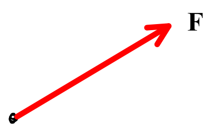
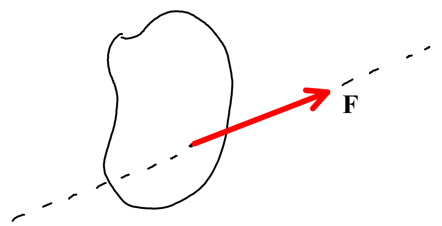
Chapter 2: Statics of Particles

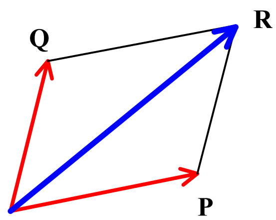
2.1 - 2.3 Forces as Vectors & Resultants

- Forces are drawn as directed arrows. The length of the arrow represents the magnitude of the force and the arrow shows its direction. Forces on rigid bodies further have a line of action.





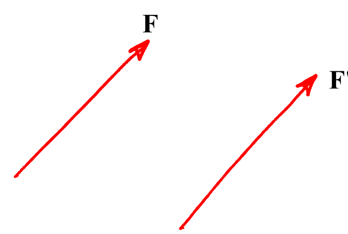
- Forces (and in general all vectors) follow the parallelogram law of vector addition. In fact, vectors are defined as quantities that follow the parallelogram law.



$$\mathbf{R} = \mathbf{P} + \mathbf{Q}$$

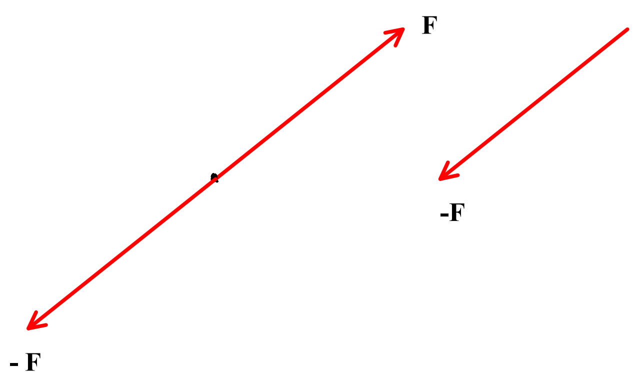
- Vector addition is represented by the same symbol +
  The meaning of plus will be clear from the context it is used in.

Note:
Vector addition is independent of any chosen coordinate system.
Two vectors are equal if they have the same magnitude and direction.



The negative of a vector **F** is simply **-F** denoted by arrow of the same size in the opposite direction.

$$\mathbf{F} + (-\mathbf{F}) = \mathbf{0}$$



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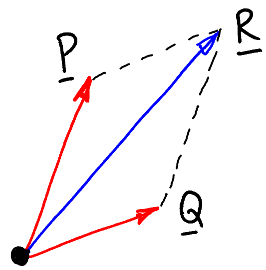
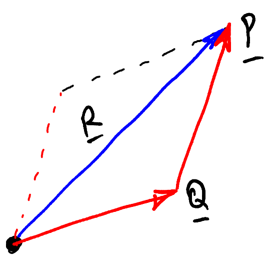
2.4-2.5 Addition of Vectors, Force resultants

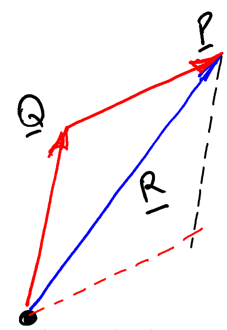
- Vector Addition Parallelogram law:
  - Commutative property

$$\mathbf{P} + \mathbf{Q} = \mathbf{Q} + \mathbf{P} = \mathbf{R}$$



- Vector Addition Triangle law (tip-to-tail):
  Derives from the parallelogram law.

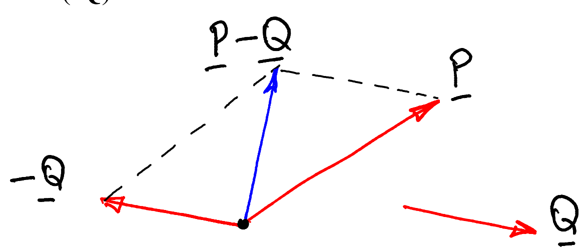




Alternatively

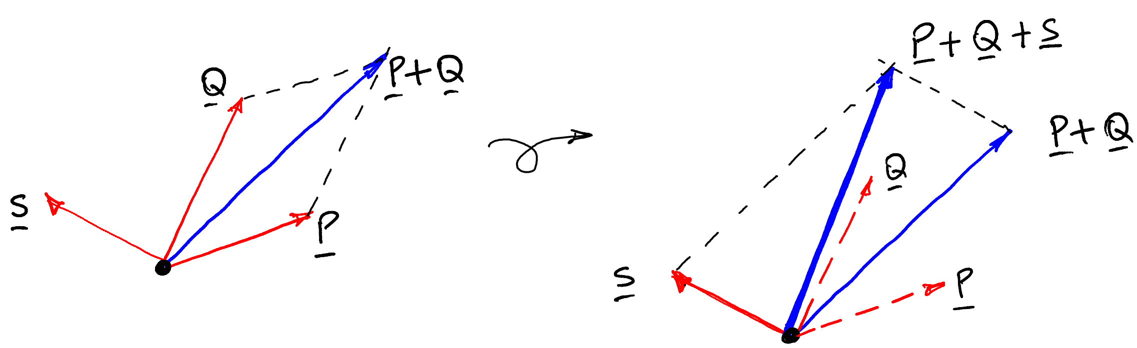
- Subtraction of a vector from another vector:
  (Addition of the negative vector)

$$\mathbf{P} - \mathbf{Q} = \mathbf{P} + (-\mathbf{Q})$$



- Addition of multiple vectors
  - Associative property

$$\mathbf{P} + \mathbf{Q} + \mathbf{S} = (\mathbf{P} + \mathbf{Q}) + \mathbf{S} = \mathbf{P} + (\mathbf{Q} + \mathbf{S}) = \mathbf{S} + \mathbf{Q} + \mathbf{P}$$



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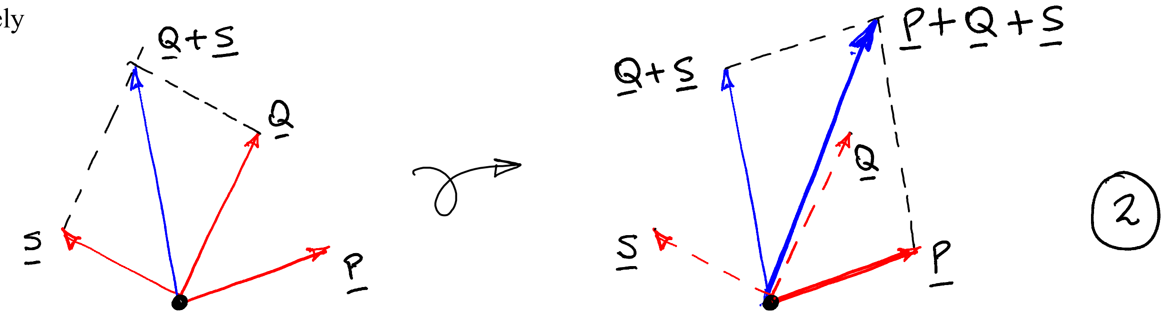
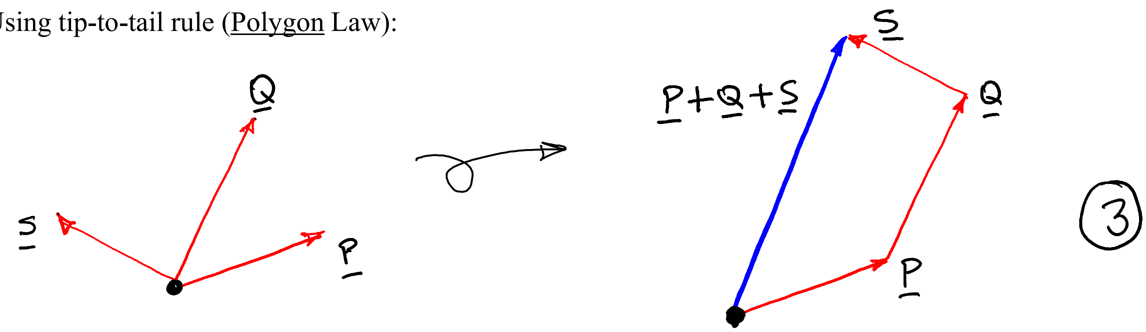
Alternatively

