Engineering Mechanics
(1st Semester)
Syllabus

1.Basic Concepts, Analysis of Forces
2.Concepts of Moments and Couples
3.Resultant of Force System
4.Equilibrium
5.Analysis of Structures: Analysis of Truss
6.The Centroid and Center of Gravity
7.Moment of Inertia.

Text book

1. ENGINEERING MECHANICS

Third Edition 2002, A. HIGDON and W. STILS

1.1 Introduction

Mechanics: is a branch of the physics which deals with the study of the effect of force system acting on a particle or a rigid body which may be at rest or in motion.

Engineering Mechanics can be subdivided into three branches:

A. Rigid- body mechanics the body is stay in the same shape after applying the forces (no deformation are considered in the body) and this branch is divided into two areas: static and dynamics.

B. Deformable-body mechanics

C. Fluid mechanics.

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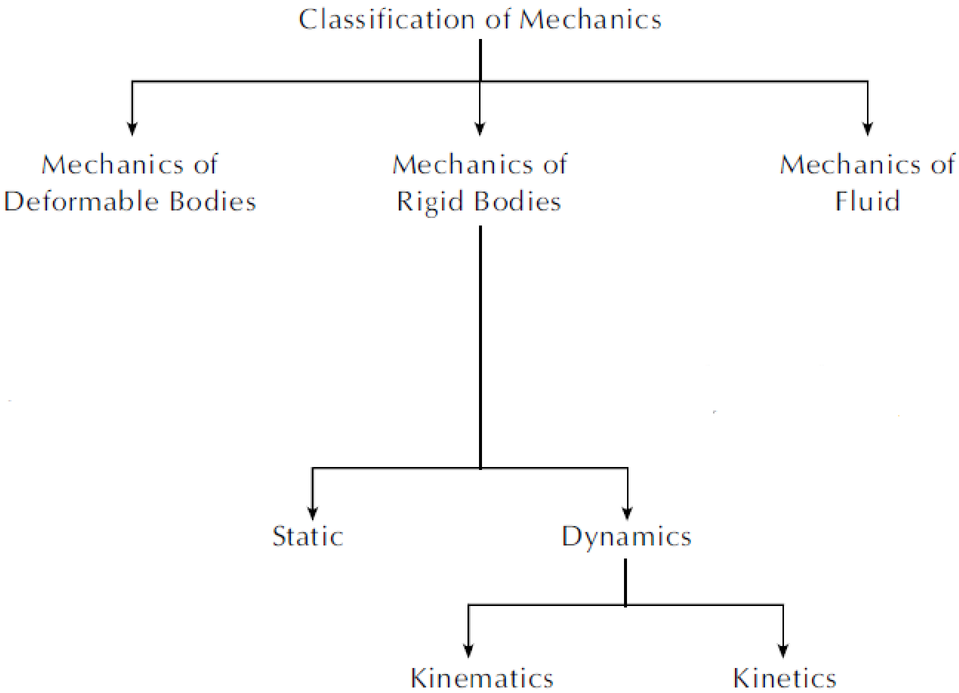


Static Mechanics:

It is the study of the effect of force system acting on a particle or rigid body which is at rest.

Dynamic Mechanics:

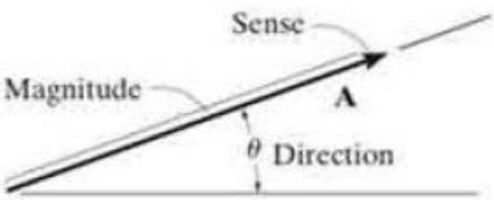
It is the study of the effect of force system acting on a particle or rigid body which is in motion.

1.2 Basic Concepts:

Particle: it is defined as an entity having considerable mass but negligible dimension.

Rigid Body: A solid body having considerable mass as well as dimension.

Vector Quantities: are the quantities which have magnitude and direction, such as force, weight, distance, speed, displacement, acceleration and velocity.



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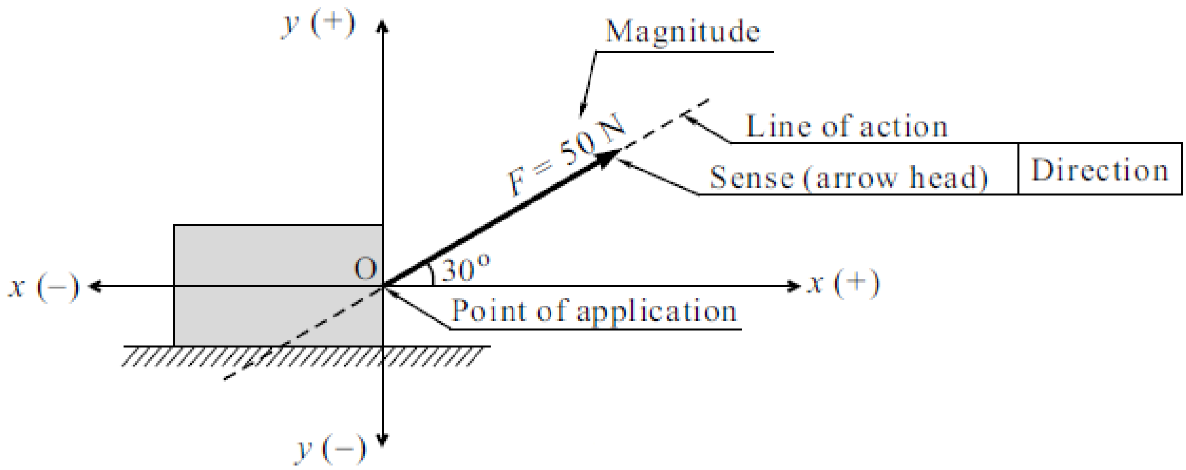
Scalar Quantities: are the quantities which have only magnitude, such as: time, size, sound, density, light and volume.

Force: is an action that changes, or tends to change, the state of motion of the body upon which it acts. In general, force is considered as a "push" or "pull "' exerted by one body on another.

A complete description of a force must include its:

1. Magnitude
2. Direction and sense.
3. Point of action.



Principle of Transmissibility of Force: It states that the condition of equilibrium or uniform motion of rigid body will remain unchanged if the point of application of a force acting on a rigid body is transmitted to act at any other point along its line of action.

