ENGINEERING MECHANICS
(BCIVC203)

Course Contents

Module 1: Analysis of Coplanar Concurrent & Non-Concurrent Force System

Module 2: Equilibrium of Coplanar Concurrent & Non-Concurrent Force System

Module 3: Friction & Analysis of Truss

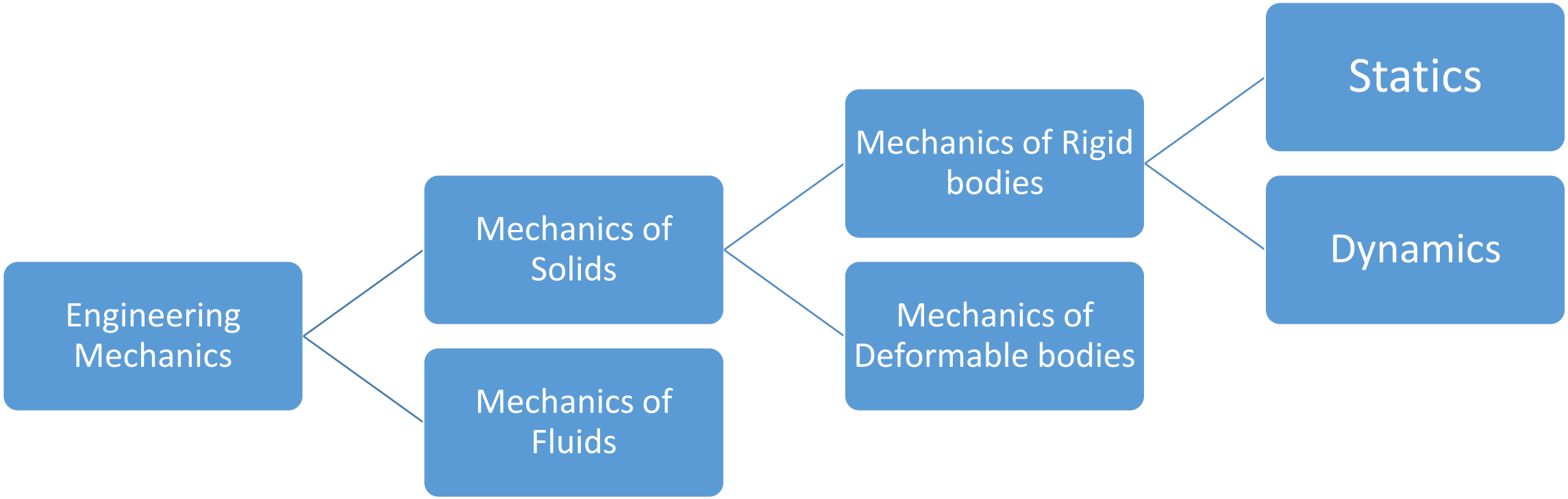
Module 4: Centroid & Moment of Inertia

Module 5: Kinematic & Kinetics

Course Outcomes

At the end of the course the student will be able to:

- Compute the resultant of a force system and resolution of a force
- Comprehend the action for forces, moments, and other types of loads on rigid bodies and compute the reactive forces
- Analyze the frictional resistance offered by different planes
- Locate the centroid and compute the moment of inertia of sections
- Analyze the bodies in motion


Engineering Mechanics
Mechanics of Solids
Mechanics of Fluids
Mechanics of Rigid bodies
Mechanics of Deformable bodies
Statics
Dynamics

MODULE – 1

Coplanar Concurrent & Non-Concurrent Force System

Basic Concepts

- Matter
- Mass
- Particle
- Volume
- Scalar and Vector Quantities
- Displacement and distance travelled
- Speed, Velocity & Acceleration
- Momentum
- Rigid & Deformable body
- Continuum

- Force
- Units of force: SI unit is Newton (N) or kilo Newton (kN)
- Point force
- **Characteristics of Force**

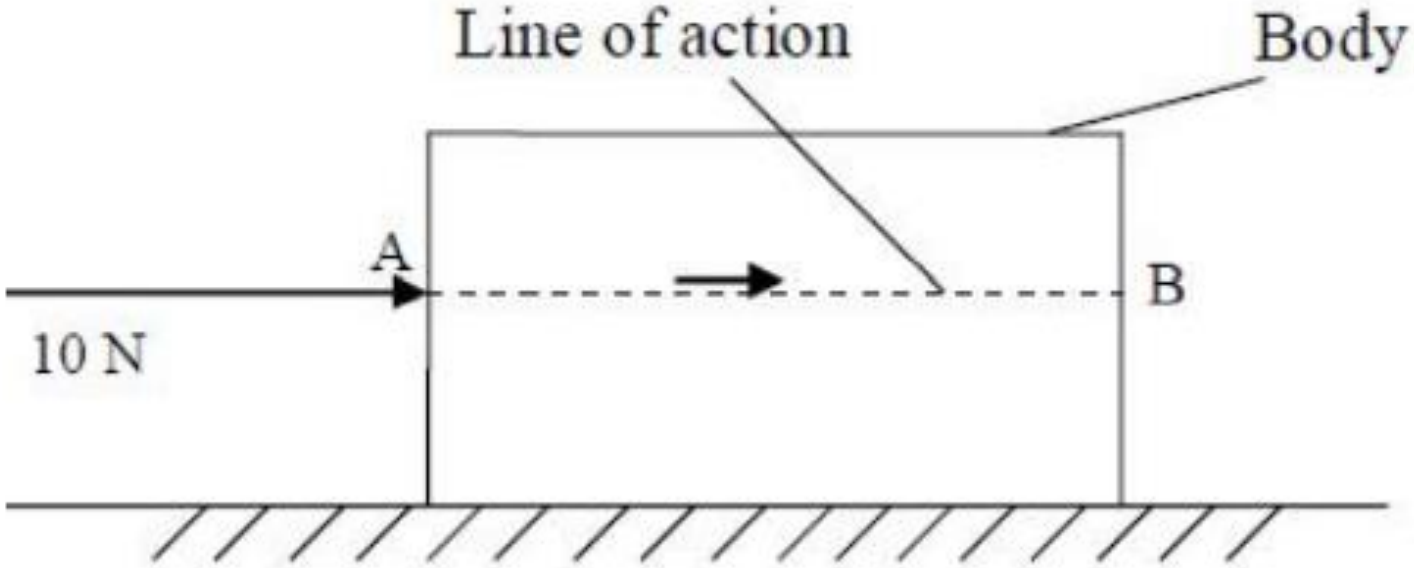
❖Magnitude

❖Line of action

❖Point of Application

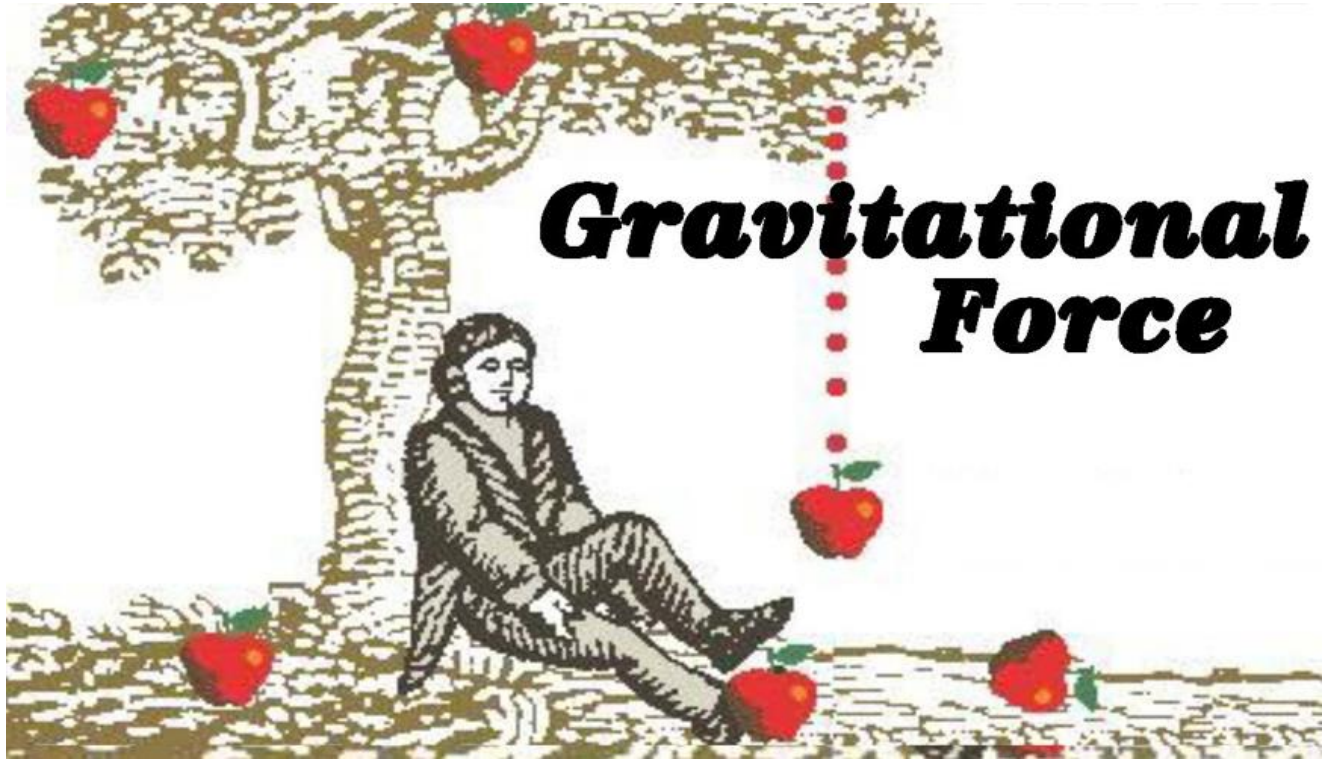
❖Direction

❖Nature of Application



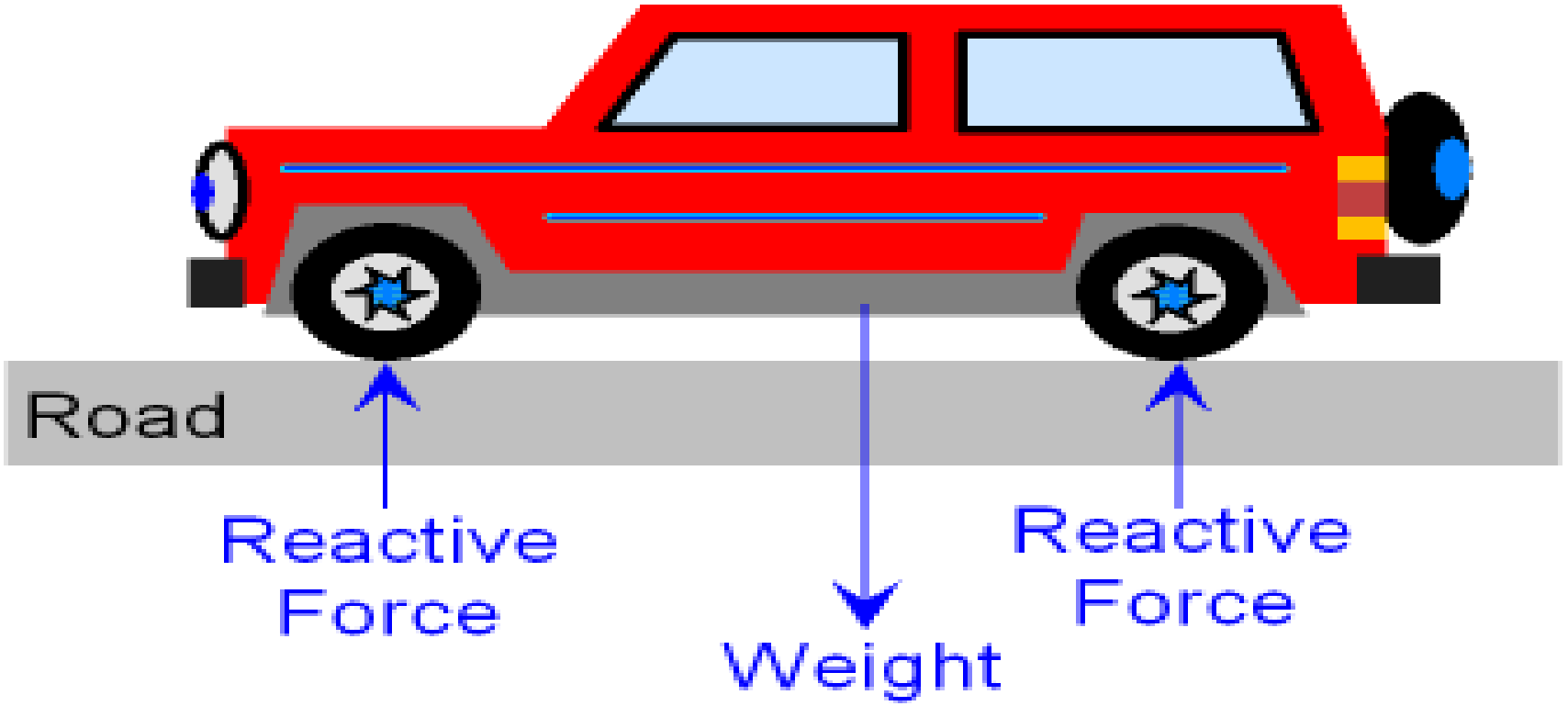
Types of Forces

1. Gravitational Force: Every object on the surface of the earth or near it, is attracted towards the center of center of the earth