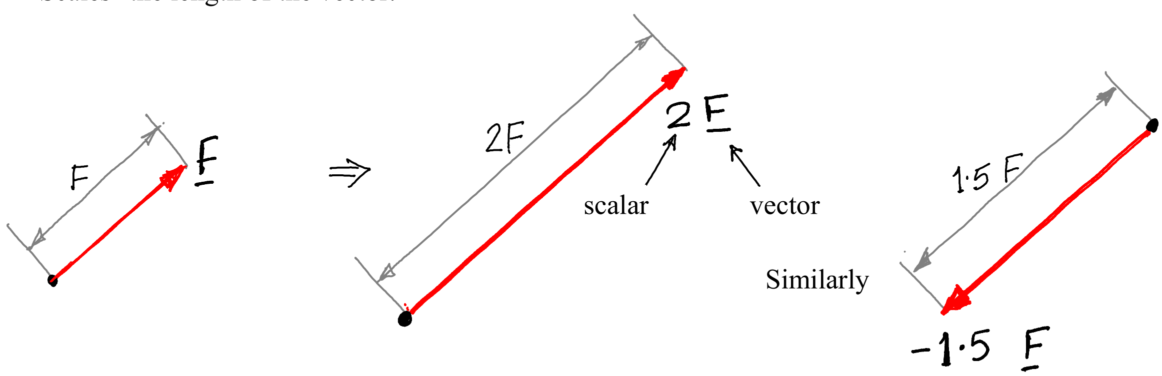


- Using tip-to-tail rule (Polygon Law):



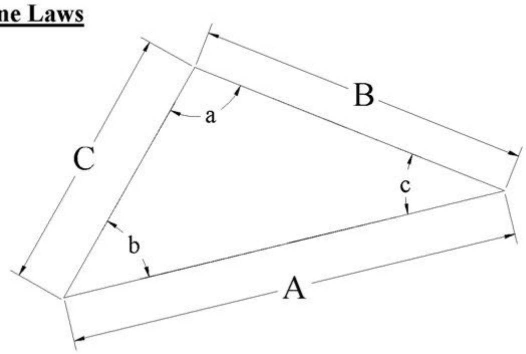
Compare 1, 2 and 3.

- Product of a scalar & a vector
  "Scales" the length of the vector.



CE 297 Useful Trigonometric Relationships

Sine and Cosine Laws



Sine Law:

$$\frac{\sin(a)}{A} = \frac{\sin(b)}{B} = \frac{\sin(c)}{C}$$

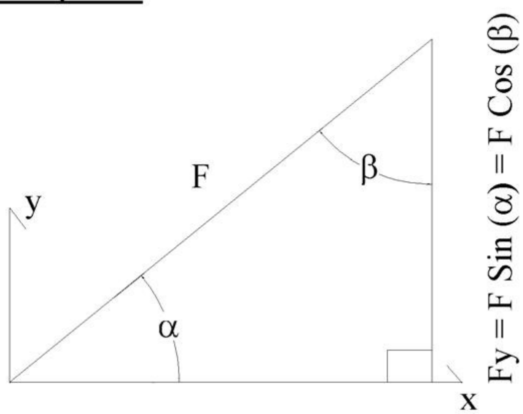
Cosine Law:

$$A^2 = B^2 + C^2 - 2 \times B \times C \times \cos(a)$$

$$B^2 = A^2 + C^2 - 2 \times A \times C \times \cos(b)$$

$$C^2 = A^2 + B^2 - 2 \times A \times B \times \cos(c)$$

Rectangular Components



$$Fx = F\ Cos(\alpha) = F\ Sin\ (\beta)$$

$$Tan(\alpha) = Fy/Fx$$

$$Tan(\beta) = Fx/Fy$$

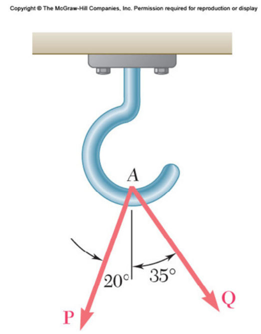
Sine and Cosine of a Sum of Angles

$$Sin(A \pm B) = Sin(A)Cos(B) \pm Sin(B)Cos(A)$$

$$Cos(A \pm B) = Cos(A)Cos(B) \mp Sin(A)Sin(B)$$

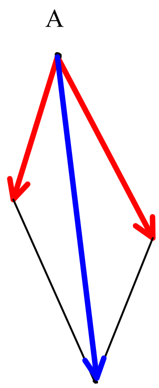
Examples

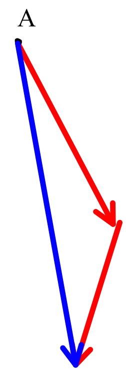
- Read Example 2.1 in book.
- Exercise 2.1



P = 75 N
Q = 125 N

Determine the resultant using
(1) Parallelogram Law,
(2) Triangle Rule,
(3) Trigonometry.

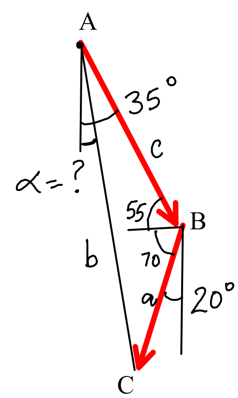




Using trigonometry

Length AC = b (unknown)
Angle α of AC with vertical (unknown)

Length AB = c = 125 N
Length BC = a = 75 N



$\angle B = 125°$
$\angle A = 35° - \alpha$
$\angle C = 20° + \alpha$

Using the cosine Law :-

$$b^2 = a^2 + c^2 - 2ac \cos B$$

$$= 75^2 + 125^2 - 2 \times 75 \times 125 \cos(125°)$$

solving:

$$b = 178.8982 \text{ N} \approx \boxed{179 \text{ N}}$$

Now using Sine Law:

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

$$\frac{\sin(125)}{178.8982} = \frac{\sin(35-\alpha)}{75} = \frac{\sin(20+\alpha)}{125}$$

$$\Rightarrow \quad \sin(20+\alpha) = \frac{125}{178.8982} \times \sin(125^\circ) = 0.5724$$

$$\Rightarrow \quad 20+\alpha = \sin^{-1}(0.5724) = 34.9149$$

$$\Rightarrow \quad \alpha = 14.9149 \approx \boxed{15^\circ}$$

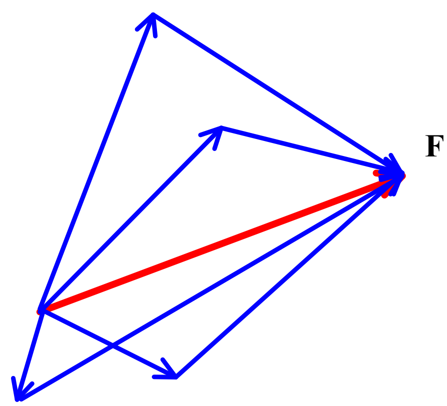
2.6 Resolving Forces into Components

- Reverse process of vector addition. Split a force into two (or more) components.