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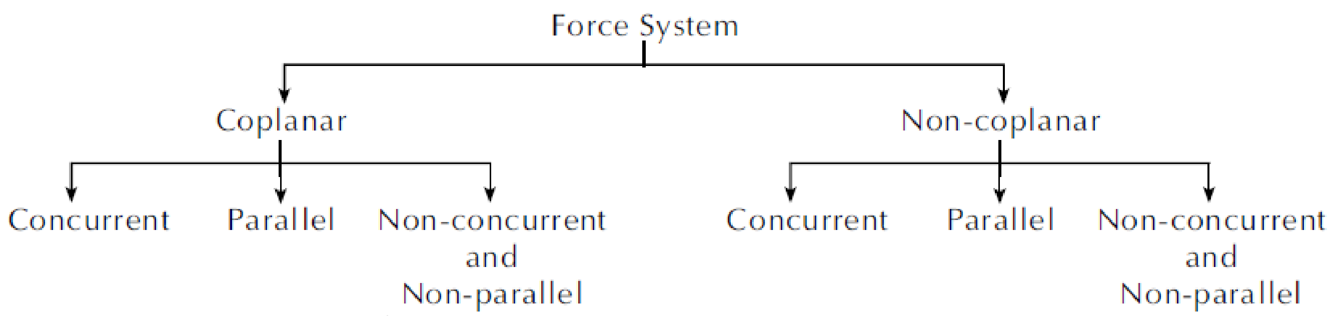
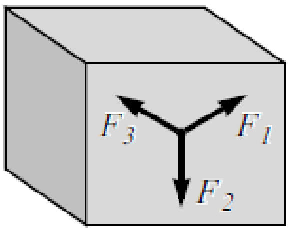
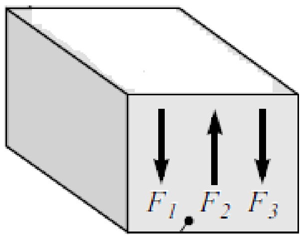
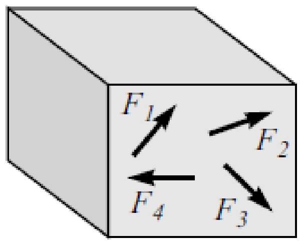
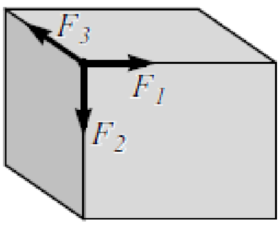
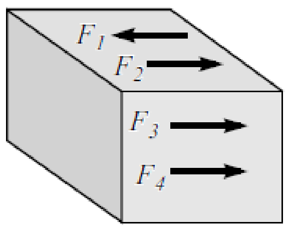
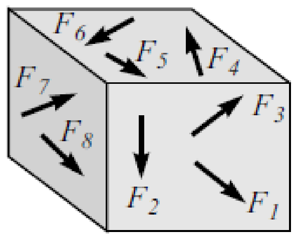
1.3 Force System

Is a number of forces acting in a given situation and can be classified according to the arrangement of the line of action of the forces on the system.



 Coplanar Concurrent Force System	 Coplanar Parallel Force System	 Coplanar Non Concurrent and Non Parallel Force System
 Non Coplanar Concurrent Force System	 Non Coplanar Parallel Force System	 Non Coplanar Non Concurrent and Non Parallel Force System

* Concurrent: all forces pass through a point.

** Coplanar: in the same plane.

***Parallel: parallel line of action.

****Collinear: common line of action.

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1.4 Units and their Relations:

QUANTITY	DIMENSIONAL SYMBOL	SI UNITS UNIT		SI UNITS SYMBOL	U.S. CUSTOMARY UNITS UNIT		U.S. CUSTOMARY UNITS SYMBOL
Mass	M	Base units	kilogram	kg		slug	—
Length	L	Base units	meter	m	Base units	foot	ft
Time	T	Base units	second	s	Base units	second	sec
Force	F		newton	N	Base units	pound	lb

TABLE 1–2 Conversion Factors

Quantity	Unit of Measurement (FPS)	Equals	Unit of Measurement (SI)
Force	lb		4.448 N
Mass	slug		14.59 kg
Length	ft		0.304 8 m

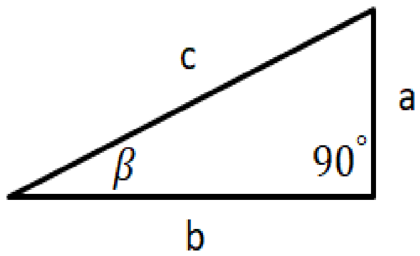
1.5 Trigonometric Relations

A. Right Angle's Triangles

$$\sin\beta = \frac{a}{c}$$

$$\cos\beta = \frac{b}{c}$$

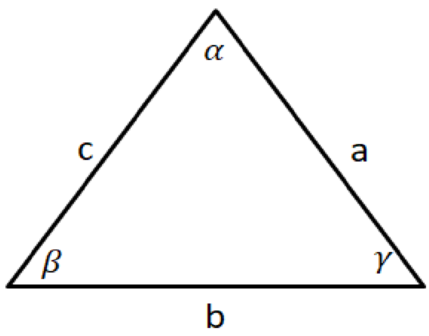
$$\tan\beta = \frac{a}{b}$$



B.Oblique Triangle

1.Sine Low

$$\frac{a}{\sin\beta} = \frac{b}{\sin\alpha} = \frac{c}{\sin\gamma}$$



2. Cosine Low

$$a^2 = b^2 + c^2 - 2bc\cos\beta$$

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

$$c^2 = a^2 + b^2 - 2ab\cos\gamma$$

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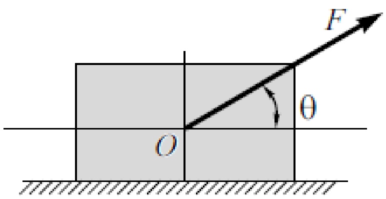
1.6. Composition and Resolution of Force.