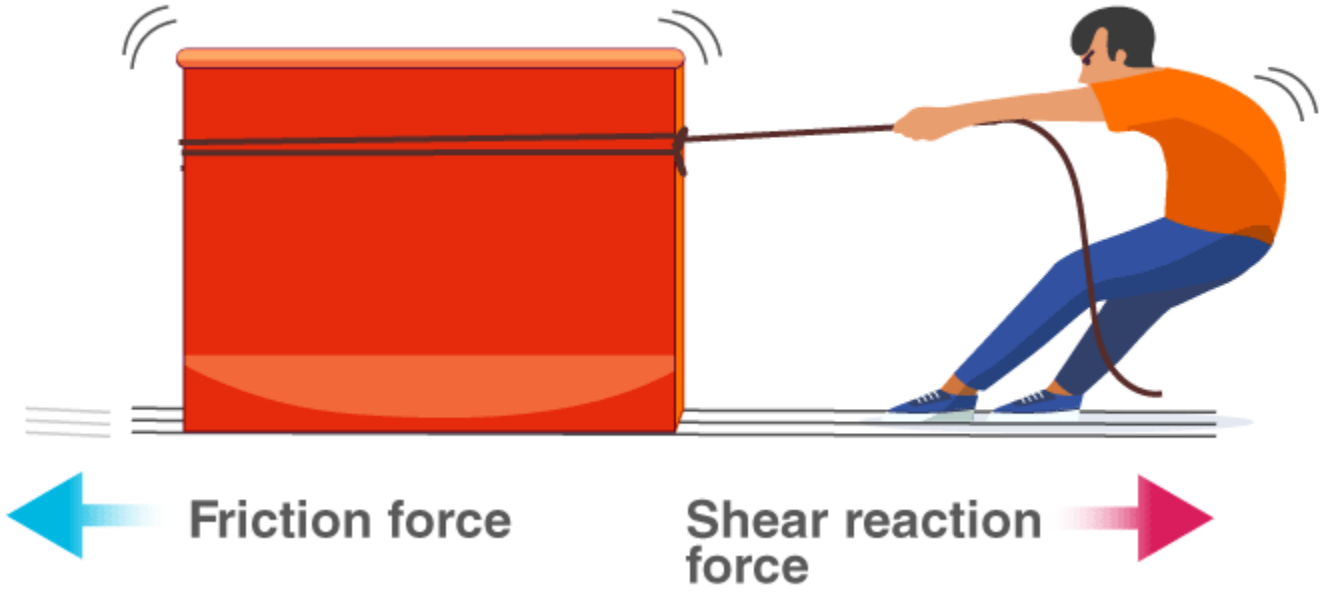
Types of Forces

2. Reactive Force: A force generated when an object applies a force on another object in contact with it



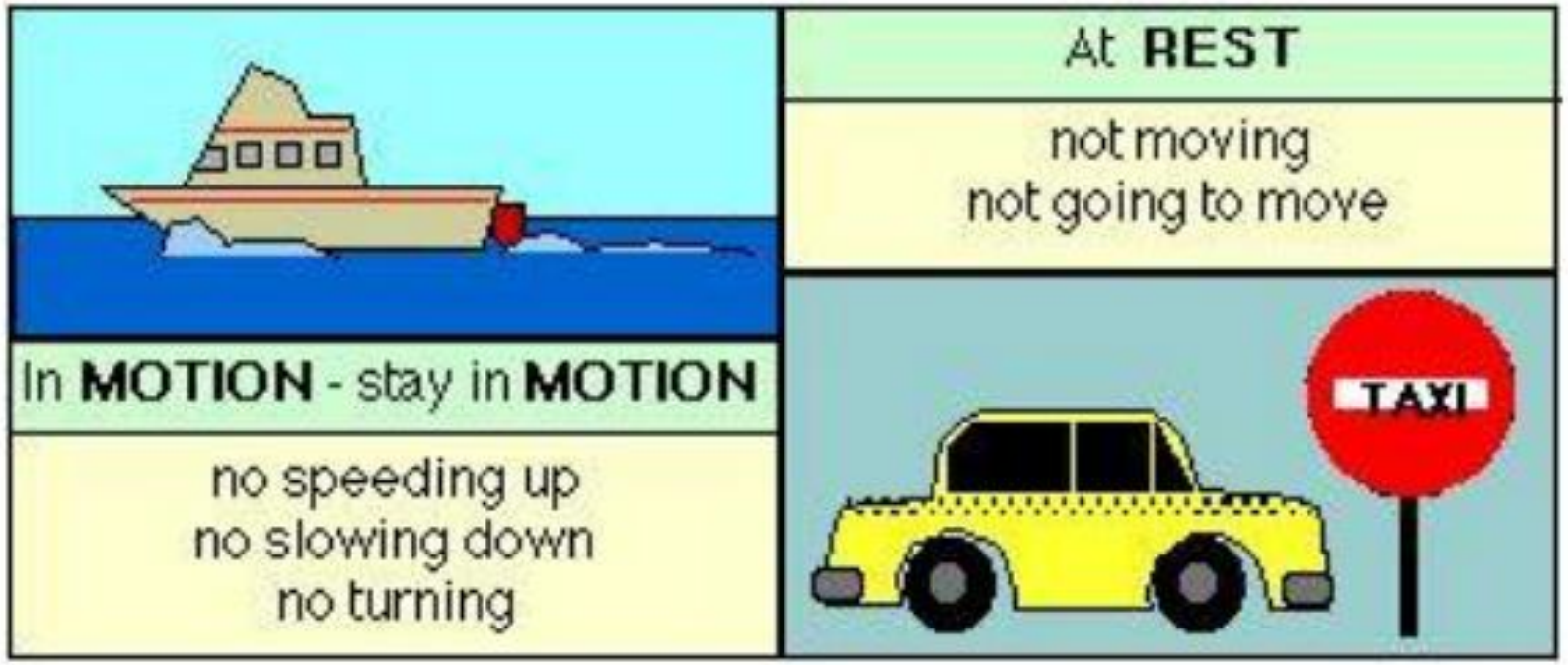
Types of Forces

3. Frictional Force: The force of friction is the one which opposes the force causing movement of the body on the surface of the other



Types of Forces

4. Inertial Force: Inertia force is present in every object which tends to resist any attempt to change its existing state of rest or motion by application of force from outside



Assumptions in Mechanics

1) A body consists of continuous distribution of matter.

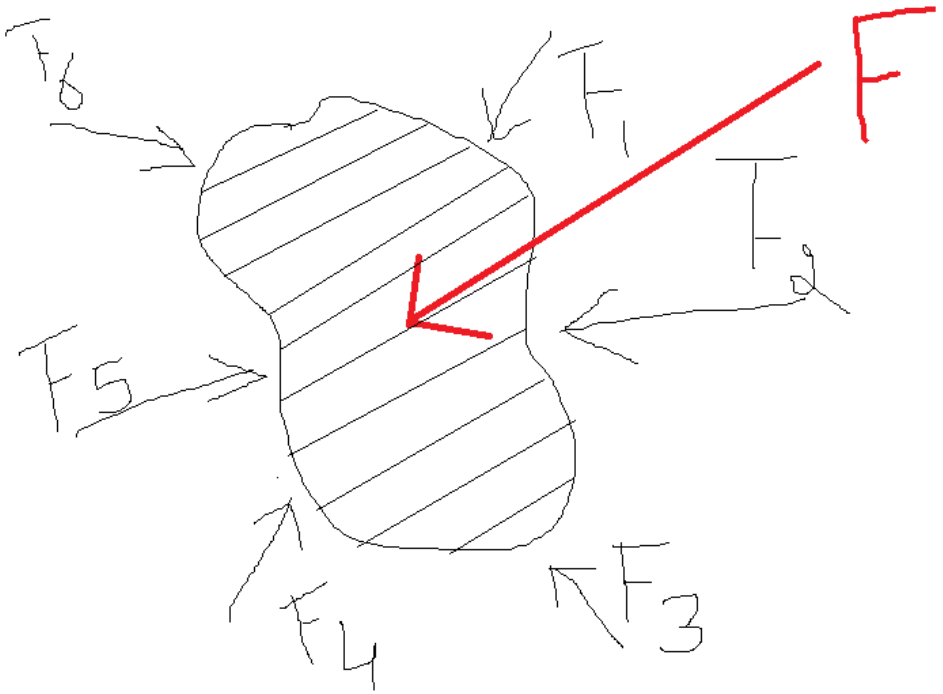
2) The body considered is perfectly rigid.

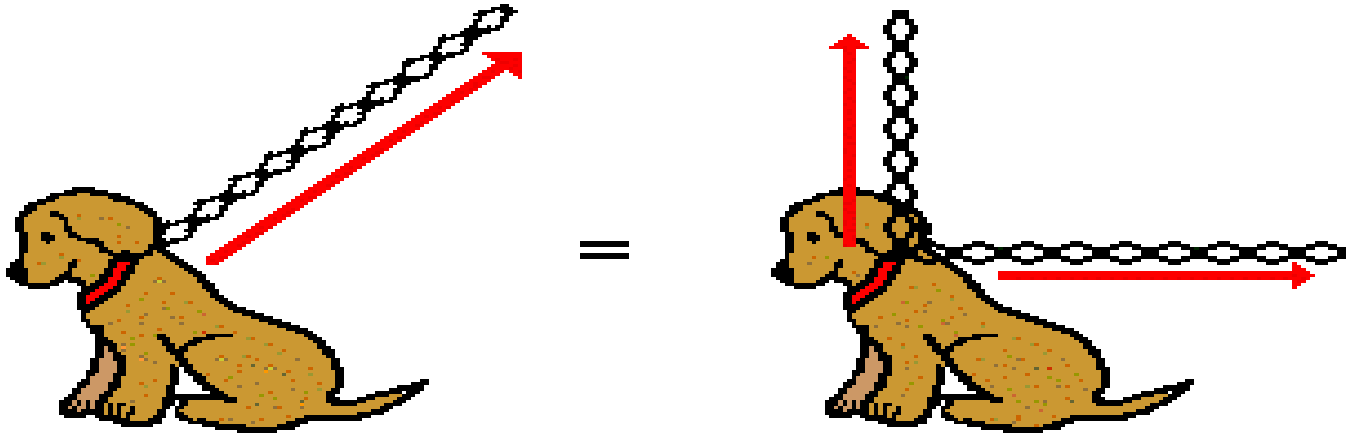
3) A particle has mass but not size.

4) A force acts through a very small point.