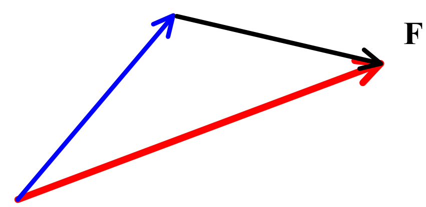
$$\mathbf{F} = \mathbf{P} + \mathbf{Q}$$

Given **F**, Find **P** and **Q** ?

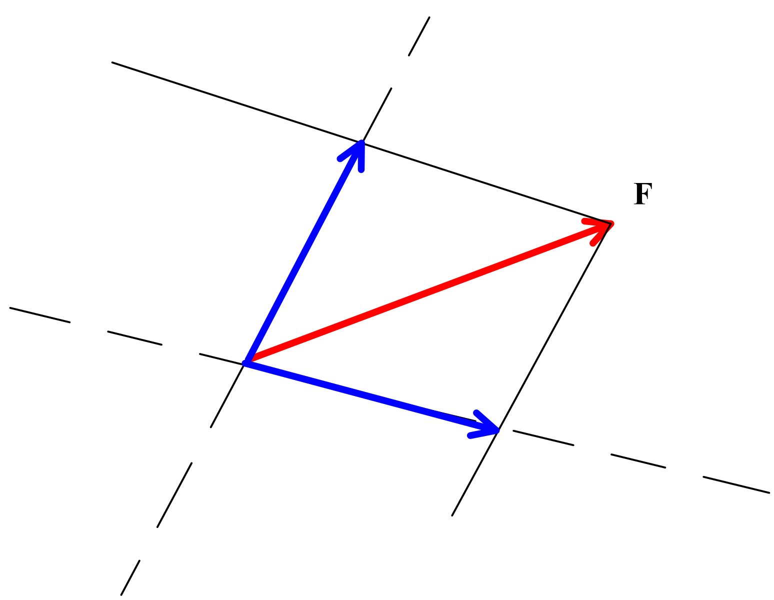
Many Possibilities



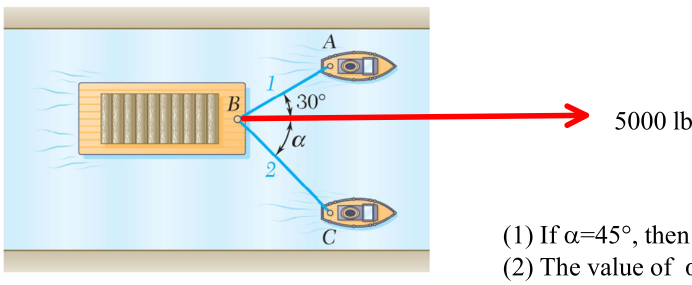
- Special cases:
  - One component (say **P**) is known:



  - The line of action of both components is known

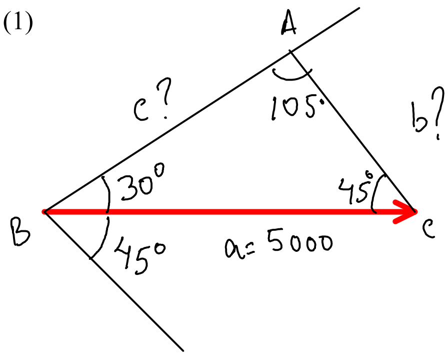


Example 2.2 in book:



(1) If α=45°, then find T1 and T2
(2) The value of α for which T2 is minimum.

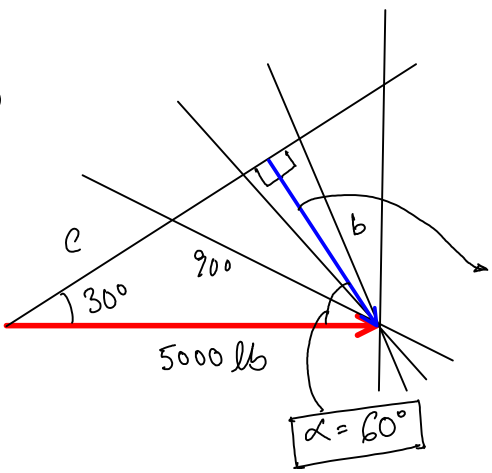
(1)



$$T2 = b = \frac{a}{\sin A} \cdot \sin B = 2590 \text{ lb.}$$

$$T1 = C = \frac{a}{\sin A} \cdot \sin C = 3660 \text{ lb}$$

(2)

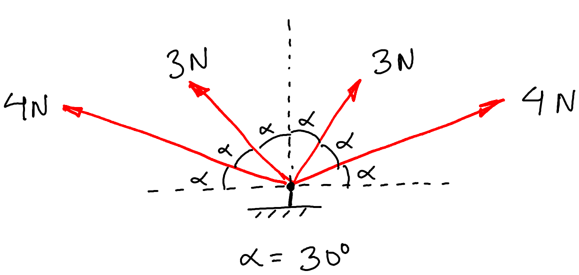


$$T1 = C = 5000 \cos(30^\circ) = 4330 \text{ lb}$$

$$T2 = b = 5000 \sin(30^\circ) = 2500 \text{ lb}$$

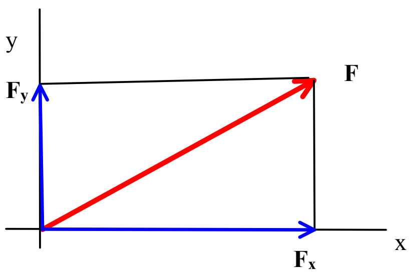
(minimum T2)

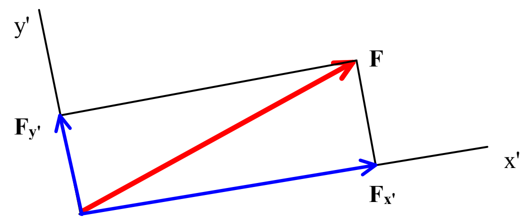
In class exercise.



2.7 Rectangular Components of Vectors; Unit vectors

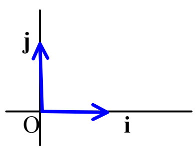
- For ease in mathematical manipulation, forces (and vectors) can be resolved into <u>rectangular</u> components along predefined x, y (and z) directions.

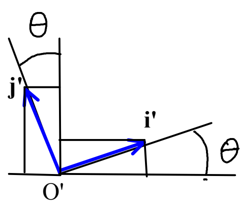




$$\mathbf{F} \quad = \quad \mathbf{F_x} + \mathbf{F_y} \quad = \quad \mathbf{F_{x'}} + \mathbf{F_{y'}}$$

- One can **choose** any coordinate system [O, **i**, **j**, **k**] and resolve forces and vectors along these directions.





i, **j**, (and **k**) are unit vectors.
(magnitude =1)

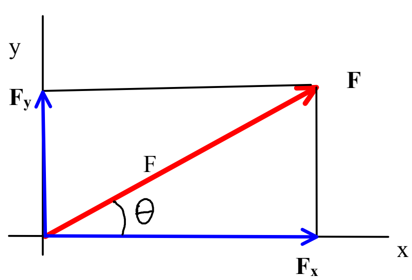
Note:

$\mathbf{i'} = \cos\theta\, \mathbf{i} + \sin\theta\, \mathbf{j}$
$\mathbf{j'} = -\sin\theta\, \mathbf{i} + \cos\theta\, \mathbf{j}$

$$\boxed{\begin{bmatrix} \mathbf{i'} \\ \mathbf{j'} \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} \mathbf{i} \\ \mathbf{j} \end{bmatrix}}$$

Useful in converting one coordinate system to another.