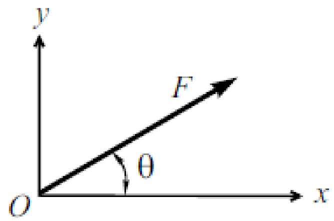
There are two common problems in statics involve either finding the resultant force, knowing its components, or resolving a known force into two components.

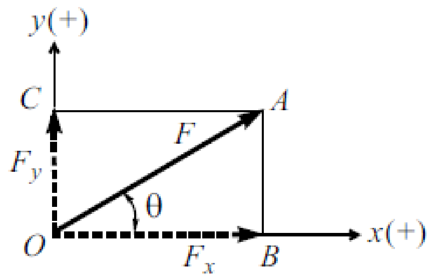
1.6.1 Finding the Components of a Force (Resolution of Force)

the process of breaking the force into a number of components, which are equivalent to the given forces is called resolution of force.

A. Resolving a force into rectangular components





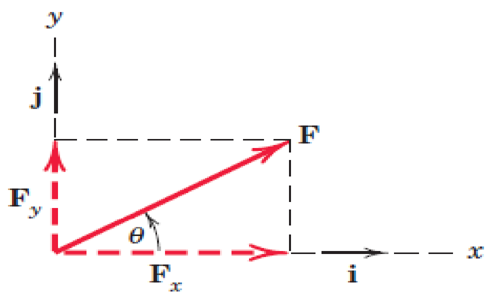


Two Dimensional Force System

Let the force (**F**) shown below with the direction (**θ**); we can resolve this force into two components:

1-Horizontal Component (**F_x**) which lies on X-axis.

2-Vertical Component (**F_y**) which lies on Y-axis.



$F_X = F \cos\theta$

$F_Y = F \sin\theta$

$F = \sqrt{{F_X}^2 + {F_Y}^2}$

In vector expression:-

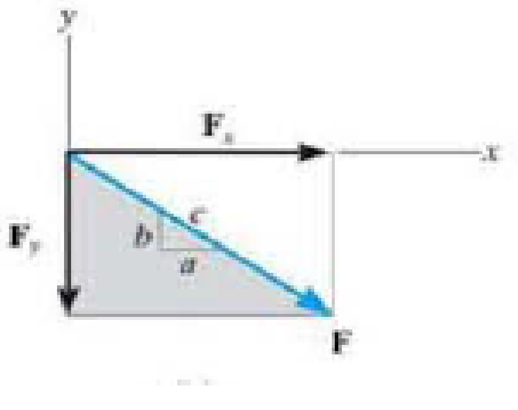
$F = F_x i + F_Y j \quad = F\cos\theta\, i + F\sin\theta\, j$

$$\theta = \tan^{-1}\frac{F_Y}{F_X}$$

Instead of using the angle however the direction of **F** can also be defined using a small slope triangle such as shown in figure below. Since this triangle and the larger shaded triangle are similar, the proportional length of the sides gives:

$F_X = F\frac{a}{c}$

$F_Y = F\frac{b}{c}$



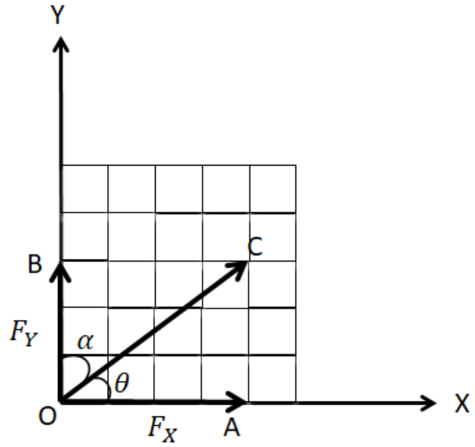
Or in another way;

$F_X = OA = F\cos\theta = \left(\frac{4}{5}\right)F =$

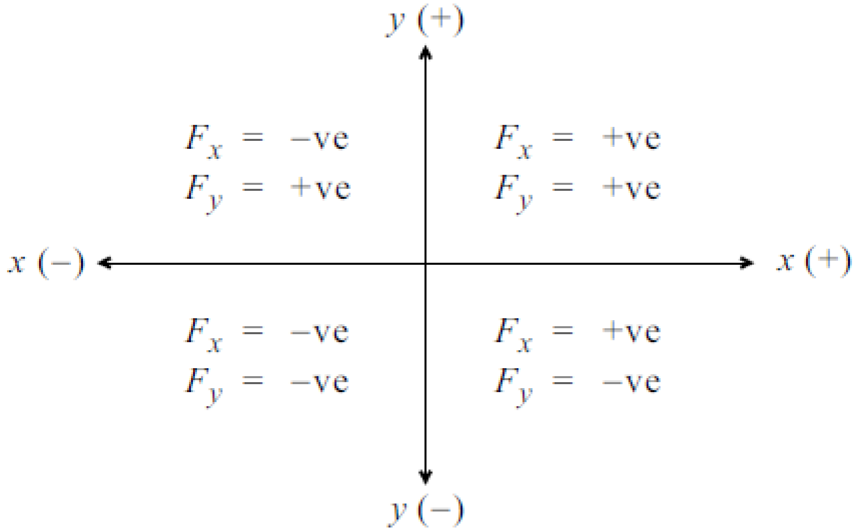
0.8 F to the right through O

$F_Y = OB = F\sin\theta = \left(\frac{3}{5}\right)F =$

0.6 F upward through O



Note (1)