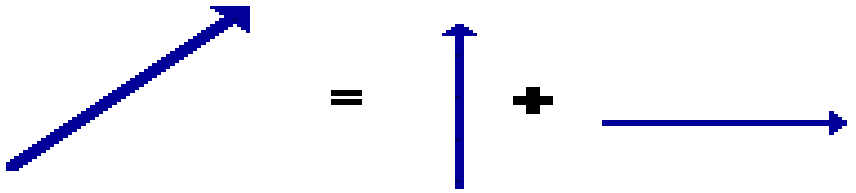
Principles of Force Systems

1. Principle of Physical Independence





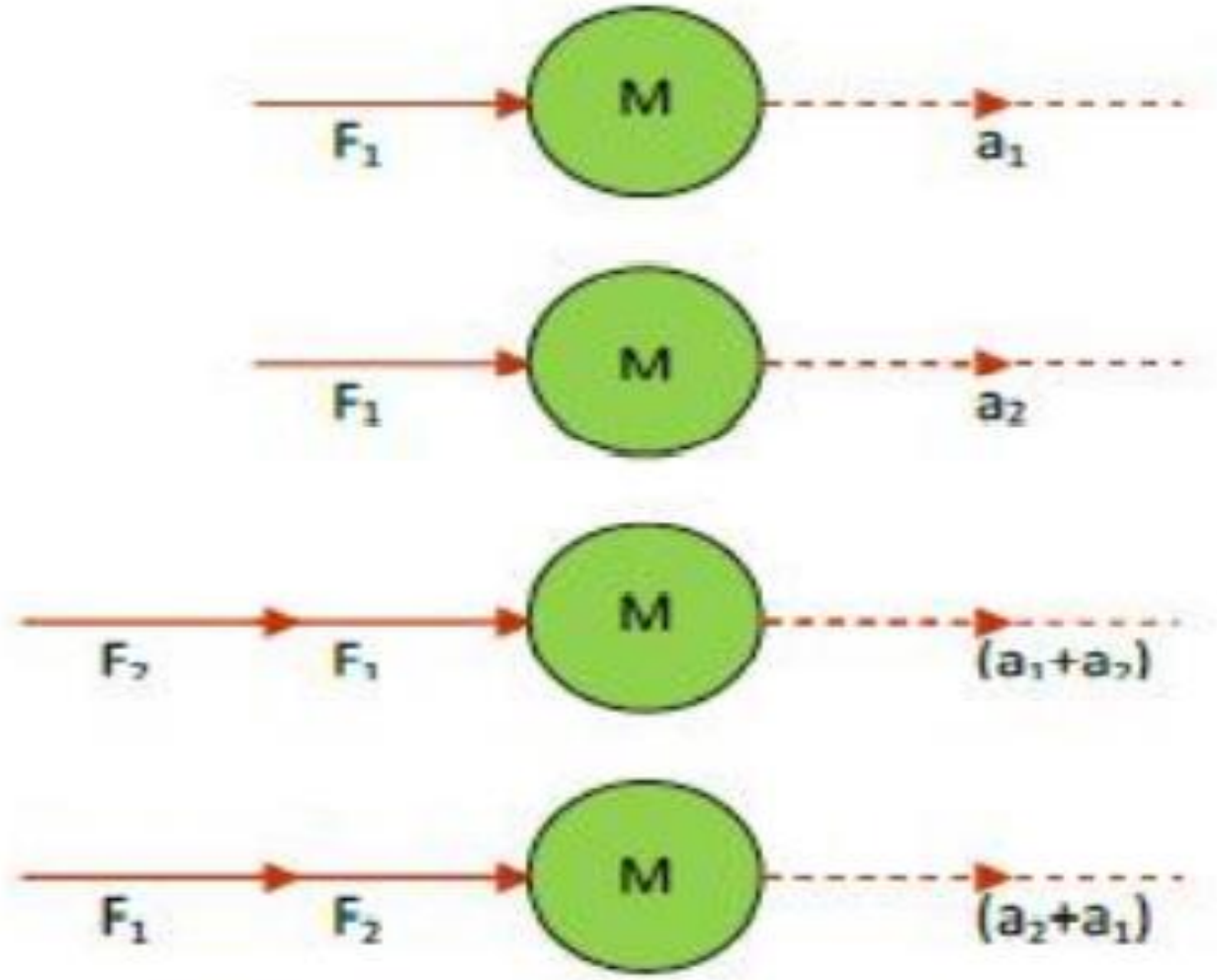
A pull upon Fido's chain in an upward and a rightward direction exerts two separate influences upon Fido – an upward and a rightward influence.



The force exerted at the angle is equal to the vector sum of the two individual forces.

