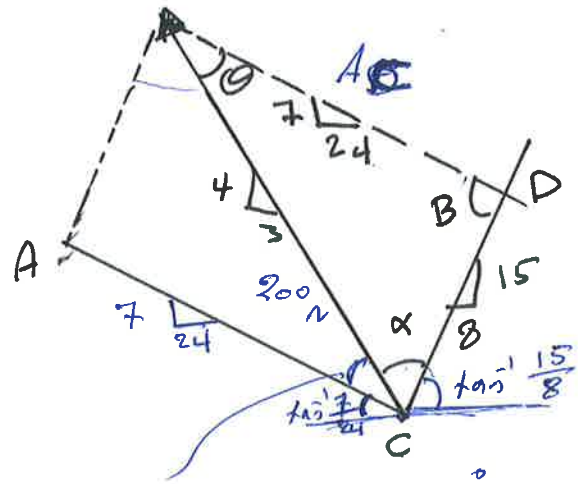
Solu:

$\theta = 36.869^\circ$

$\alpha = 1 + 2 = 64.942^\circ$

$\beta = 78.189^\circ \longrightarrow \beta = 180 - (\alpha + \theta)$

$$\frac{200}{\sin\beta} = \frac{CD}{\sin\theta} = \frac{AC}{\sin\alpha}$$



$CD = 122.593$ (15, 8)

$AD = 185.094$ N (7, 24)

$\theta = \tan^{-1}\frac{4}{3} = 36.869^\circ$

$$\alpha = 180 - (\theta + \tan^{-1}\frac{7}{24} + \tan^{-1}\frac{15}{8})$$

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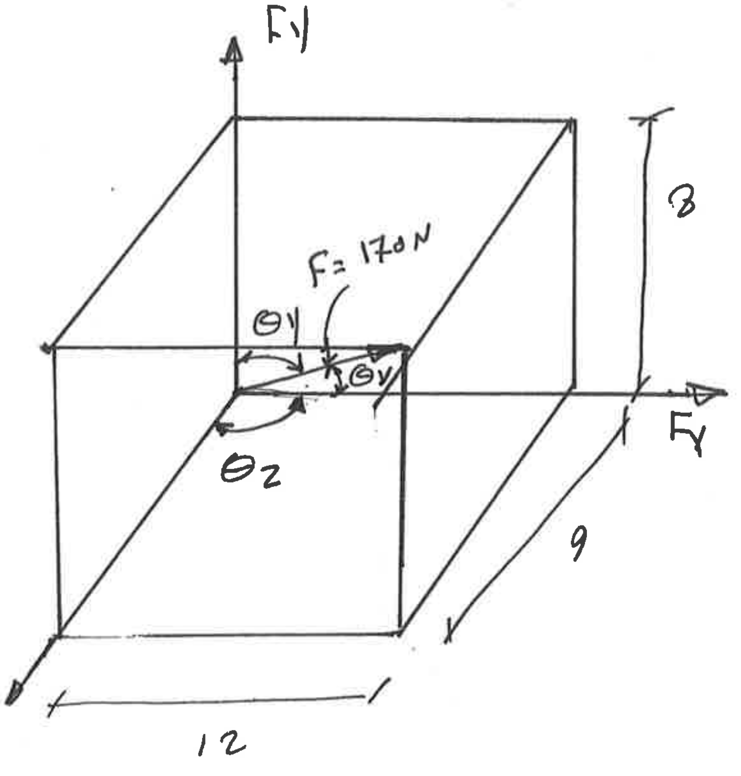
1.13 Determine asd of three rectangular components of the 170 N force.



Solu:

$$L = \sqrt{12^2 + 8^2 + 9^2} = 17$$

$$F_x = 170 \times \frac{12}{17} = 120\ N \longrightarrow$$

$$F_y = 170 \times \frac{8}{17} = 80\ N \uparrow$$

$$F_z = 170 \times \frac{9}{17} = 90 \swarrow$$