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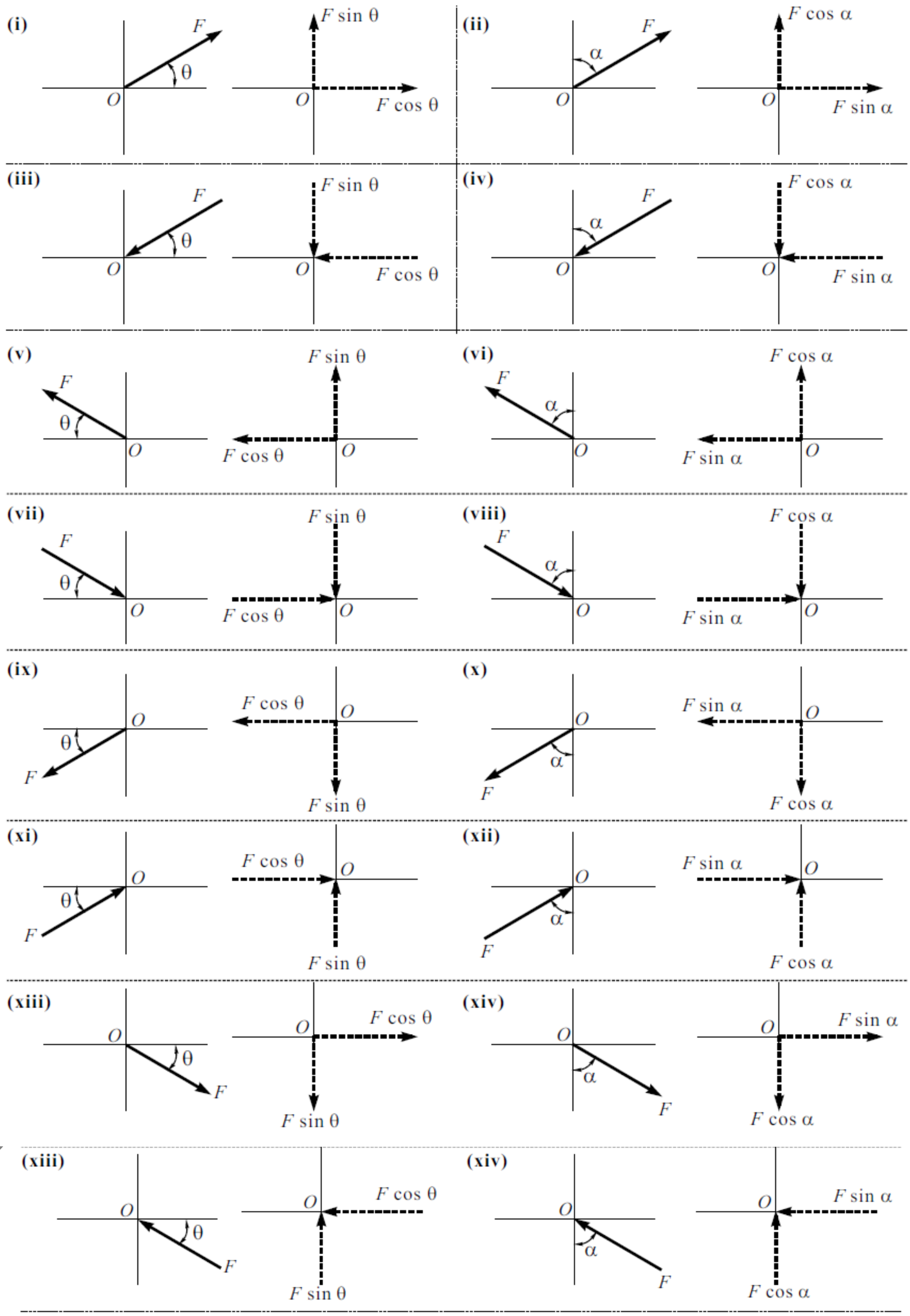
Note(2)



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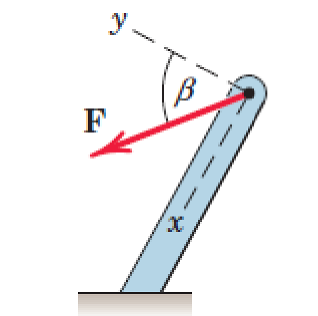
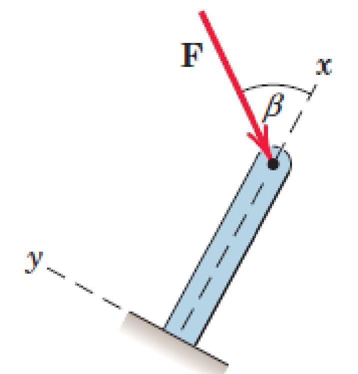
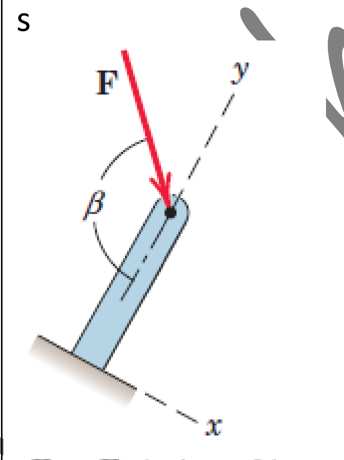
Note(3): Dimensions are not always given in horizontal and vertical directions, angles need not be measured counterclockwise from the X-axis, and the origin of coordinates need not be on the line of action of a force. Therefore, it is essential that we be able to determine the correct components of a force no matter how the axes are oriented or how the angles are measured. The figure below suggests a few typical examples of force resolution in two dimensions.



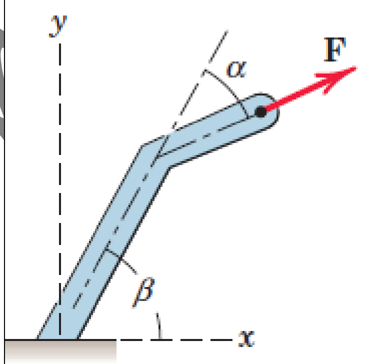
$F_x = F \sin \beta$
$F_y = F \cos \beta$



$F_x = -F \cos \beta$
$F_y = -F \sin \beta$



$F_x = F \sin(\pi - \beta)$
$F_y = -F \cos(\pi - \beta)$



$F_x = F \cos(\beta - \alpha)$
$F_y = F \sin(\beta - \alpha)$

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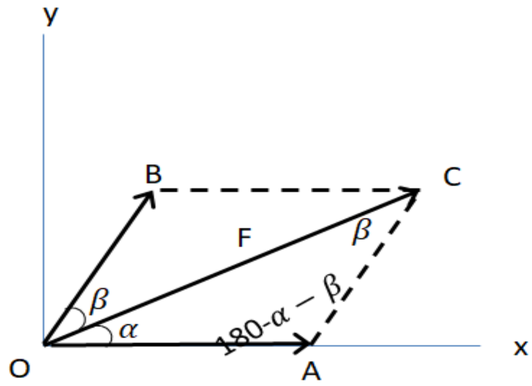
B. Resolving a force into nonrectangular components

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

$$F = \sqrt{OA^2 + OB^2 - 2(OA)(OB)\cos(180 - \alpha - \beta)}$$



Examples

Example (1)

The direction of the force (**P**) is (**30**°), find the horizontal components if the vertical components is (**30N**).