- Using the unit vectors:



$\mathbf{F_x} = F_x\ \mathbf{i}$
$\mathbf{F_y} = F_y\ \mathbf{j}$

Vector
Scalar (Magnitude)
Unit Vector (Direction)

$F_x = F \cos\theta$
$F_y = F \sin\theta$

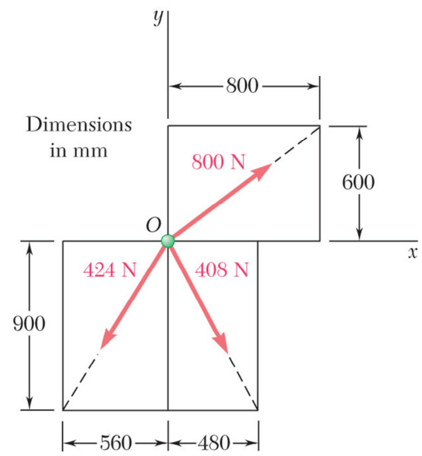
$$\mathbf{F} \quad = \quad \mathbf{F_x} + \mathbf{F_y} \quad = \quad F_x\ \mathbf{i} + F_y\ \mathbf{j}$$

<u>Examples</u>

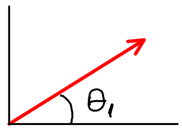
- Read examples 1, 2 & 3 in section 2.7 of the book.

- Exercise 2.21

Determine the x, y components of the 3 forces.



(i) $F = 800 \text{ N}$



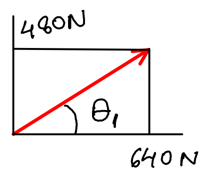
Note: $\tan\theta_1 = \frac{600}{800} = \frac{3}{4}$

$$\Rightarrow F_x = F\cos\theta_1$$
$$= 800 \times \frac{4}{5} = \boxed{640 \text{ N}} \quad \Rightarrow \underline{F}_x = 640\,\underline{i} \text{ N}$$

$$F_y = F\sin\theta_1$$
$$= 800 \times \frac{3}{5} = \boxed{480 \text{ N}} \quad \Rightarrow \underline{F}_y = 480\,\underline{j} \text{ N}$$

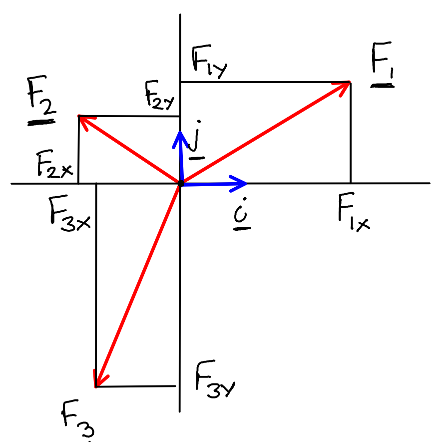
$$\Rightarrow \underline{F} = \underline{F}_x + \underline{F}_y$$

$$\boxed{\underline{F} = 640\,\underline{i} + 480\,\underline{j} \text{ N}}$$



Similarly solve for the other two forces.

2. 8 Addition of forces in x-y components



- The vector sum of two or more forces can be obtained by
  - Resolving each force into x-y components
  - Simply adding the individual components

$$\underline{F} = \underline{F}_1 + \underline{F}_2 + \underline{F}_3$$

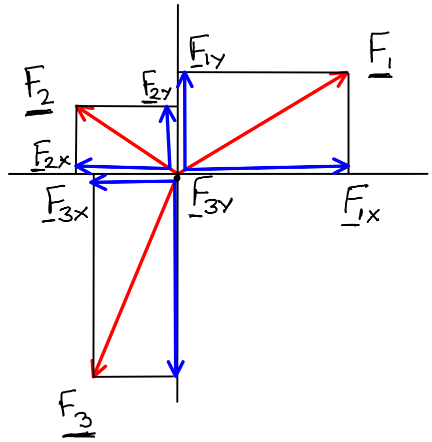
$$\underline{F} = (F_{1x} + F_{2x} + F_{3x})\,\underline{i} + (F_{1y} + F_{2y} + F_{3y})\,\underline{j}$$

$$\underline{F} = F_x\,\underline{i} + F_y\,\underline{j}$$

where

$$F_x = F_{1x} + F_{2x} + F_{3x}$$

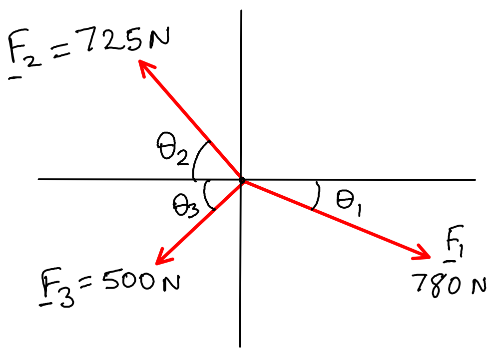
$$F_y = F_{1y} + F_{2y} + F_{3y}$$

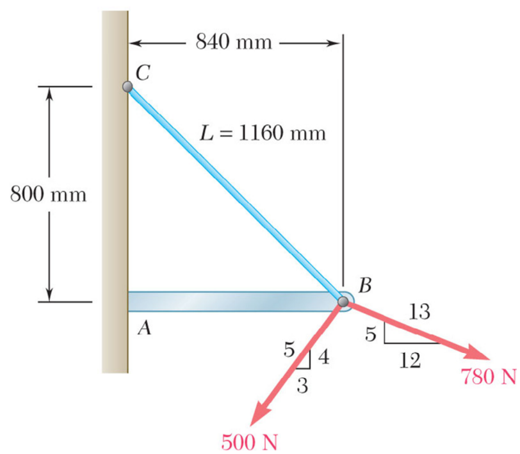


Example

- Read example 2.3 in book.
- Exercise 2.36

Tension in BC = 725 N.
Determine the resultant of the 3 forces at B.





Note: $\sin\theta_1 = \frac{5}{13}$; $\cos\theta_1 = \frac{12}{13}$

$\sin\theta_2 = \frac{800}{1160}$; $\cos\theta_2 = \frac{840}{1160}$

$\sin\theta_3 = \frac{4}{5}$; $\cos\theta_3 = \frac{3}{5}$

$$F_{1x} = F_1\cos\theta_1 = 780 \times \frac{12}{13} = 720\text{ N}$$

$$F_{1y} = (-)F_1\sin\theta_1 = -780 \times \frac{5}{13} = -300\text{ N}$$

$$F_{2x} = (-) F_2 \cos\theta_2 = -725 \times \frac{840}{1160} = -525 \text{ N}$$

$$F_{2y} = F_2 \sin\theta_2 = 725 \times \frac{800}{1160} = 500 \text{ N}$$

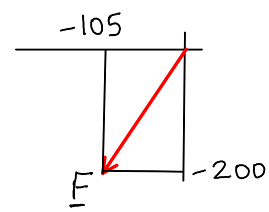
$$F_{3x} = (-) F_3 \cos\theta_3 = -500 \times \frac{3}{5} = -300 \text{ N}$$

$$F_{3y} = (-) F_3 \sin\theta_3 = -500 \times \frac{4}{5} = -400 \text{ N}$$

Thus the resultant is:

$$\underline{F} = (720 - 525 - 300)\,\underline{i} + (-300 + 500 - 400)\,\underline{j}$$

$$\boxed{\underline{F} = -105\,\underline{i} - 200\,\underline{j} \text{ N}}$$

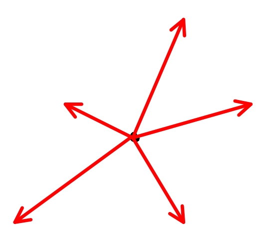


2.9-2.11 Equilibrium of a Particle; Free Body Diagrams

- If the resultant of all the forces acting on a particle is zero, the particle is said to be in **equilibrium**.