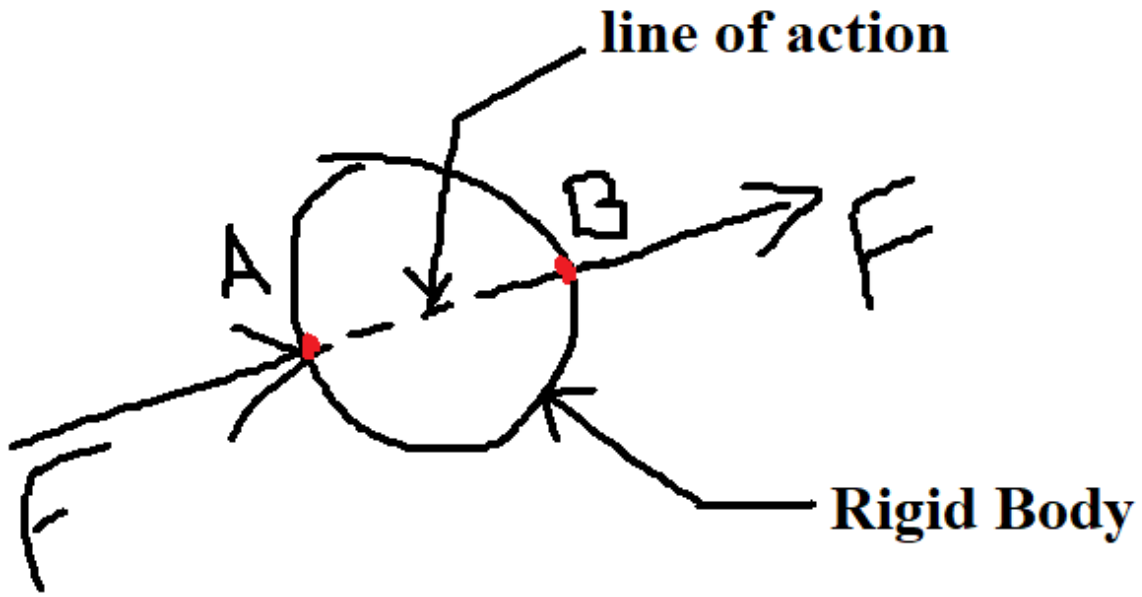
Principles of Force Systems

2. Principle of Superposition of forces



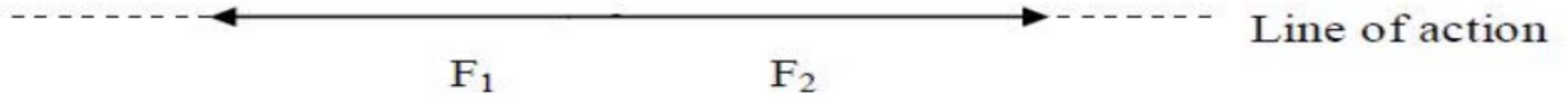
Principles of Force Systems

3. Principle of Transmissibility



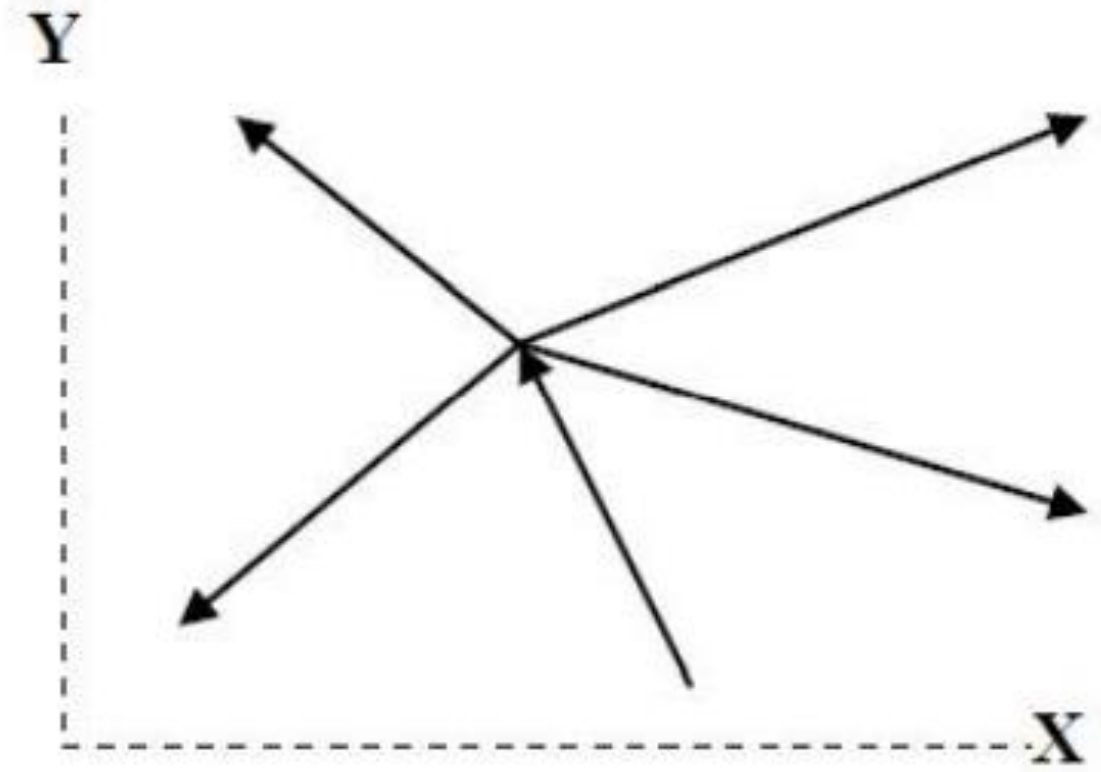
Classification of Force System

Collinear Forces



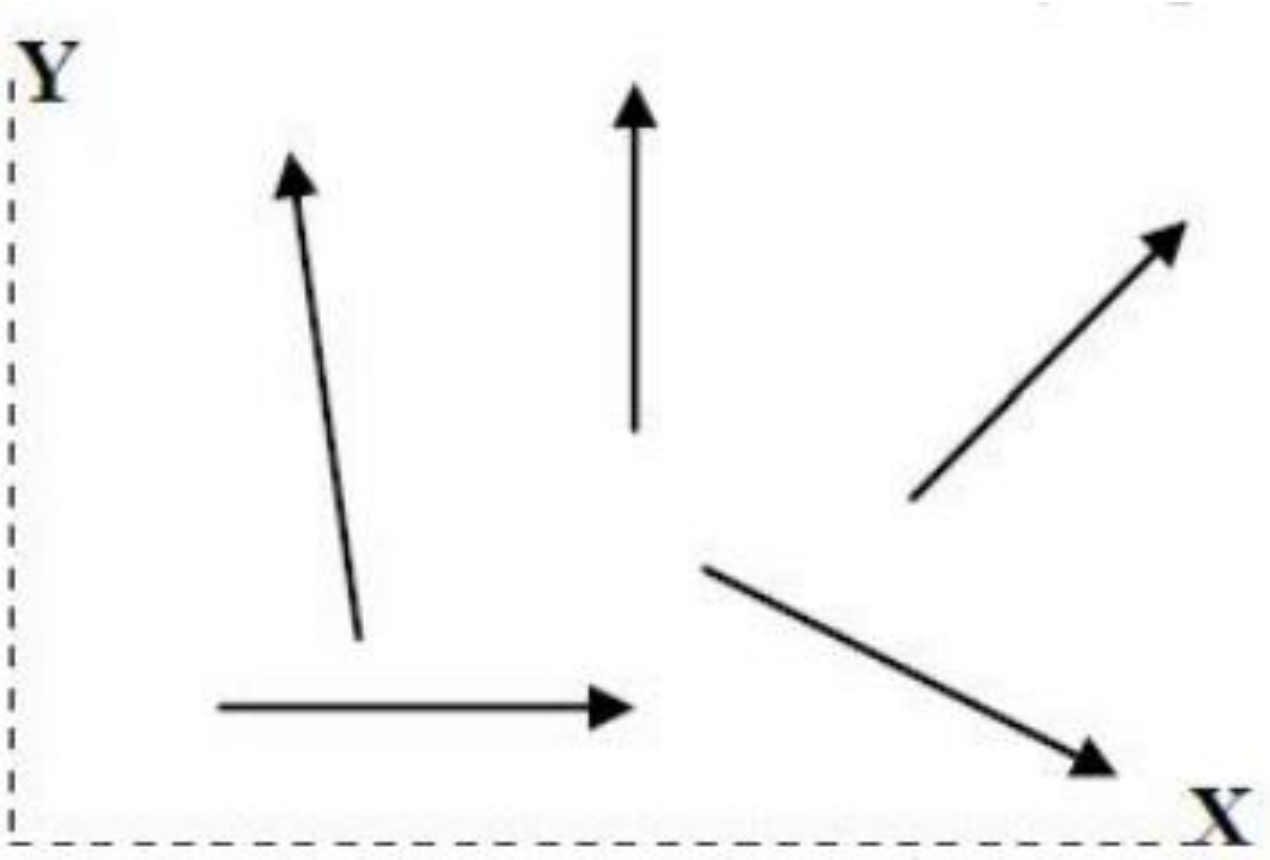
Classification of Force System

Coplanar Concurrent forces



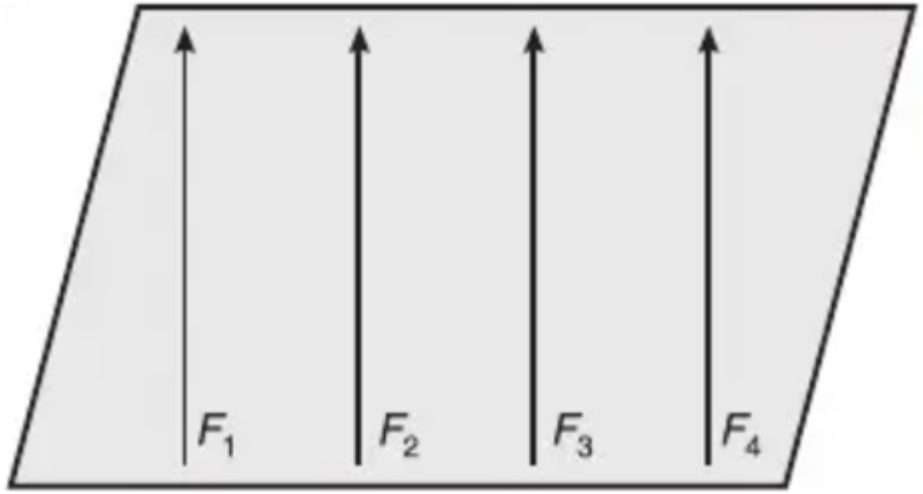
Classification of Force System

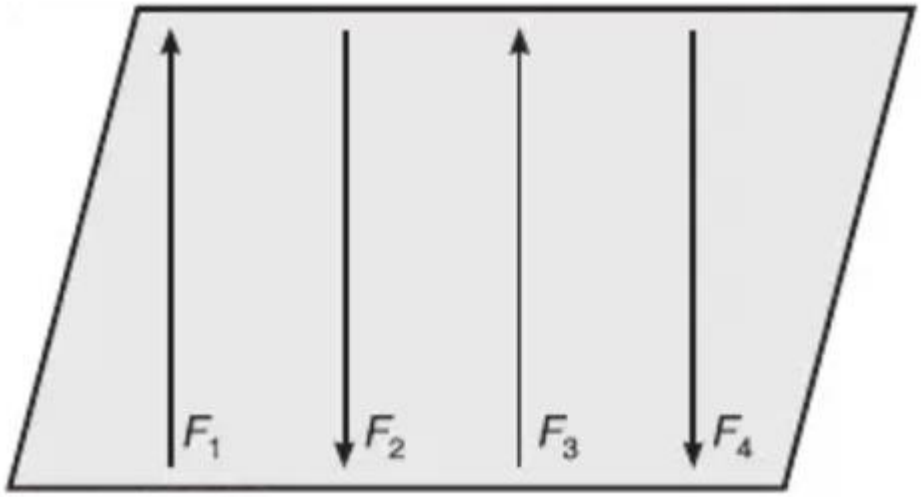
Coplanar non-concurrent forces



Classification of Force System

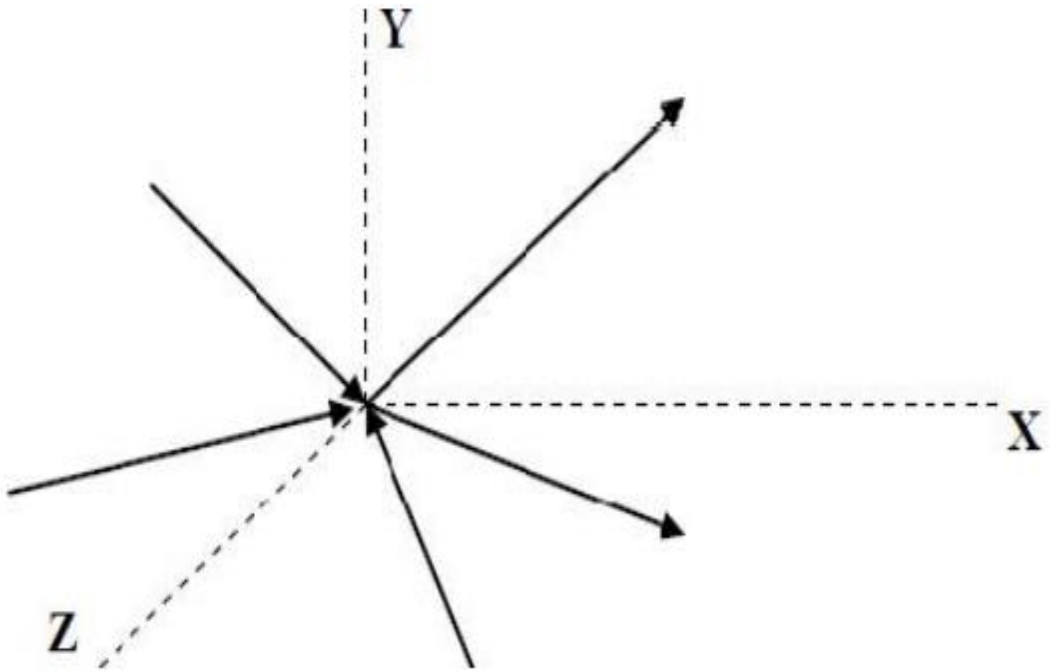
Coplanar parallel forces

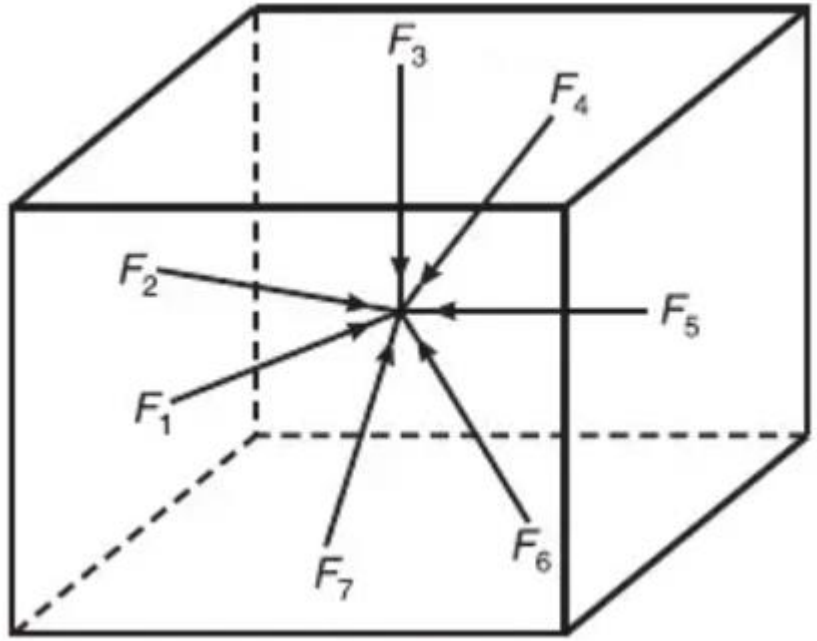




Classification of Force System

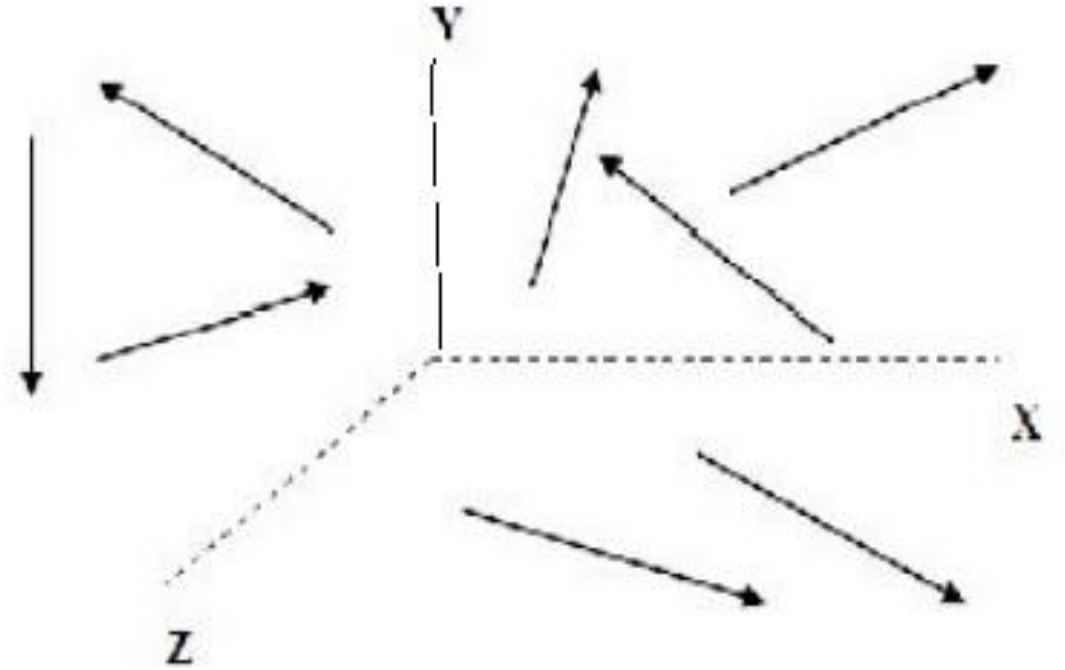
Non- coplanar concurrent forces

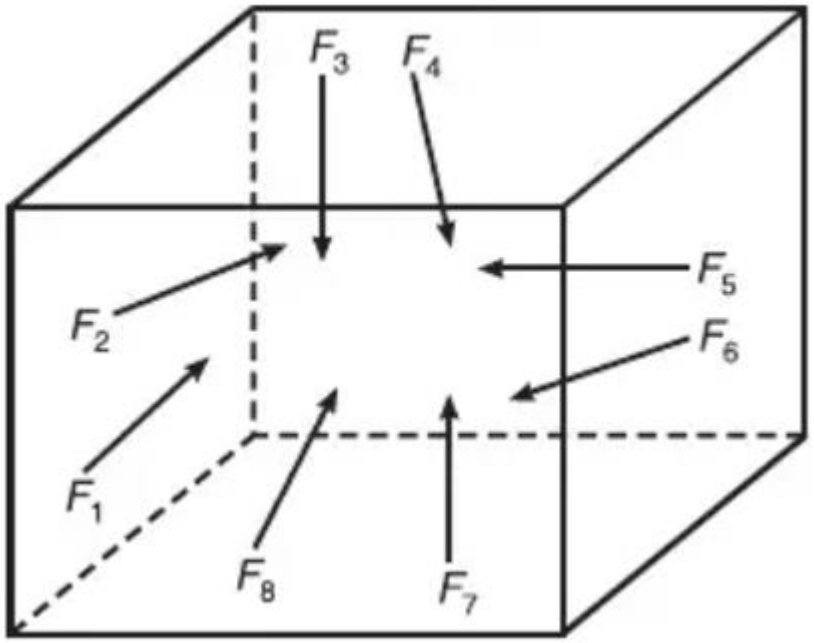




Classification of Force System

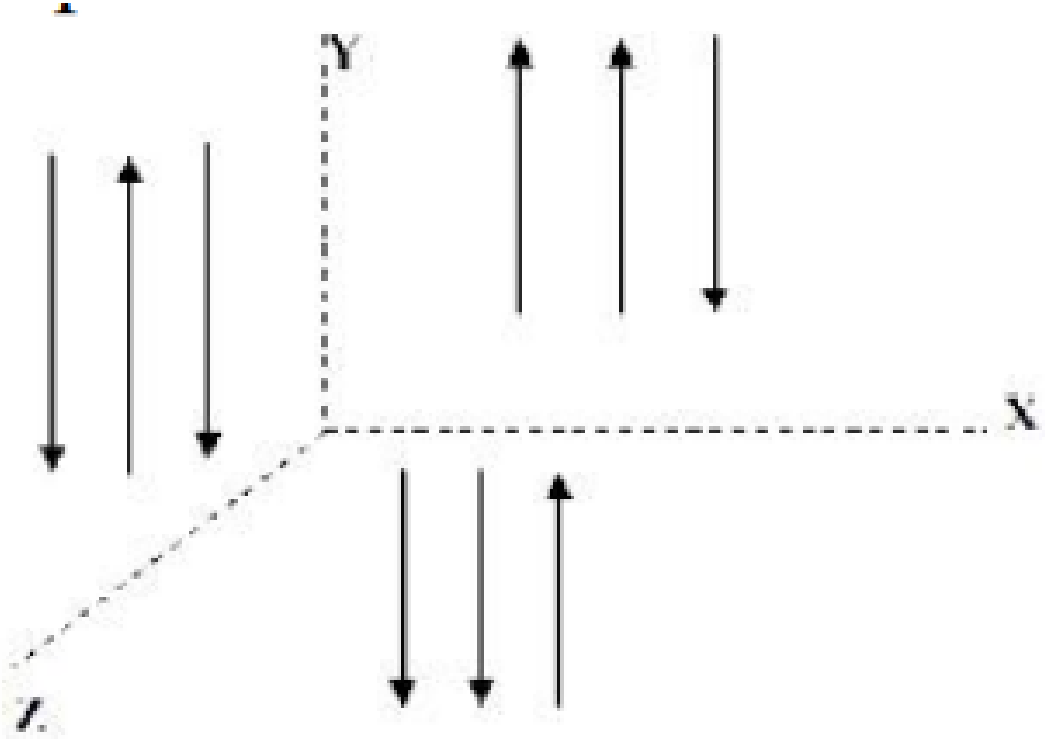
Non- coplanar non-concurrent forces:

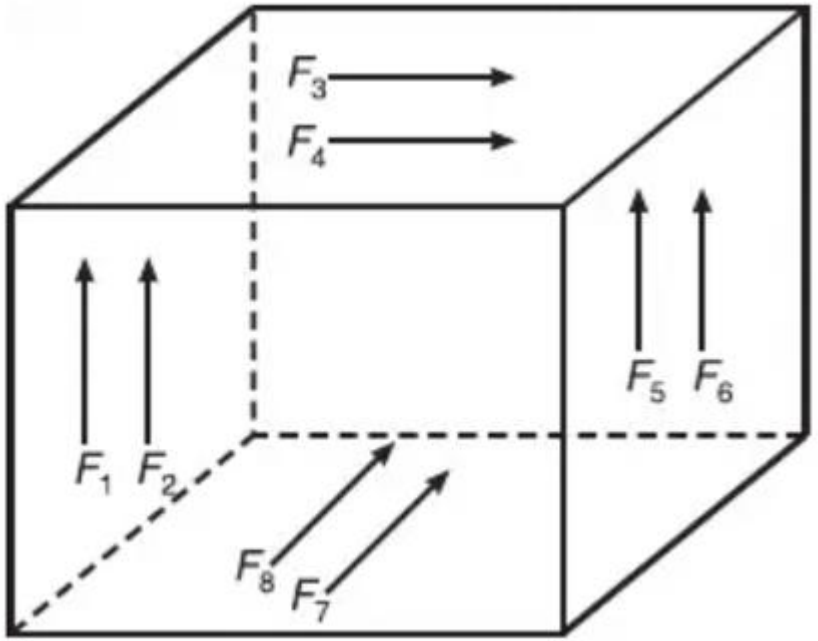




Classification of Force System

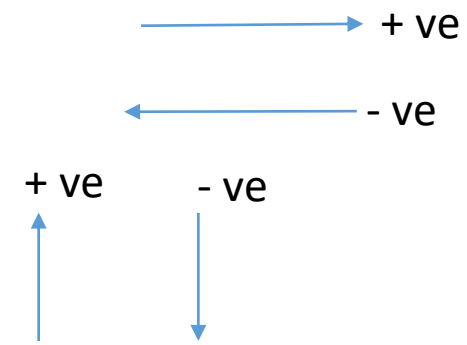
Non- coplanar parallel forces



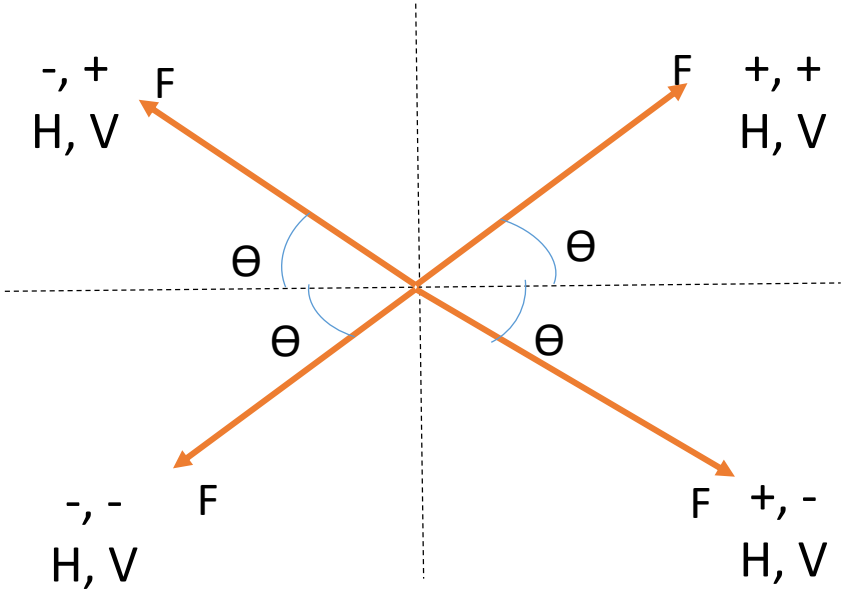


BASICS OF SIGN CONVENTION

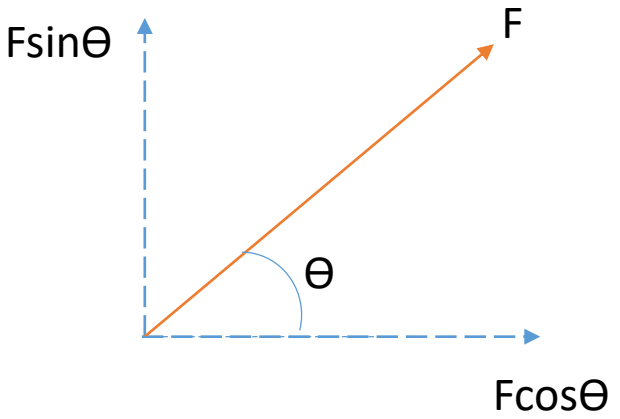
- Horizontal Force
- Vertical Force

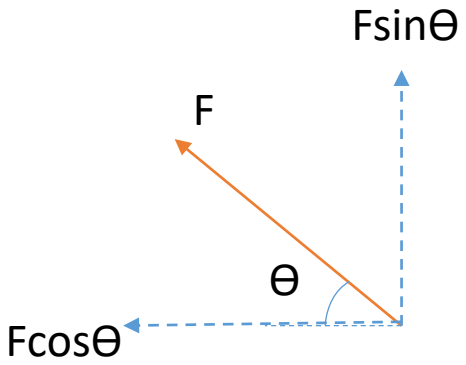


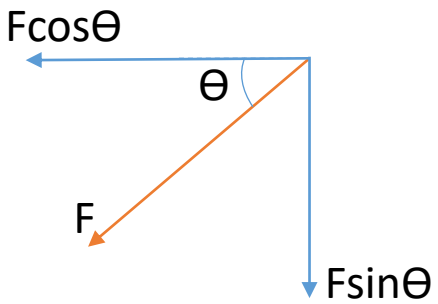
- For Inclined Resolution of Forces

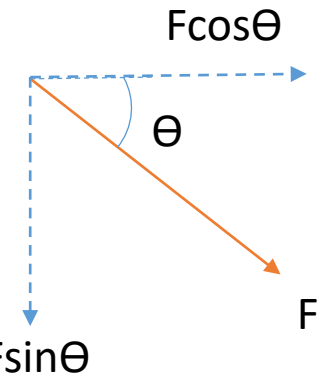


Quadrant System









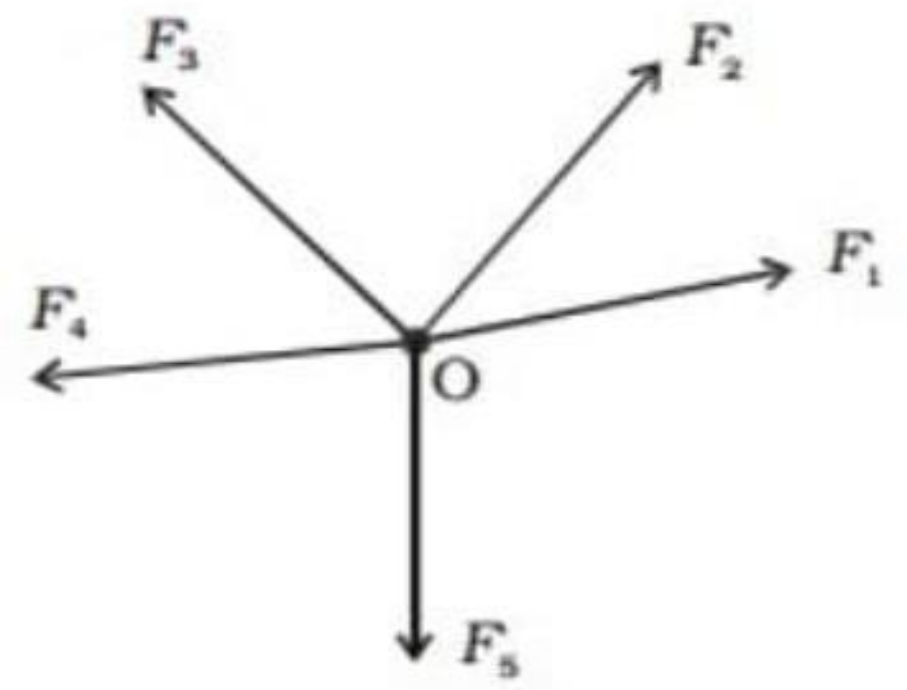
CO-PLANAR CONCURRENT FORCE SYSTEM

- Add all the Horizontal forces by considering the sign convention ie $\sum F_x$
- Add all the Vertical forces by considering the sign convent
- Determine the magnitude of Resultant

$$R = \sqrt{(\sum F_X)^2 + (\sum F_y)^2}$$

- Direction of Resultant

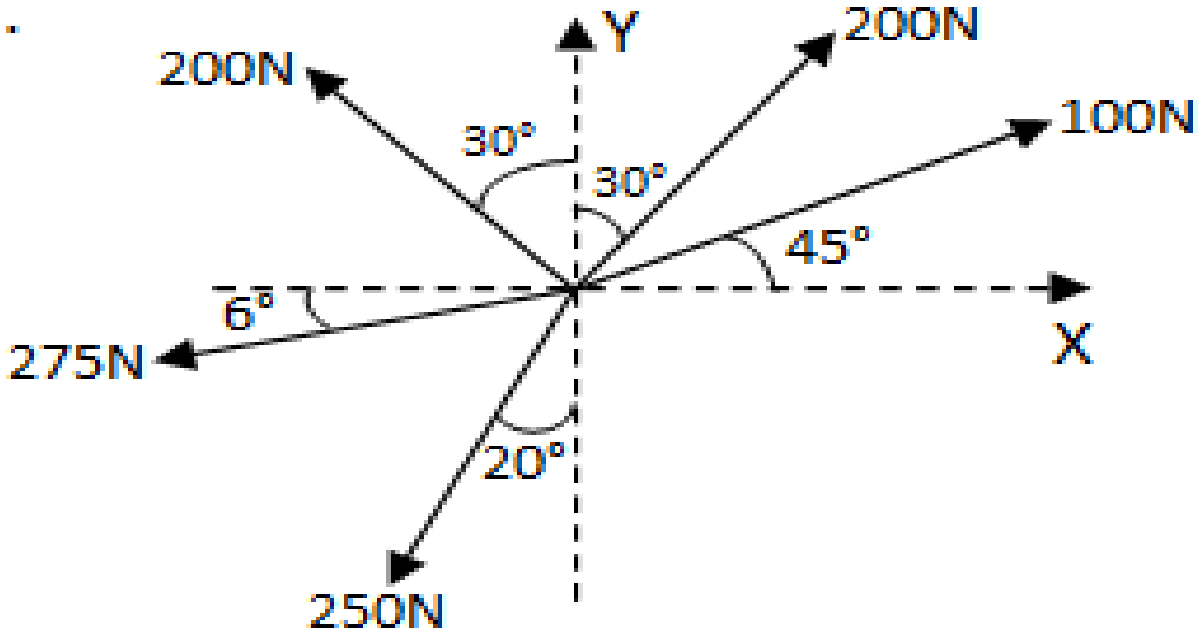
$$\tan\theta = \frac{\sum F_y}{\sum F_x}$$