Solution:-

From the diagram shown:

$F_Y = 30\text{N} \quad \uparrow$

$F_Y = F\sin\theta$

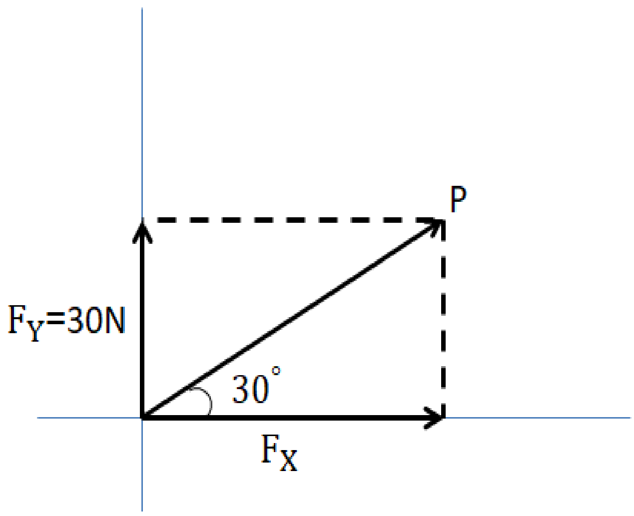
30=P sinθ

30=P. 0.5

P=60 N

$F_X = F\cos\theta = 60\cos 30$

$F_X = 60X\frac{\sqrt{3}}{2} = 30\sqrt{3}\ \text{N} \quad \rightarrow$



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Example(2)

Determine the magnitude and direction of force (**P**), if the horizontal and vertical components are (**20N**),(**40N**) respectively.

Solution:

$$F = \sqrt{(F_X)^2 + (F_Y)^2}$$

$$F = \sqrt{(20)^2 + (40)^2} = \sqrt{400 + 1600} = \sqrt{2000} = 44.72\text{N}$$

$$\theta = \tan^{-1}\left(\frac{F_Y}{F_X}\right) = \tan^{-1}\left(\frac{40}{20}\right) = 63.43^\circ$$

Example(3)

Find the two components of the force (**100 N**) if:

θ=$\mathbf{30^\circ, 120^\circ, 270^\circ}$

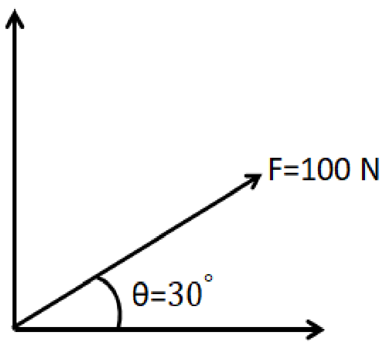
Solution:

$\boldsymbol{\theta = 30^\circ}$

$Fx = F \,.\cos\theta =$

$100 \text{ x} \cos 30 = 100\text{x}\ \frac{\sqrt{3}}{2} =$

$50\sqrt{3}\ \text{N} \quad \rightarrow$



$Fy = F.\sin\theta =$

$100 \text{ x} \sin 30 = 100 \text{ x } 0.5 =$

$50\ \text{N} \quad \uparrow$

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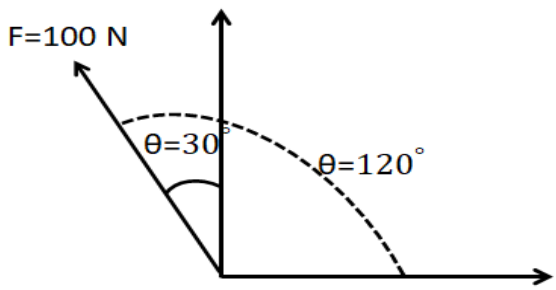
$\boldsymbol{\theta = 120^{\circ}}$

$\mathrm{Fx = F.\cos\theta =}$

$100 \text{ x} \cos 120 =$

$100 \text{ x}(-0.5) = -50 \text{ N} \quad \leftarrow$

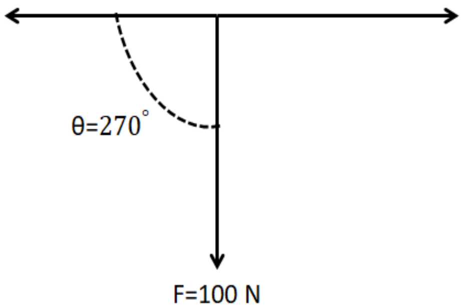


$\mathrm{Fy = F.\sin\theta =}$

$100 \text{ x} \sin 120 = 100 \text{ x } \frac{\sqrt{3}}{2} =$

$50\sqrt{3} \text{ N} \quad \uparrow$

$\boldsymbol{\theta = 270^{\circ}}$



$\mathrm{Fx = F.\cos\theta =}$

$100 \text{ x} \cos 270 = 100 \text{ x } 0 =$

0

$\mathrm{Fy = F.\sin\theta =}$

$100 \text{ x} \sin 270 =$

$100 \text{ x } (-1) = -100 \text{ N} \quad \downarrow$

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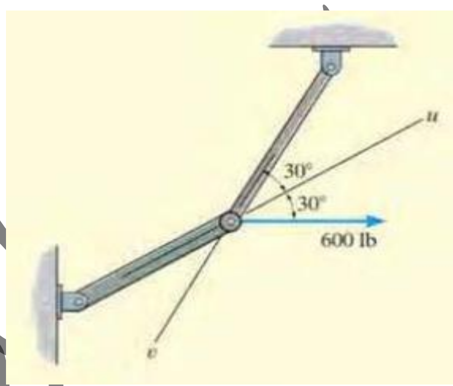
Example(4)

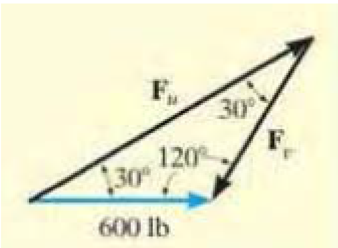
Resolve the horizontal **600 lb** force shown in figure into components acting along the **u** and **v** axes and determine the magnitudes of these components.