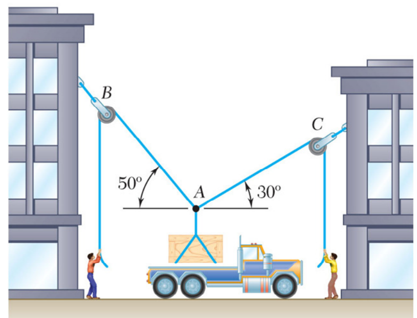
$$\mathbf{R} = \Sigma\mathbf{F} = \mathbf{0}$$

$$\boxed{\Sigma F_x = 0 \quad ; \quad \Sigma F_y = 0}$$



- Recall, Newton's 1st Law.
- Choose the particle judiciously.
- FREE BODY DIAGRAMS
  - A diagram showing all the forces acting on a particle or an object.

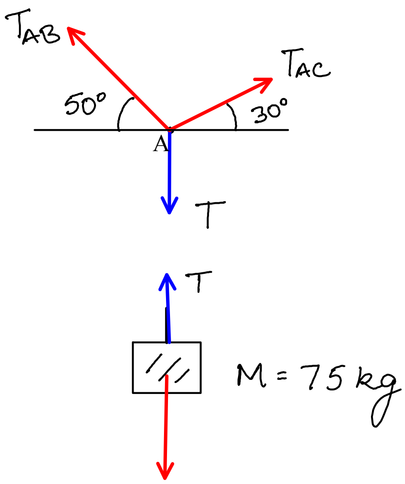
In 2 dimensions, we have <u>two equations</u> of equilibrium, thus the maximum number of unknowns we can solve for is <u>two</u>.



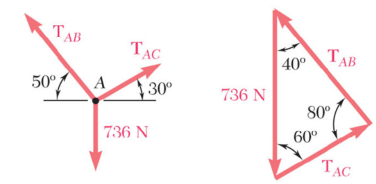
(a) Space diagram

<u>Examples:</u>

- Unloading a truck.



$W = 75 \times 9.81 = 736$ N

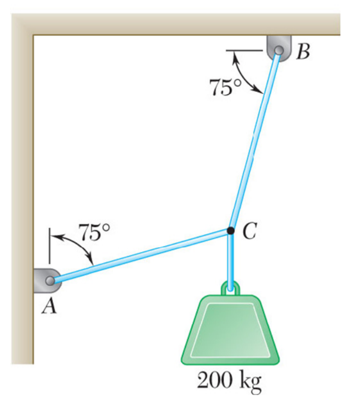


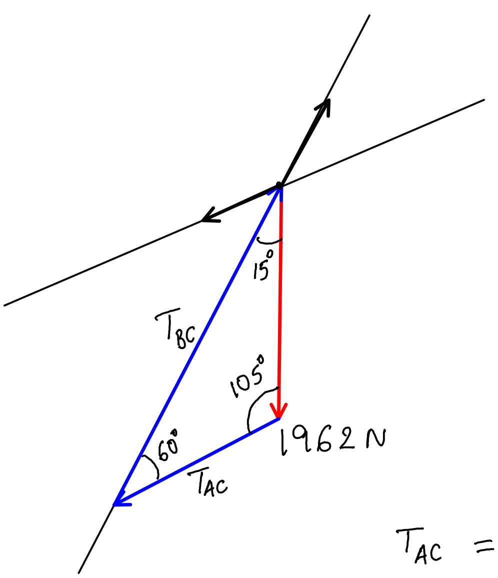
(b) Free-body diagram (c) Force triangle

$$T_{AC} = \frac{736}{\sin(80°)} \times \sin(40°) = \boxed{480\text{ N}}$$

$$T_{AB} = \frac{736}{\sin(80°)} \times \sin(60°) = \boxed{647\text{ N}}$$

- Read Examples 2.4, 2.5 and 2.6 in book.
- Exercise 2.46:
  Determine T_{AC} and T_{BC}





$W = 200 \times 9.81$
$= 1962$ N

$$T_{AC} = \frac{1962}{\sin(60°)} \cdot \sin(15°) = 586.3604 \approx \boxed{586\text{ N}}$$

$$T_{BC} = \frac{1962}{\sin(60°)} \cdot \sin(105°) = 2188.3 \approx \boxed{2188\text{ N}}$$

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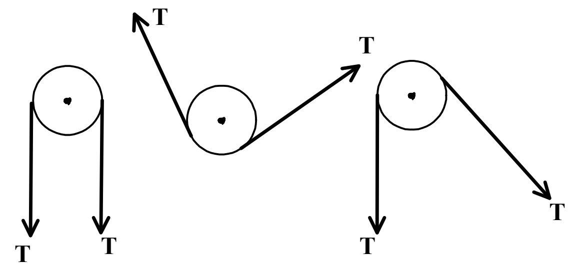
Pulleys

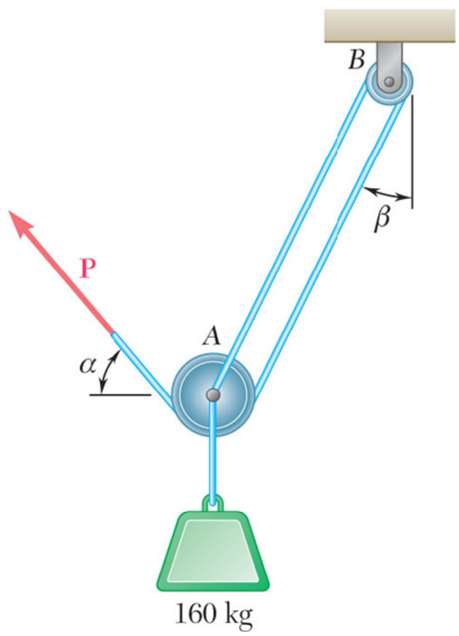
- The tension on both sides of a frictionless pulley is the same (under Equilibrium).



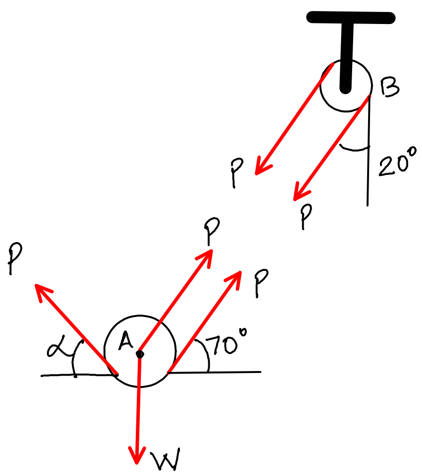
- Exercise 2.65

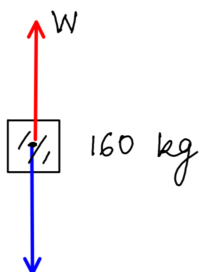
$\beta = 20^\circ$

Find **P** for equilibrium.



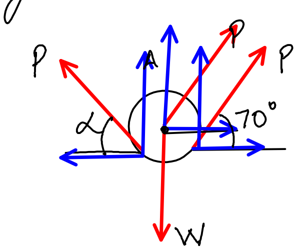
We wave to consider the free body diagrams of all the "particles" in the system here.





$W = 160 \times 9.81$
$= 1569.6\ N$

Equilibrium of the pulley A:



$\boxed{\sum F_x = 0}$

$\Rightarrow (-)P\cos\alpha + 2P\cos(70^\circ) = 0$

$\Rightarrow \cos\alpha = 2\cos(70^\circ)$

$\Rightarrow \boxed{\alpha = 46.84^\circ}$

$\boxed{\sum F_y = 0}$

$\Rightarrow -W + P\sin\alpha + 2P\sin(70^\circ) = 0$

$\Rightarrow P = \dfrac{W}{(\sin\alpha + 2\sin(70^\circ))}$

$\Rightarrow P = 601.6486 \approx \boxed{P = 601.65\ N}$

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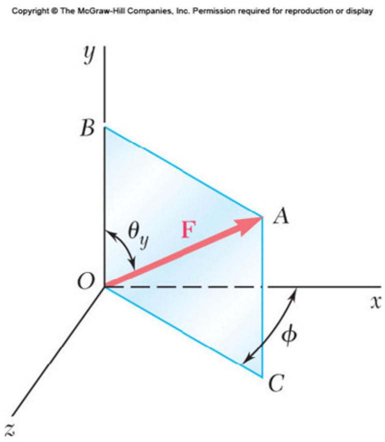
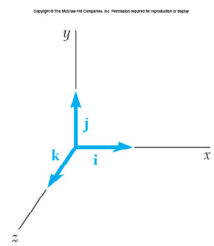
2.12 - 2.14 Forces (and Vectors) in 3-Dimensional Space



(a)

A force in 3-dimensional space can be represented with the angles ϕ and θ that it makes with the x-axis and the vertical axis respectively.