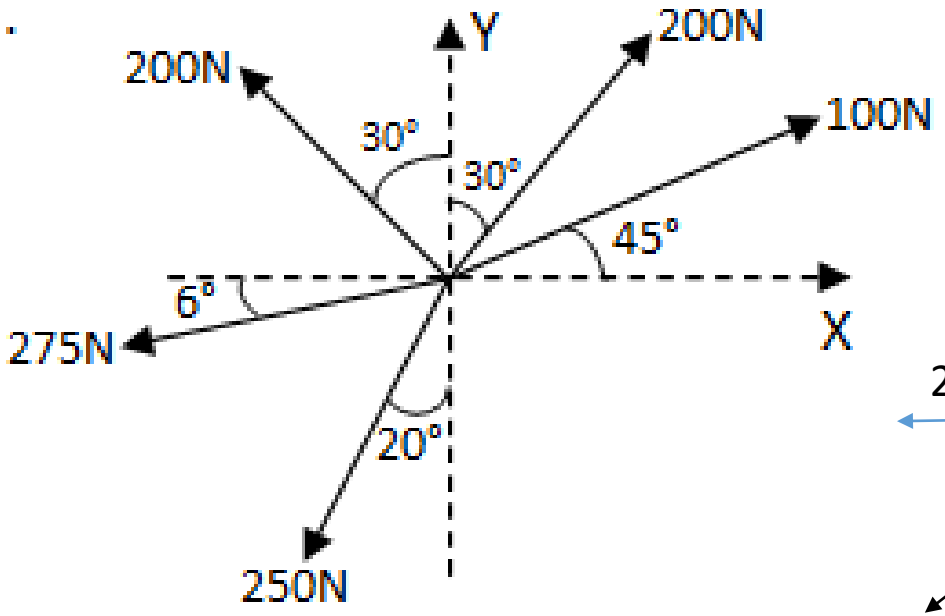
PROBLEMS ON CO-PLANAR CONCURRENT FORCE SYSTEM

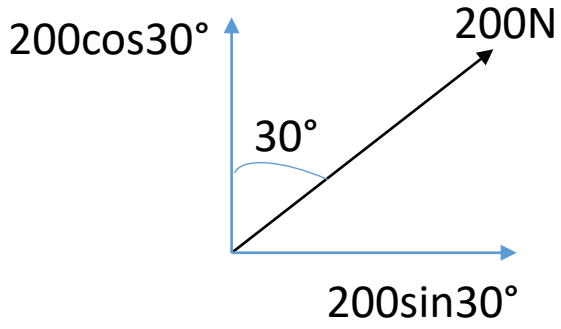
Five coplanar forces are acting at a point as shown in figure. Determine the resultant in terms of magnitude & direction

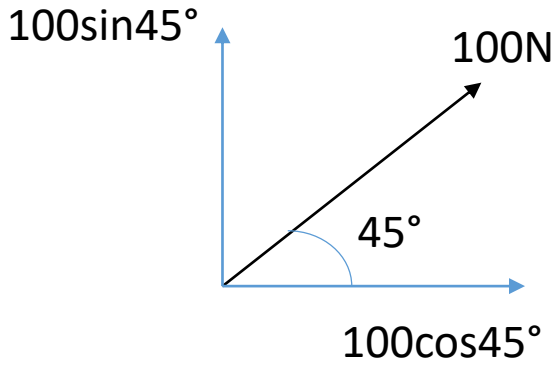
To find: R=? & Θ=?

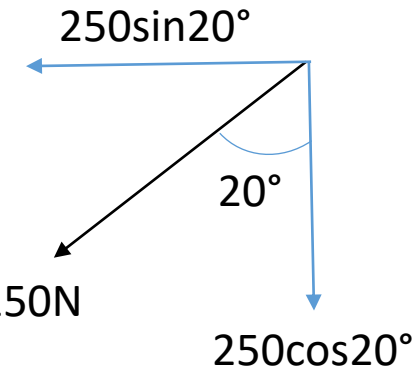


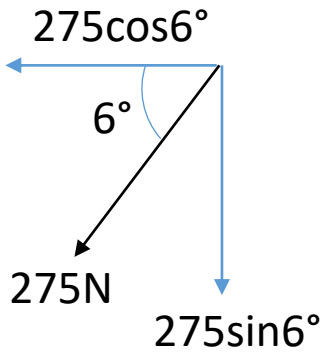
Resolving the inclined forces

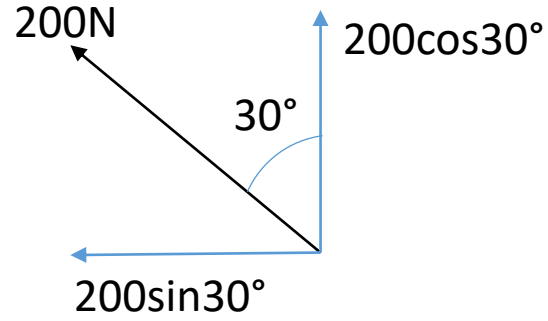












$$\sum F_x = 200\sin30° + 100\cos45° - 250\sin20° - 275\cos6° - 200\sin30° = -288.28N$$

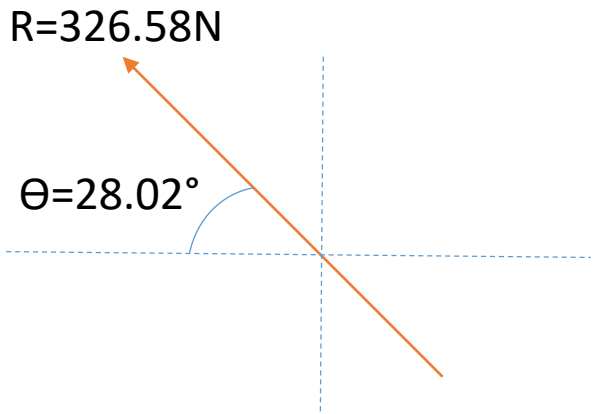
$$\sum F_y = 200\cos30° + 100\sin45° - 250\cos20° - 275\sin6° + 200\cos30° = 153.45N$$

Magnitude of Resultant

$$R = \sqrt{(\sum F_X)^2+(\sum F_y)^2} = \sqrt{(-288.28)^2+(153.45)^2} = 326.58N$$

Direction of Resultant

$$\tan\Theta = \frac{\sum F_y}{\sum F_x} = \frac{153.45}{-288.28} = 28.02° \text{ (-ve sign is neglected)}$$

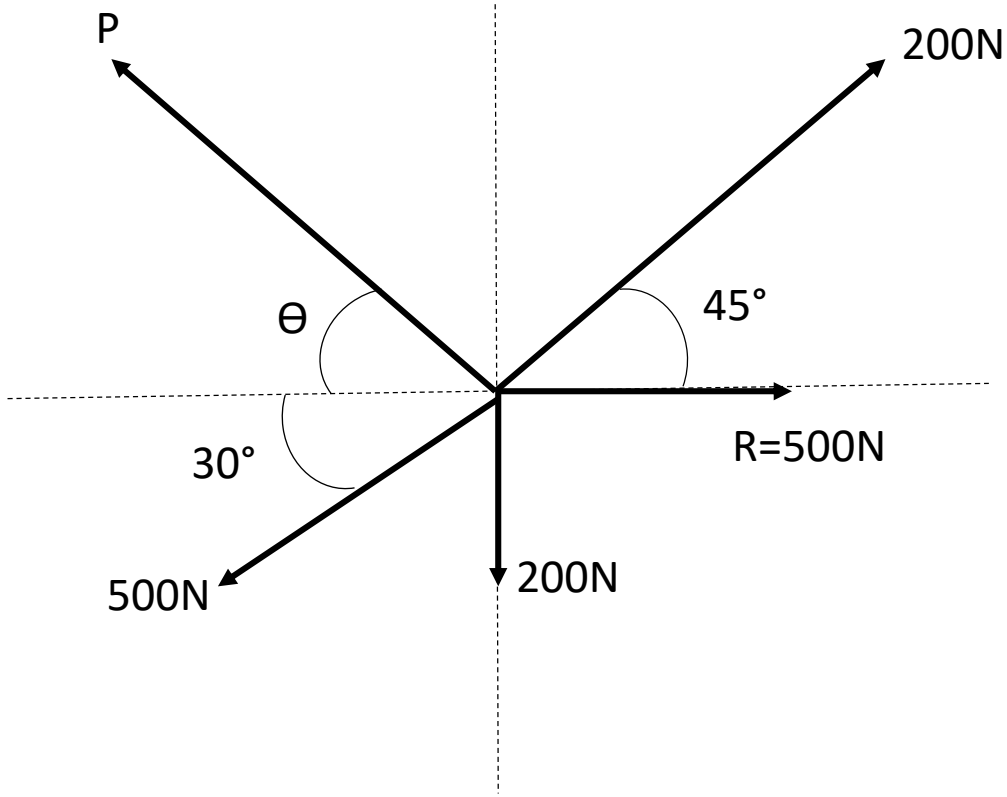


Result

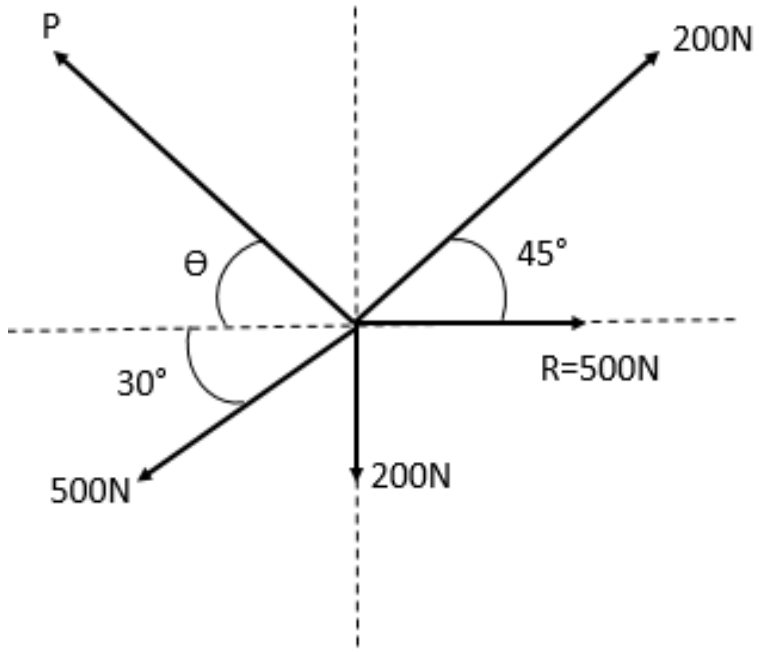
Four co-planar forces acting at a point are shown in fig. One of the force is unknown & its magnitude is represented by P. The resultant has a magnitude of 500N & it is acting along the x-axis. Determine the unknown force P & its inclination wrt x-axis.

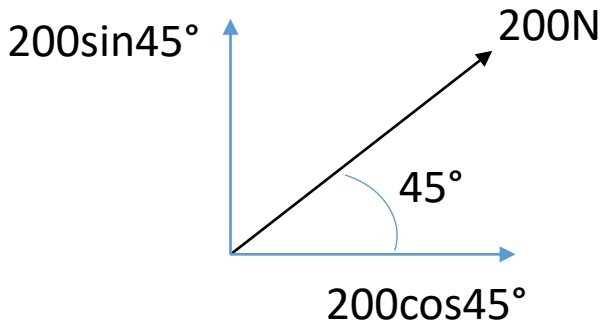
Given: R = 500N

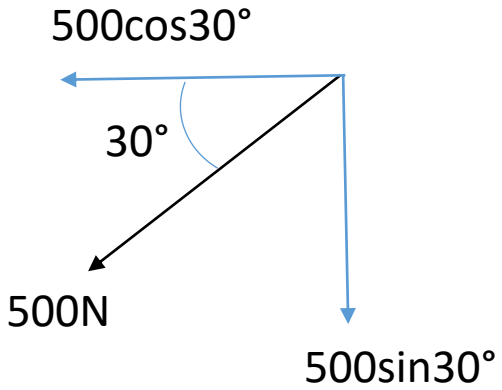
To find: P=? & Θ=?

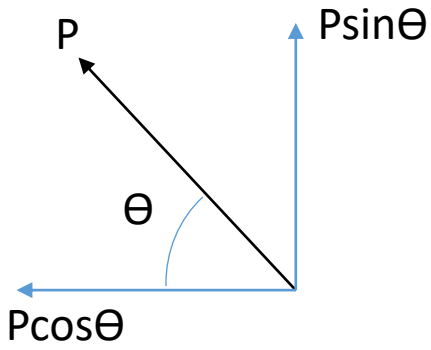


Resolving the inclined forces









$\sum F_x$ = ..