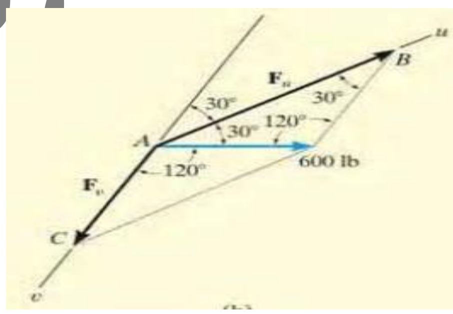


Solution:-

$$\frac{F_u}{\sin 120} = \frac{600}{\sin 30} \qquad F_u = 1039\ lb$$

$$\frac{F_v}{\sin 30} = \frac{600}{\sin 30} \qquad F_v = 600\ lb$$





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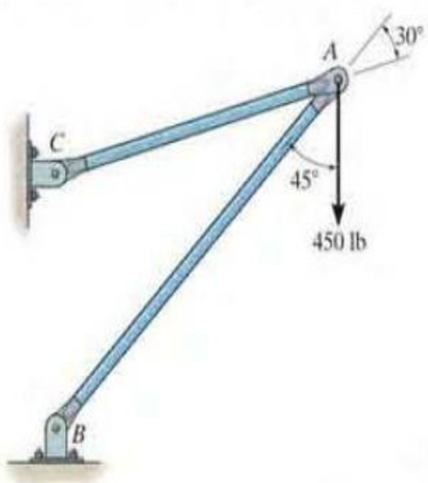
Example(5)

The force **F=450 lb** acts on the frame. Resolve this force into components acting along members **AB** and **AC**,and determine the magnitude of each components.



Solution:-

$$\frac{F_{AB}}{\sin 105} = \frac{450}{\sin 30} \qquad F_{AB} = 869\ lb$$

$$\frac{F_{AC}}{\sin 45} = \frac{450}{\sin 30} \qquad F_{AC} = 636\ lb$$

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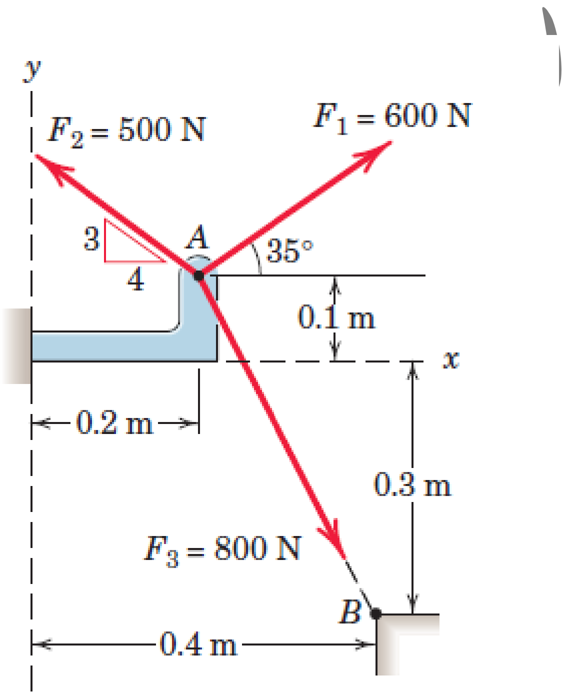
Example (6)

The forces **F**1, **F**2, and **F**3, all of which act on point *A* of the bracket, are specified in three different ways. Determine the *x* and *y* components of each of the three forces.

Solution:-



The components of F1 are

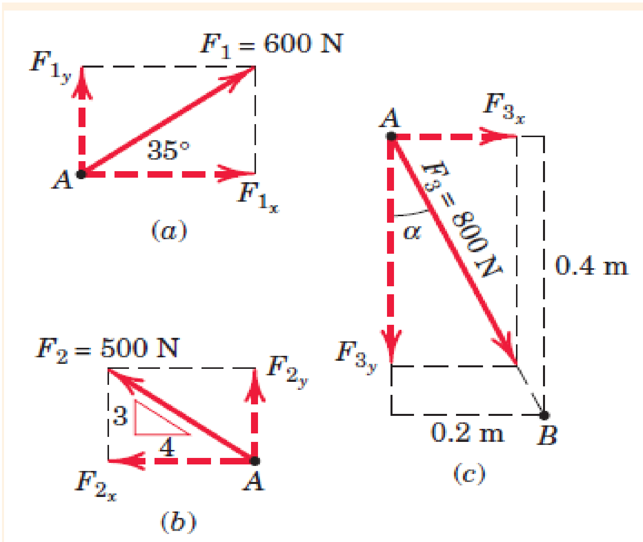
$$F1_X = 600\cos 35^\circ = 491\ N \rightarrow$$

$$F1_Y = 600\sin 35^\circ = 344\ N \uparrow$$

The components of F2 are

$$F2_X = -500\left(\frac{4}{5}\right) = -400\ N \leftarrow$$

$$F2_Y = 500\left(\frac{3}{5}\right) = 300\ N \uparrow$$



The components of F3 are

$$\alpha = \tan^{-1}\left(\frac{0.2}{0.4}\right) = 26.6^\circ$$

$$F3_X = F3\sin\alpha = 800\sin 26.6^\circ = 358\ N \rightarrow$$

$$F3_Y = -F3\cos\alpha = -716\ N \downarrow$$

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Example(7)

Determine the **x** and **y** components of $\mathbf{F_1}$ and $\mathbf{F_2}$ acting on the boom shown in figure.

Solution:-

By the parallelogram law.F1 is resolved into x and y components, Fig (b), since F1x acts in the -x direction, and F1y acts in the +y direction, we have.