Unit vectors in space.

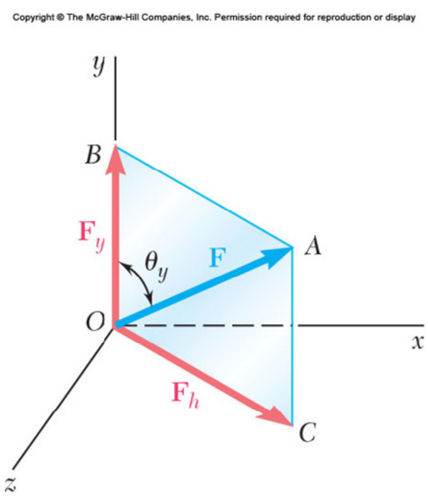
$$\mathbf{F} = F_x\ \mathbf{i} + F_y\ \mathbf{j} + F_z\ \mathbf{k}$$

scalar

Unit vector

$$\underline{F} = \underbrace{F_x \underline{i}}_{\underline{F}_x} + \underbrace{F_y \underline{j}}_{\underline{F}_y} + \underbrace{F_z \underline{k}}_{\underline{F}_z}$$

Vector

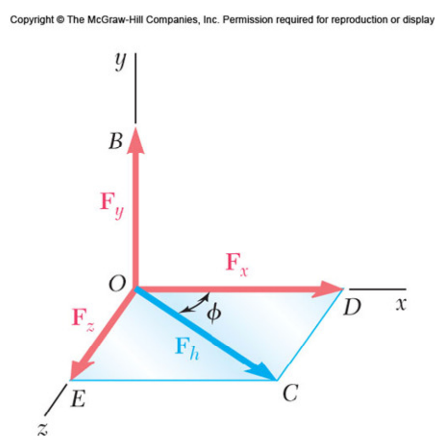


(b)

- Resolve $\vec{F}$ into horizontal and vertical components.

$$\boxed{F_y = F\cos\theta_y}$$

$$F_h = F\sin\theta_y$$



(c)

- Resolve F_h into rectangular components

$$\boxed{\begin{aligned} F_x &= F_h\cos\phi \\ &= F\sin\theta_y\cos\phi \end{aligned}}$$

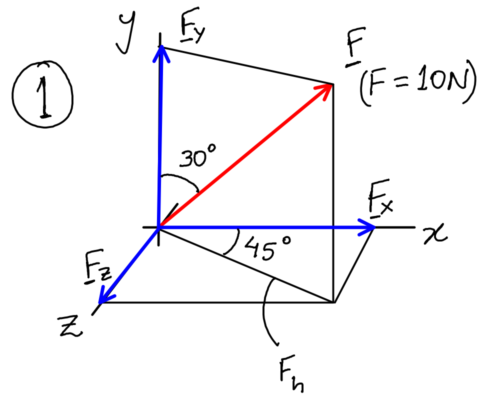
$$\boxed{\begin{aligned} F_z &= F_h\sin\phi \\ &= F\sin\theta_y\sin\phi \end{aligned}}$$

Note:

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

Example:

Consider the force shown:



$$F_y = F\cos 30^\circ = 10 \times \frac{\sqrt{3}}{2}\ N$$

$$\Rightarrow \boxed{\underline{F}_y = 8.66\ \underline{j}\ N}$$

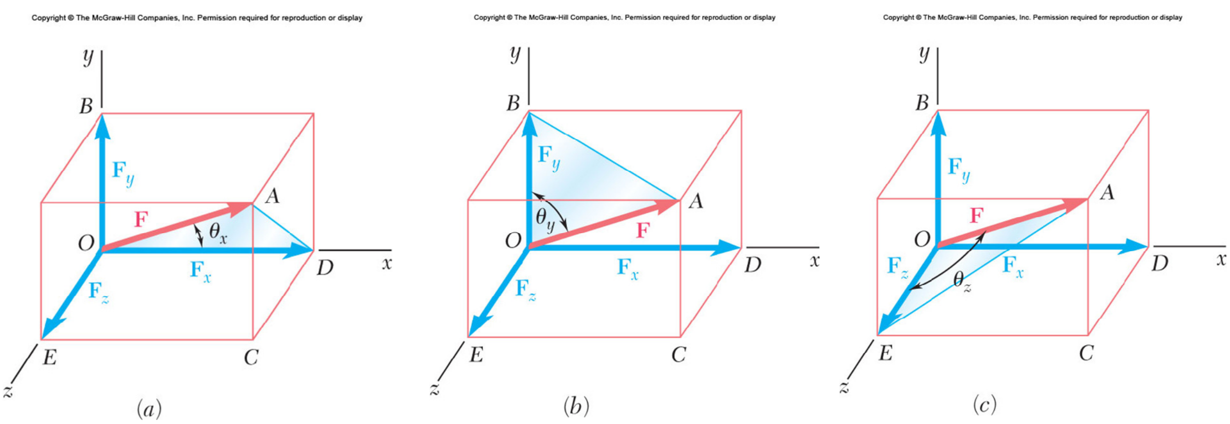
$$F_h = F\sin 30^\circ = 5N$$

Thus $F_x = F_h \cos 45^\circ = 5 \times \frac{1}{\sqrt{2}} = 3.54\ N$

$F_z = F_h \sin 45^\circ = 5 \times \frac{1}{\sqrt{2}} = 3.54 N$

$$\Rightarrow \boxed{\begin{aligned} \underline{F}_x &= 3.54\ \underline{i}\ N \\ \underline{F}_z &= 3.54\ \underline{k}\ N \end{aligned}}$$

Direction Cosines



$$\boxed{\cos^2\theta_x + \cos^2\theta_y + \cos^2\theta_z = 1}$$

$$\boxed{\begin{aligned} F_x &= F\cos\theta_x \\ F_y &= F\cos\theta_y \\ F_z &= F\cos\theta_z \end{aligned}}$$

Example:

For the example shown above in figure 1:

$$\cos\theta_x = \frac{F_x}{F} = \frac{3.54}{10} \Rightarrow$$

$$\cos\theta_y = \frac{F_y}{F} = \frac{8.66}{10} \Rightarrow$$

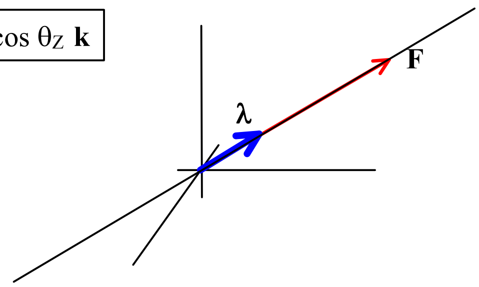
$$\cos\theta_z = \frac{F_z}{F} = \frac{3.54}{10} \Rightarrow$$

$$\boxed{\begin{aligned} \theta_x &= 69.3^\circ \\ \theta_y &= 30^\circ \\ \theta_z &= 69.3^\circ \end{aligned}}$$

General 3-dimensional Unit Vector

A general 3-D unit vector can be used to represent the line of action of a 3-D force.