200cos45°- 500cos30° - PcosΘ = 500N ⟹ PcosΘ = -791.59N ----- (1)

$\sum F_y = 0$

200sin45°- 500sin30° + PsinΘ -200 = 0 ⟹ PsinΘ = 308.58N ------ (2)

Divide equation (2) by (1)

$$\Rightarrow \frac{Psin\theta}{Pcos\theta} = \frac{308.58}{-791.59}$$

tanΘ = - 0.389 therefore Θ = 21.25° (-ve sign is neglected)

Substituting the values of Θ in equation (2)

PsinΘ = 308.58

Psin21.25° = 308.58

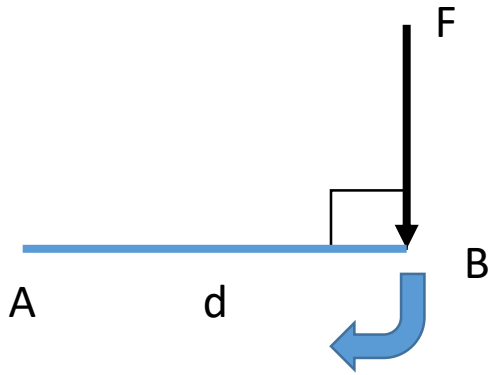
Therefore P = 851.39N

Moment of a force

- It is the capacity of a force to produce rotator motion.

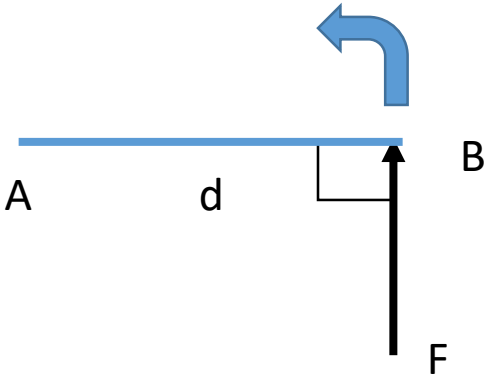
Nature of Moment

1. Clockwise Moment (+ve)



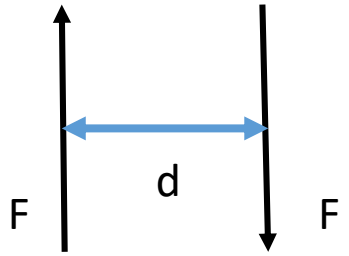
$M_A = + (F \times d)$

2. Anti-clockwise moment (-ve)



$M_A = - (F \times d)$

- **Couple**



- **Characteristics of couple**

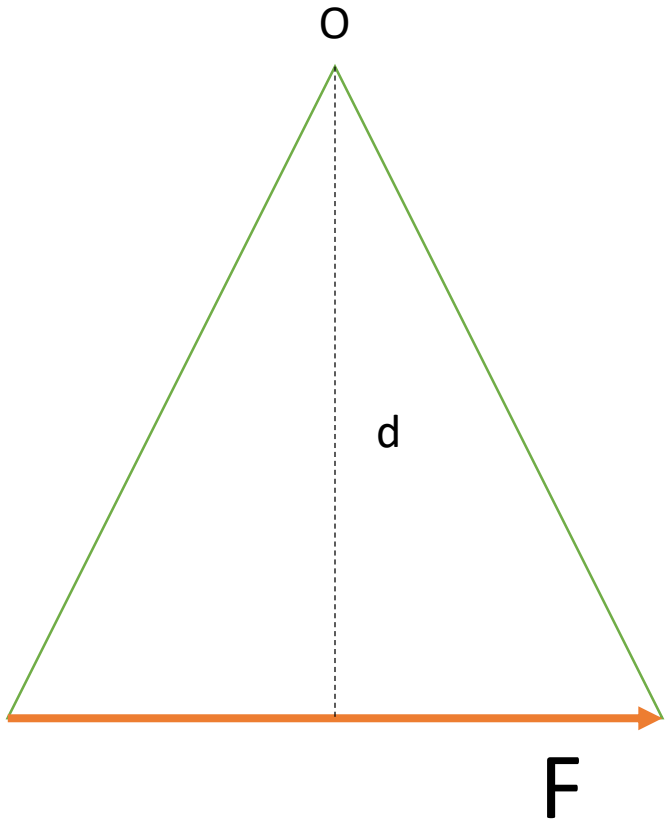
➢Resultant effect of couple in a system is equal to zero

➢Moment of forces constituting a couple about any point in a plane are same

➢Couple can be balanced by another couple of same magnitude but acting in opposite direction

➢A couple acting on a rigid body can produce only rotational motion. It cannot produce translational motion.

To Prove: Moment of force = 2 * Area of Triangle



Moment = Force * Perpendicular Distance

M = F * D

Area of Triangle = ½ * base * Height

= ½ * F * d

Area of Triangle = ½ * base * Height

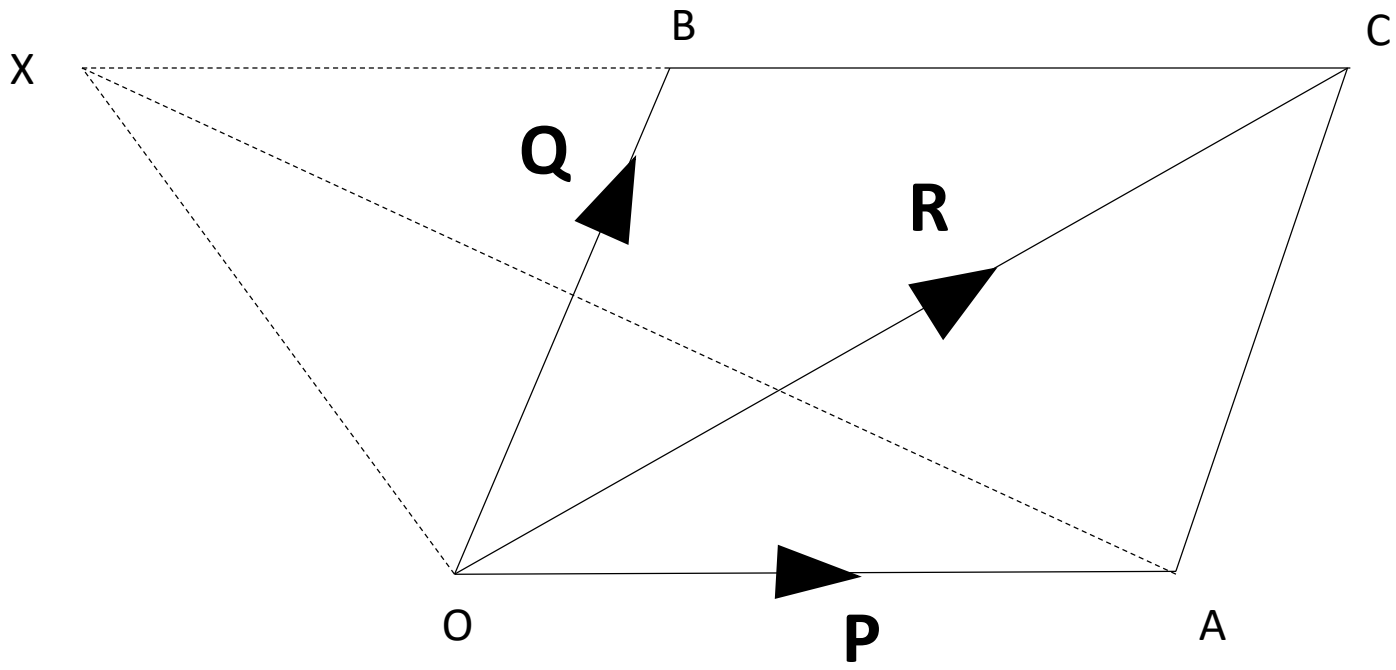
= ½ * M or

2 * Area of Triangle = Moment of force

Varignon's theorem of moment

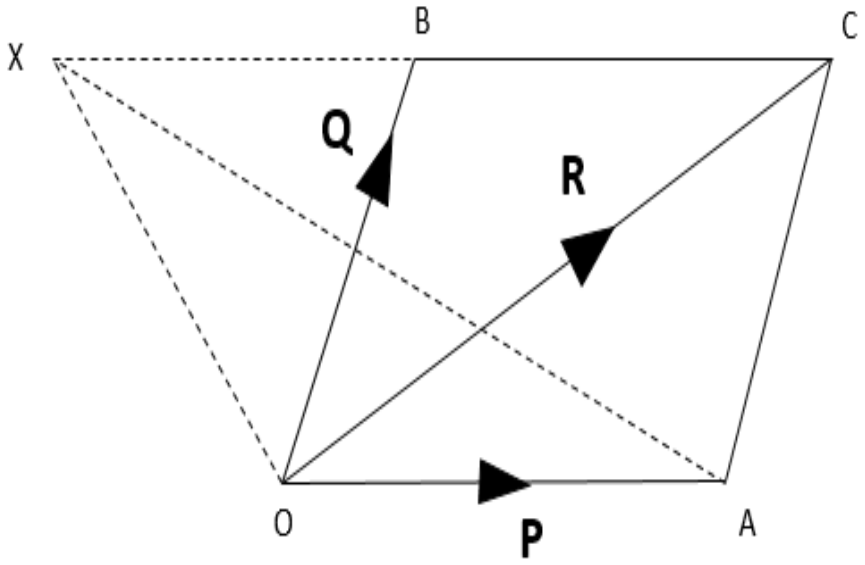
Statement: It states that the algebraic sum of moments due to all forces acting on an object about any point is equal to the moment of their resultant about the same point.

Construction



Varignon's theorem of moment

Proof: Let P & Q be the coplanar forces acting along the sides OA & OB of the parallelogram OACB. R is the resultant of the two forces acting along the diagonal of the parallelogram.



Moment of a force P about X = 2 * Area of Triangle OXA

Moment of a force Q about X = 2 * Area of Triangle OXB

Moment of a force R about X = 2 * Area of Triangle OXC

But $\triangle$ OXC = $\triangle$ OXB + $\triangle$ OBC

By geometry, $\triangle$ OBC = $\triangle$ OCA = $\triangle$ OXA are smililar

Therefore, Moment of a force R about X = 2 * (Area of Triangle OXB + Area of Triangle OXA)

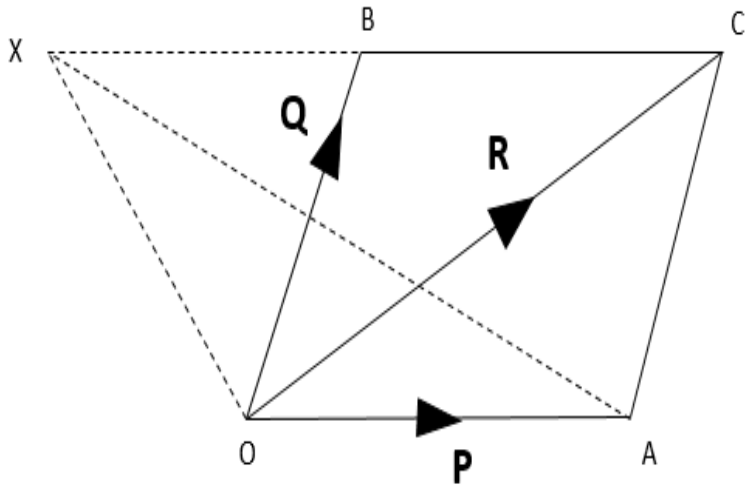
Hence

Therefore, Moment of a force R about X = 2 * (Area of Triangle OXB + Area of Triangle OXA)

Moment of a force R about X = Moment of a force Q about X + Moment of a force P about X

Therefore

Moment of Resultant about a point = Algebraic sum of moment of all the forces about the same point