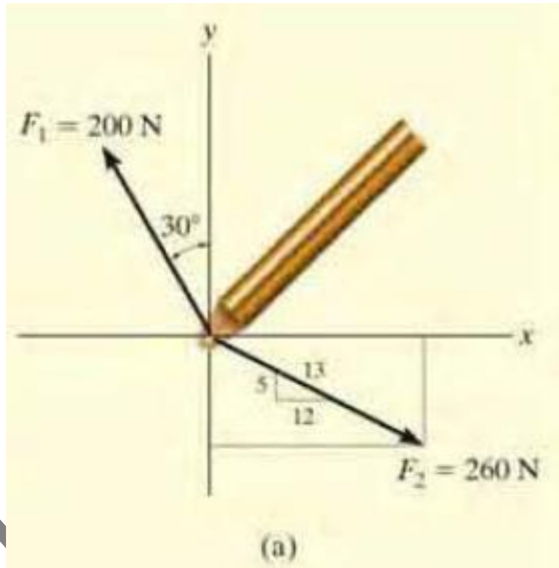
$$F_{1x} = -200\sin 30 = -100\ N\ \ \leftarrow$$

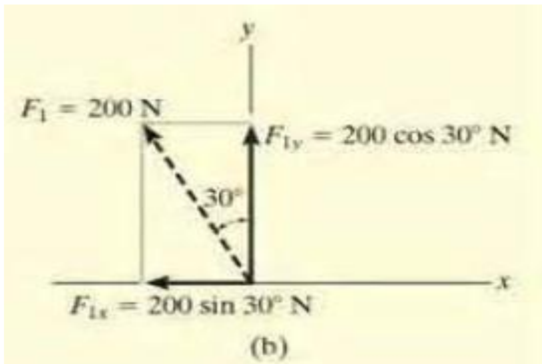
$$F_{1y}\ = 200\cos 30 = 173\ N\ \uparrow$$

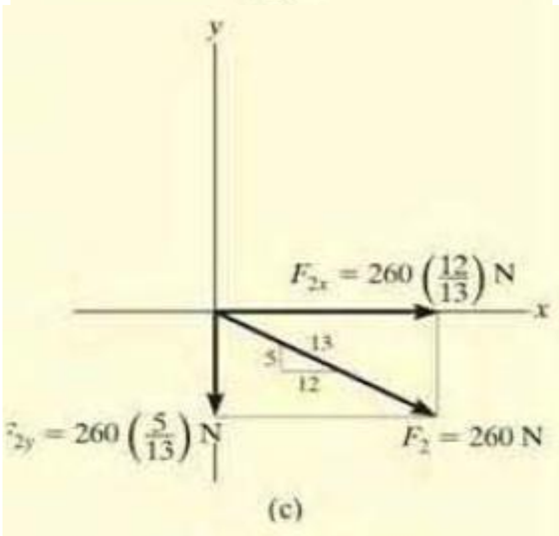
$$\frac{F_{2x}}{260} = \frac{12}{13} \qquad F_{2x} = 260\left(\frac{12}{13}\right) = 240\ \mathrm{N} \rightarrow$$

similarly

$$\mathrm{F_{2x}} = 260\left(\frac{5}{13}\right) = 100\ \mathrm{N} \downarrow$$







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Example(8)

The **500 N** force **F** is applied to the vertical pole as shown in figure.

1. Determine the components of the force **F** along the **x́** and **ý** axis.

2. Determine the components of the force **F** along the **x** and **ý** axis.

Solution:-

1. From Fig (b)

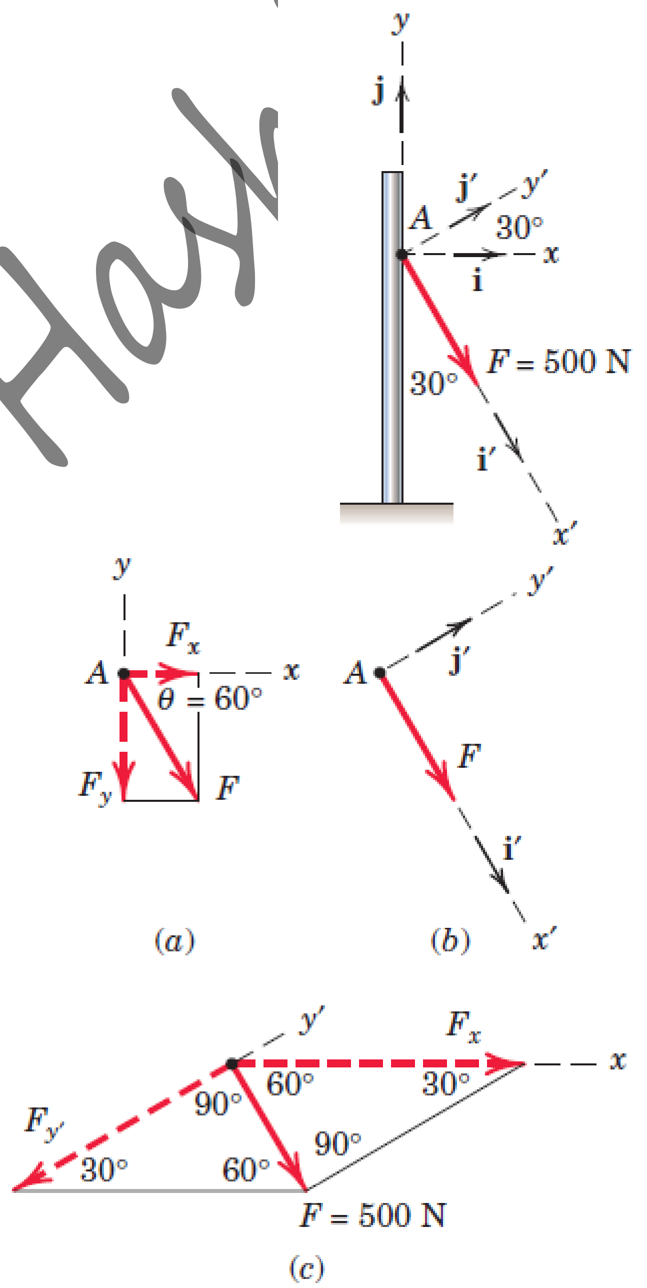
$F_{\acute{x}} = 500\ N \rightarrow \quad F_{\acute{y}} = 0$