$$\boxed{\boldsymbol{\lambda} = \cos\theta_x\,\mathbf{i} + \cos\theta_y\,\mathbf{j} + \cos\theta_Z\,\mathbf{k}}$$



$$\mathbf{F} = F\,\boldsymbol{\lambda}$$

$$\underline{F} = F\,\underline{\lambda}$$

Example

For the example in figure 1:

$$\boldsymbol{\lambda} = 0.354\,\mathbf{i} + 0.866\,\mathbf{j} + 0.354\,\mathbf{k}$$

$$\mathbf{F} = 10\ \boldsymbol{\lambda}\ \text{N}$$

Addition of forces (vectors) in 3-D space

Simply add the x, y, and z components.

$$\mathbf{R} = \Sigma\mathbf{F}$$ ie.

$$R_x = \sum F_x$$

$$R_y = \sum F_y$$

$$R_z = \sum F_z$$

$$R = \sqrt{R_x^2 + R_y^2 + R_z^2}$$

2.15 Equilibrium of Particles in 3D Space

$$\mathbf{R} = \Sigma\mathbf{F} = \mathbf{0}$$

$$\boxed{\Sigma F_x = 0\ ;\quad \Sigma F_y = 0\ ;\quad \Sigma F_z = 0}$$

Note:

3 Independent equations. Thus 3 unknowns can be solved for.

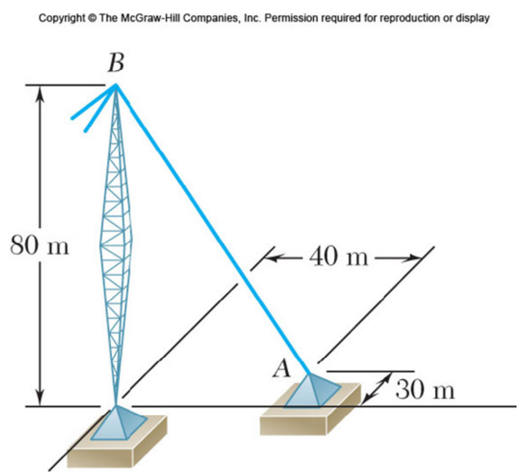
- Example 2.7 in book

Tension in wire = 2500 N

Find

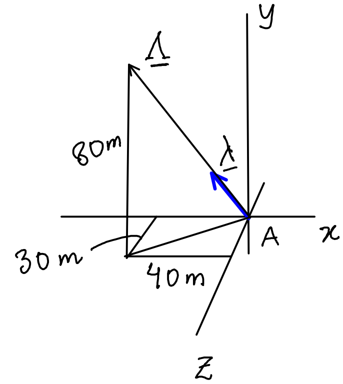
F_x, F_y, F_z at A

and $\theta_x, \theta_y, \theta_z$.



Approach:

If we know the "direction" of $\underline{F}$, we can find F_x, F_y, F_z.



Direction ↔ Unit Vector $\underline{\lambda}$

$$\underline{\Lambda} = -40\,\underline{i} + 80\,\underline{j} + 30\,\underline{k} \text{ m}$$

$$|\underline{\Lambda}| = \Lambda = \sqrt{(-40)^2 + (80)^2 + (30)^2}$$

$$= 94.34 \text{ m}$$

⇒ Unit Vector

$$\underline{\lambda} = \frac{\underline{\Lambda}}{\Lambda} = \frac{-40}{94.34}\underline{i} + \frac{80}{94.34}\underline{j} + \frac{30}{94.34}\underline{k}$$

$$\Rightarrow \underline{\lambda} = -0.424\,\underline{i} + 0.848\,\underline{j} + 0.318\,\underline{k}$$

Recall:

$$\underline{F} = F\underline{\lambda} = 2500\,(\underline{\lambda}) \text{ N}$$

$$\underline{F} = \underbrace{-1060}_{F_x}\,\underline{i} + \underbrace{2120}_{F_y}\,\underline{j} + \underbrace{795}_{F_z}\,\underline{k} \text{ N}$$

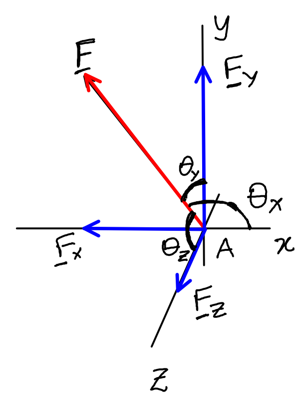
Also recall:

$$\Rightarrow \underline{\lambda} = \underbrace{-0.424}_{\cos\theta_x}\,\underline{i} + \underbrace{0.848}_{\cos\theta_y}\,\underline{j} + \underbrace{0.318}_{\cos\theta_z}\,\underline{k}$$

$$\Rightarrow \theta_x = \cos^{-1}(-0.424) = 115.1^\circ$$

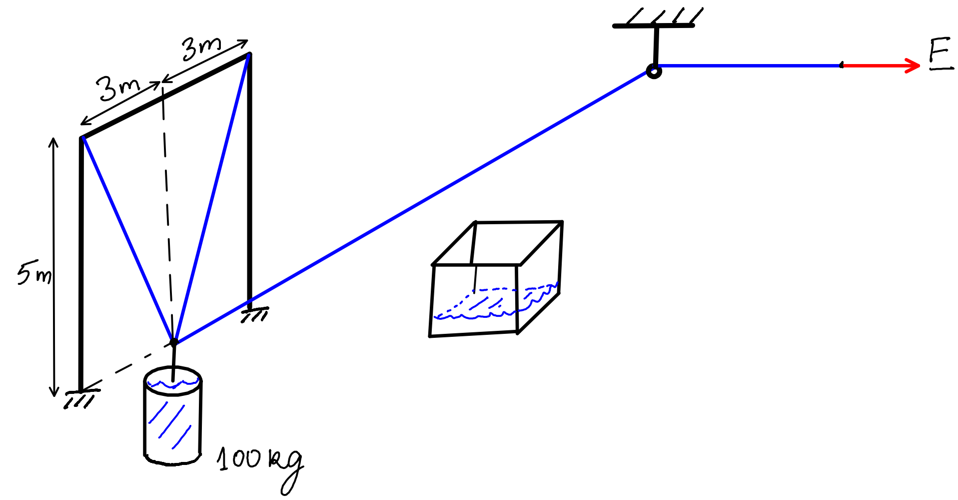
$$\theta_y = \cos^{-1}(0.848) = 32^\circ$$

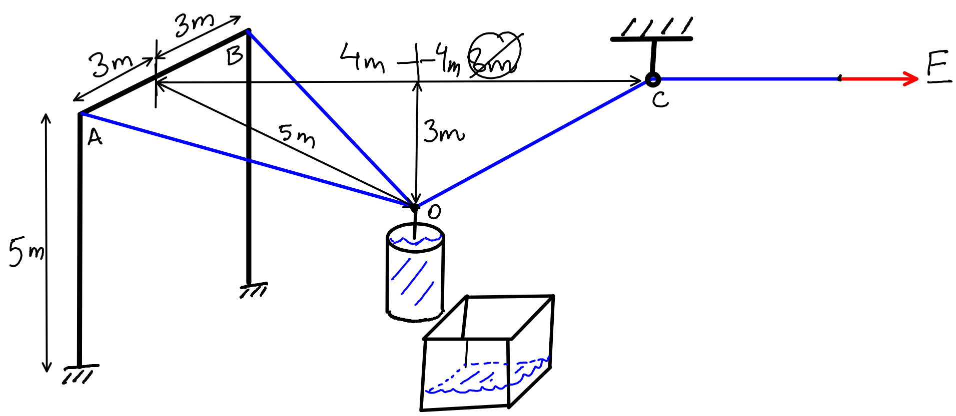
$$\theta_z = \cos^{-1}(0.318) = 71.5^\circ$$



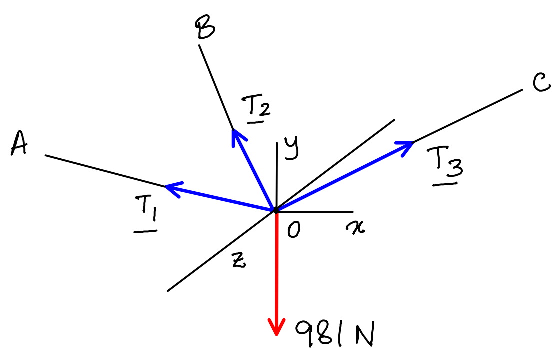
Example

Friday, September 04, 2009
9:47 AM





Free body diagram of point O:



Note:

$\underline{T_1} = T_1\,\underline{\lambda_1}$

$\underline{T_2} = T_2\,\underline{\lambda_2}$

$\underline{T_3} = T_3\,\underline{\lambda_3}$

$$\vec{OA} = -4\,\underline{i} + 3\,\underline{j} + 3\,\underline{k}\ \text{m}$$

$$\Rightarrow |OA| = \sqrt{4^2 + 3^2 + 3^2} = 5.83\ \text{m}$$

$$\Rightarrow \text{Unit vector } \underline{\lambda_1} = \frac{\vec{OA}}{|OA|} = \frac{-4}{5.83}\,\underline{i} + \frac{3}{5.83}\,\underline{j} + \frac{3}{5.83}\,\underline{k}$$

Similarly

$$\overrightarrow{OB} = -4\,\underline{i} + 3\underline{j} - 3\,\underline{k} \text{ m}$$

$$\Rightarrow |OB| = \sqrt{4^2+3^2+3^2} = 5.83\text{m}$$

$$\Rightarrow \lambda_2 = \frac{\overrightarrow{OB}}{|OB|} = \frac{-4}{5.83}\,\underline{i} + \frac{3}{5.83}\,\underline{j} - \frac{3}{5.83}\,\underline{k}$$

and

$$\overrightarrow{OC} = 4\,\underline{i} + 3\underline{j} \text{ m}$$

$$\Rightarrow |OC| = 5 \text{ m}$$

$$\Rightarrow \underline{\lambda}_3 = 0.8\,\underline{i} + 0.6\,\underline{j}$$

Finally enforcing equilibrium of point O:-

$\boxed{\sum F_x = 0}$

$$\Rightarrow T_1\left(\frac{-4}{5.83}\right) + T_2\left(\frac{-4}{5.83}\right) + T_3(0.8) = 0 \quad — 1$$

$\boxed{\sum F_y = 0}$

$$\Rightarrow T_1\left(\frac{3}{5.83}\right) + T_2\left(\frac{3}{5.83}\right) + T_3(0.6) - 981 = 0 \quad — 2$$

$\boxed{\sum F_z = 0}$

$$\Rightarrow T_1\left(\frac{3}{5.83}\right) + T_2\left(\frac{-3}{5.83}\right) = 0 \quad \Rightarrow \boxed{T_1 = T_2}$$

From 1:-

$$T_3 = 2T_1\left(\frac{5}{5.83}\right) \Rightarrow \boxed{T_1 = 0.583\,T_3}$$

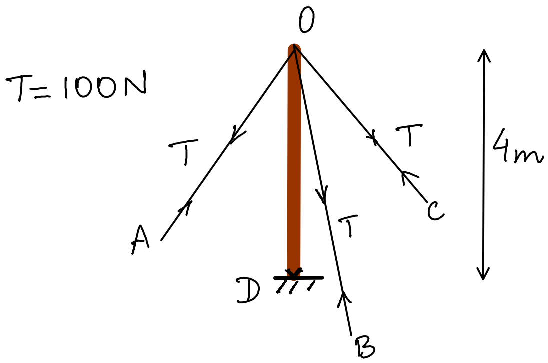
Substituting into 2:-

$$T_3\left(\frac{0.583}{5.83}\times 3 + \frac{0.583}{5.83}\times 3 + 0.6\right) = 981 \Rightarrow \boxed{T_3 = 817.5\text{N}}$$

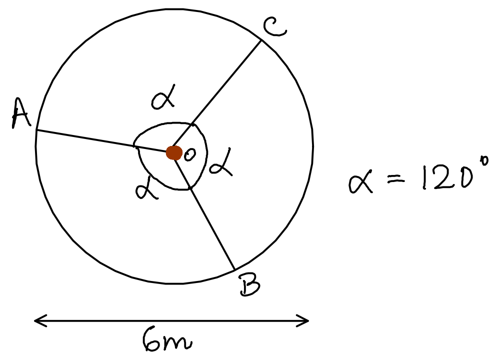
Thus the force $\boxed{\underline{F} = 817.5\,\underline{i}\text{ N}}$

In Class Assignment 2:

Side View:



Top View:

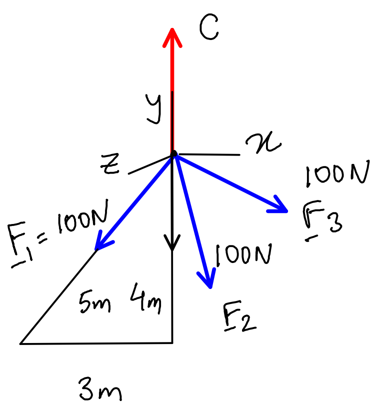


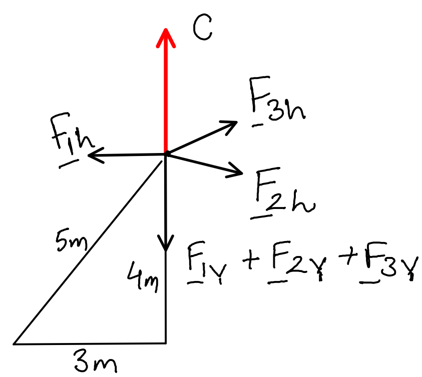
Find:

(i) Is the pole OD in "tension" or "compression".

(ii) Magnitude of the force in the pole OD.

Consider point O:





Choose x, y, z such that "y" is vertical; and **F1h** is in the (-) "x" direction.

Note:

This is an arbitrary choice. You may choose a different x, y, z, and the result will be the same.

$\underline{F}_{1y} = \underline{F}_{2y} = \underline{F}_{3y}$

$= -80 \, \underline{j} \text{ N}$

$F_{1h} = F_{2h} = F_{3h}$

$= 60 \text{ N}$ (magnitude)

Resolving the 3 forces into "vertical" and "horizontal" components, rather than x, y, z.

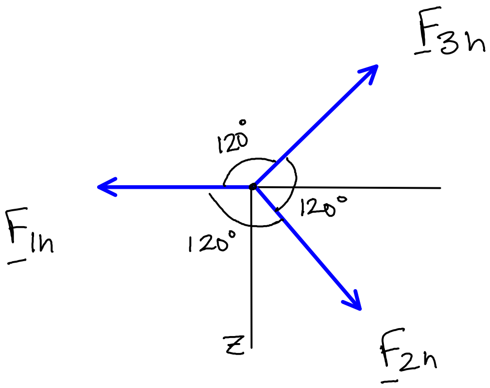
Each of the 3 triangles will be "similar".

$$\boxed{\sum F_y = 0}$$

$$\Rightarrow \quad F_{1y} + F_{2y} + F_{3y} + C = 0$$

$$\Rightarrow \quad \boxed{\underline{C} = 240 \, \underline{j} \text{ N}}$$

On the x-z plane:



$$\boxed{\sum F_x = 0}$$

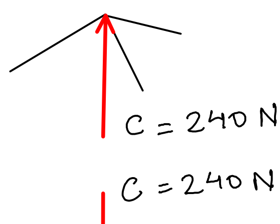
$\Rightarrow \; -60 + 60\cos(60^\circ) + 60\cos(60^\circ) = 0$

satified!

$$\boxed{\sum F_z = 0}$$

$\Rightarrow \; 60\sin(60^\circ) - 60\sin(60^\circ) = 0$

satisfied!



Free body diagram of the pole:

$\Rightarrow$ Compression