2. The components of F in the x and ý directions are nonrectangular and are obtained by completing the parallelogram as shown in fig (c). The magnitudes of the components may be calculated by the law of sines. Thus,

$$\frac{|F_X|}{\sin 90} = \frac{500}{\sin 30} \qquad |F_X| = 1000N$$

$$\frac{|F_{\acute{Y}}|}{\sin 60} = \frac{500}{\sin 30} \qquad |F_{\acute{Y}}| = 866N$$

=-866 N↓$F_X = 1000\ N \rightarrow \quad F_{\acute{Y}}$



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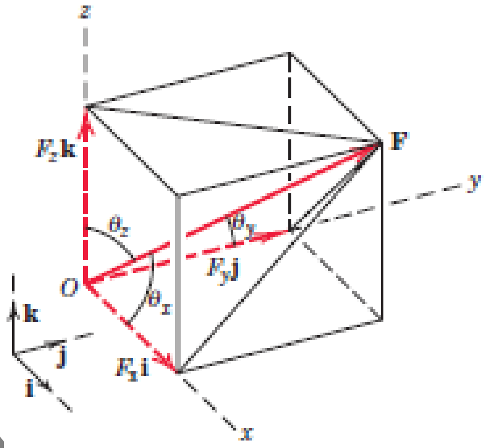
Three Dimensional Force System

Resolving a force into rectangular components

The force **F** acting at point O in figure

has the rectangular components Fx, Fy, Fz, where



$F_x = F\cos\theta_x \qquad \cos\theta_x = \frac{F_x}{F}$

$F_y = F\cos\theta_y \qquad \cos\theta_y = \frac{F_y}{F}$

$F_z = F\cos\theta_z \qquad \cos\theta_z = \frac{F_z}{Z}$

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

In vector expression:-

$$F = F_x i + F_y j + F_z k$$

$$F = F(i\cos\theta_x + j\cos\theta_y + k\cos\theta_z)$$

Note:-

The cosine of θ_x, θ_y and θ_z are called direction cosine.

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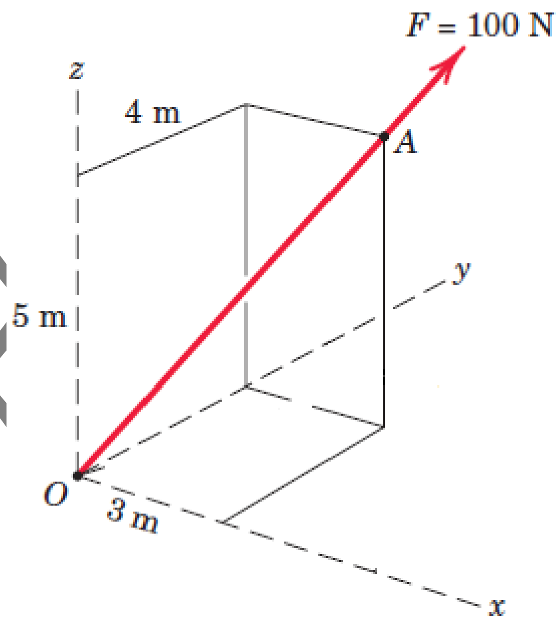
Example(9)

A force **F** with a magnitude of **100 N** is applied at the origin **O** of the axes **x-y-z** as shown. The line of action of **F** passes through a point **A** whose coordinates are **3** m, **4** m, and **5** m. Determine the **x, y,** and **z** scalar components of **F**.

Solution:-



Length of OA=$\sqrt{3^2+4^2+5^2} = 7.07$

$$\cos\theta_x = \frac{3}{7.07}$$
$$\cos\theta_y = \frac{4}{7.07}$$
$$\cos\theta_z = \frac{5}{7.07} = 0.707$$

$$F_x = F\cos\theta_x = 100\frac{3}{7.07} = 42.4$$
$$F_y = F\cos\theta_y = 100\frac{4}{7.07} = 56.6$$
$$F_z = F\cos\theta_z = 100\frac{5}{7.07} = 70.7$$

To express the force as a vector

$$\vec{F} = 100\left(\frac{3}{7.07}\vec{\imath} + \frac{4}{7.07}\vec{\jmath} + \frac{5}{7.07}\vec{k}\right)$$

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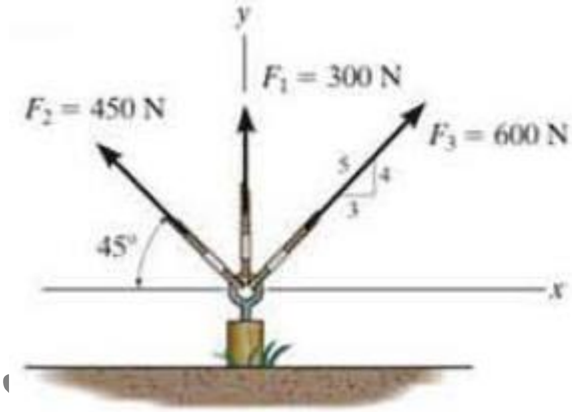
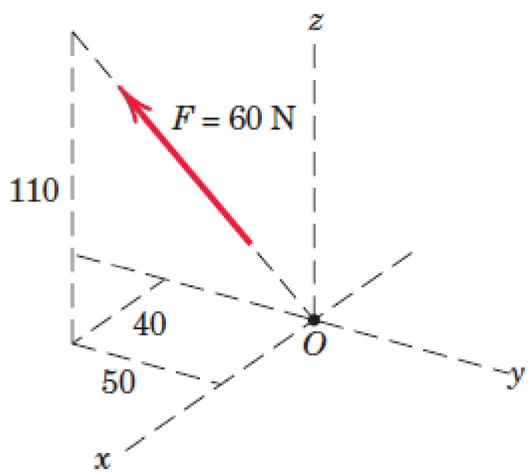
Home Work(1)

1. Resolve each force acting on the post into its x and y components.



2. Express **F** as a vector in terms of the unit vectors **i**, **j**, and **k**. Determine the angle between **F** and the y-axis.



Dimensions in millimeters

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