- Add all the Horizontal forces by considering the sign convention ie $\sum F_x$
- Add all the Vertical forces by considering the sign convention ie $\sum F_y$
- Determine the magnitude of Resultant

$$R = \sqrt{(\sum F_X)^2 + (\sum F_y)^2}$$

- Direction of Resultant

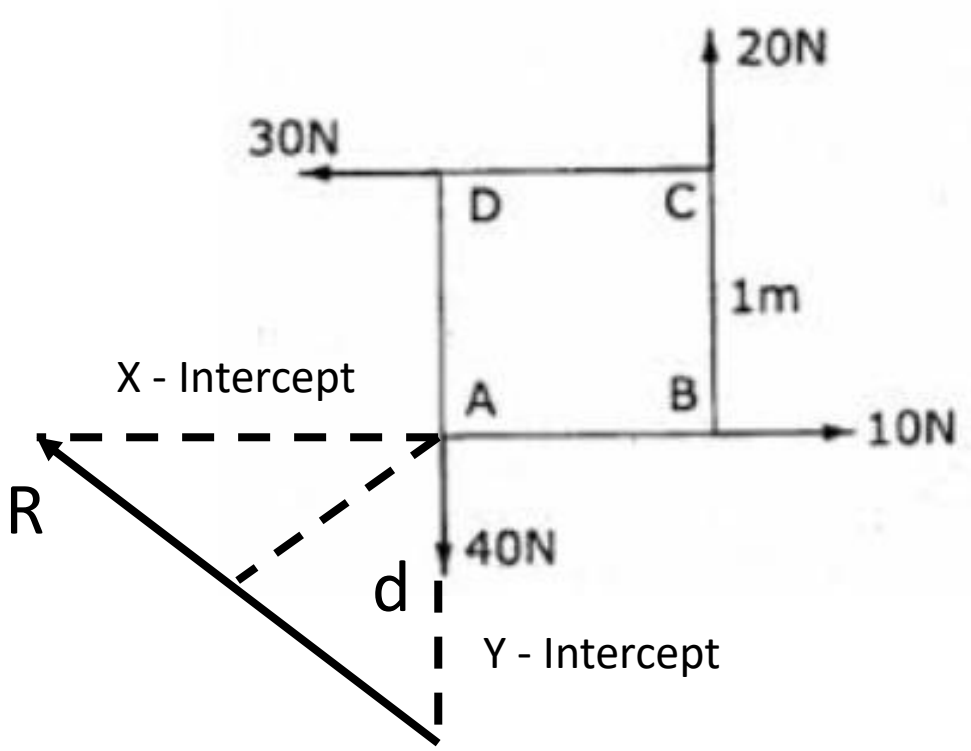
$$\Theta = tan^{-1}\left(\frac{\sum F_y}{\sum F_x}\right)$$

- For position of Resultant

Inclined Distance $d = \frac{\sum M}{R}$

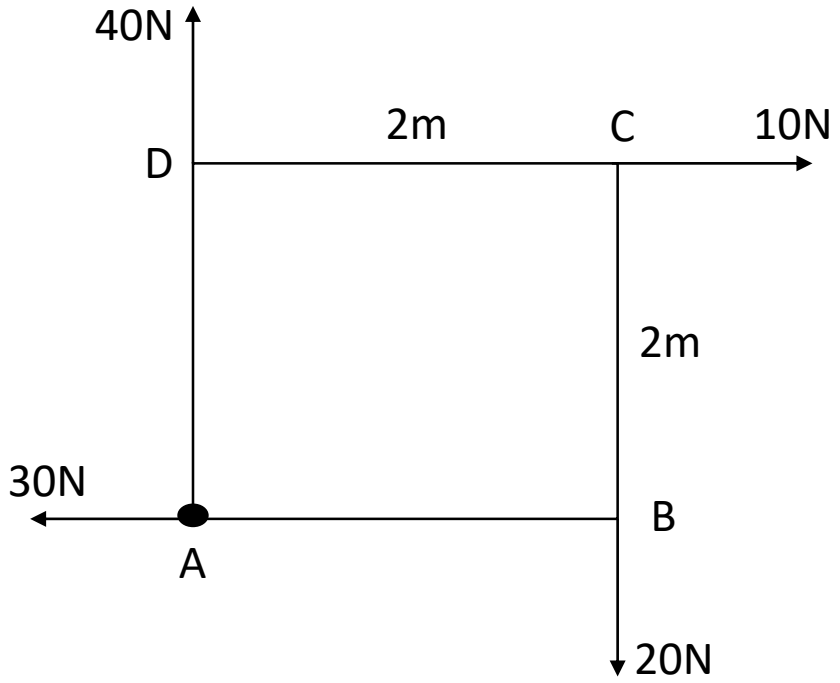
$$x - intercept = \left|\frac{\Sigma M}{\Sigma Fy}\right|$$

$$y - intercept = \left|\frac{\Sigma M}{\Sigma Fx}\right|$$



Four forces of magnitude 10N, 20N, 30N & 40N are simultaneously acting along the sides of a square of size 2mX2m as shown in fig. Determine the magnitude, direction & position of resultant force wrt point A

To find: R=?, Θ=?, d=?, x-int=? & y-int=?

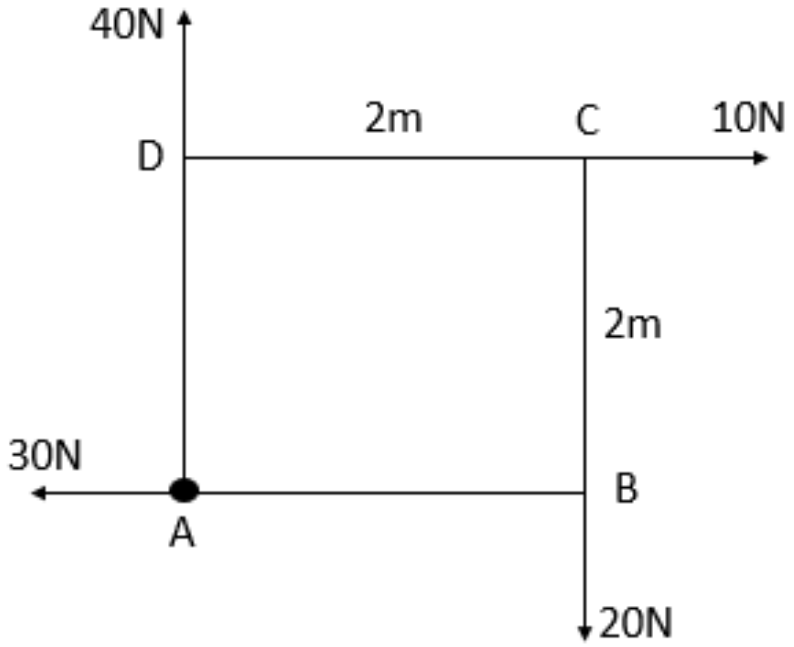


Step 1: $\sum F_x = 10 - 30 = -20N$

Step 2: $\sum F_y = 40 - 20 = 20N$

Step 3: Magnitude of resultant

$$R = \sqrt{(\sum F_X)^2 + (\sum F_y)^2} = \sqrt{(20)^2 + (20)^2} = 28.28N$$



Step 4: Direction of resultant

$$\tan\Theta = \frac{\sum F_y}{\sum F_x} = \frac{20}{-20} = -1$$

Therefore $\Theta = \tan^{-1}(1) = -45°$ (Should be marked in clockwise direction)

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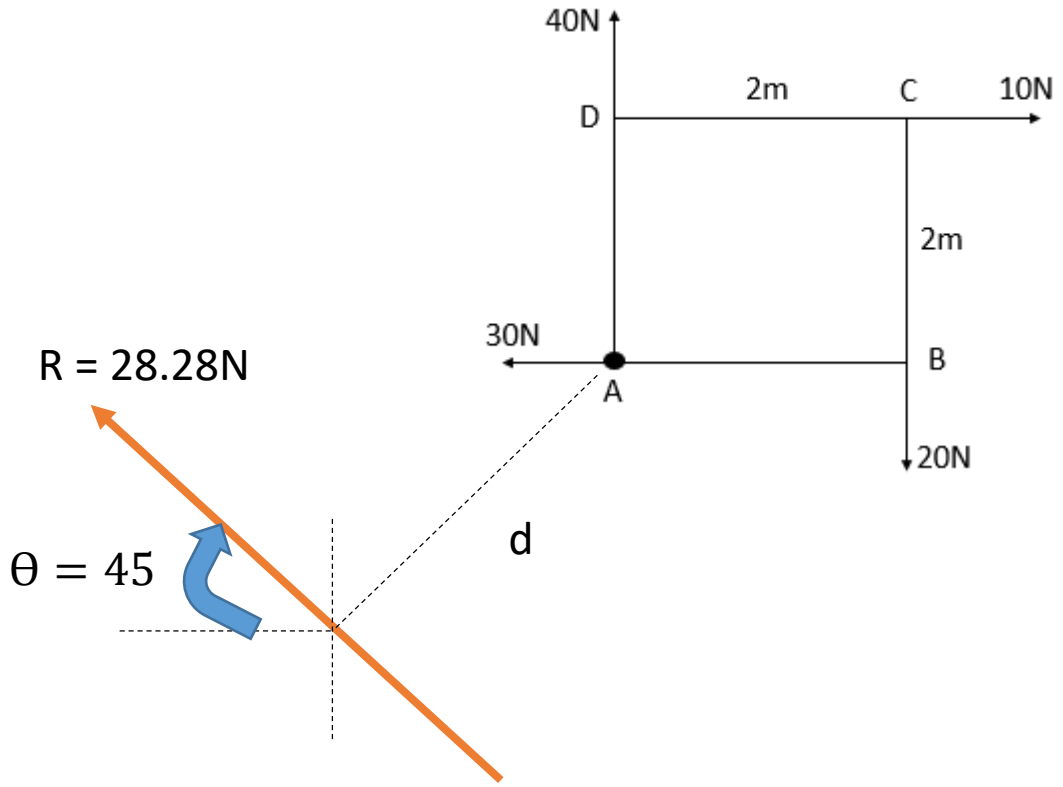

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Taking Moment of all the forces about point A

$\sum M_A$ = (10 X 2) + (20 X 2) = 60N-m

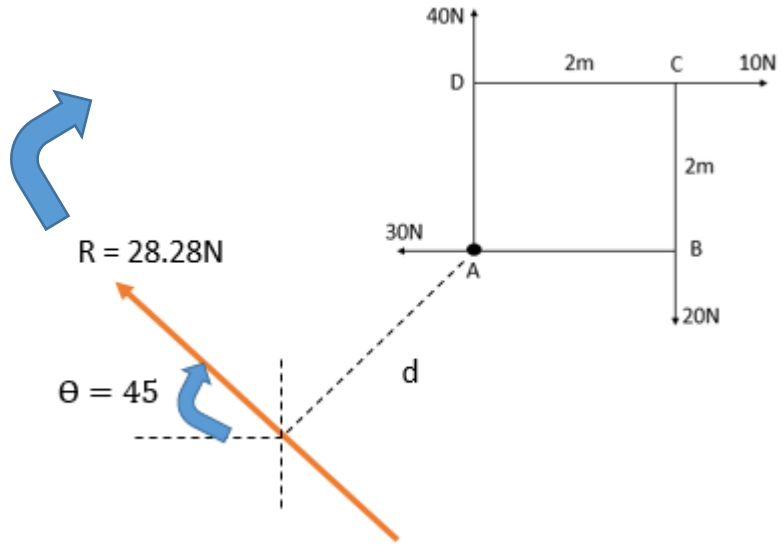
Assuming the position of resultant towards left of

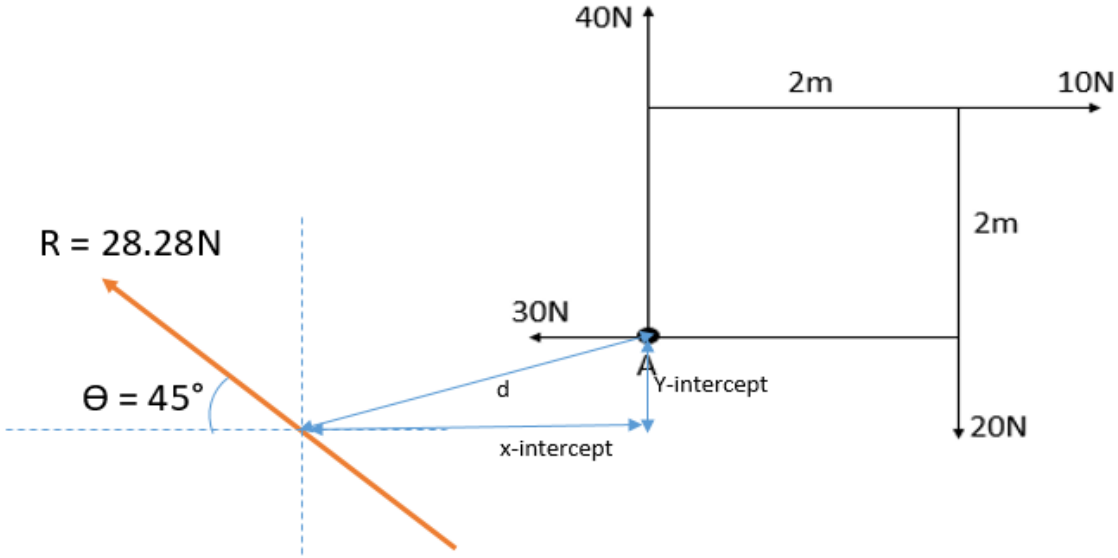
Point A R * d = $\sum M_A$

d = $\frac{\sum M}{R} = \frac{60}{28.28}$ = 2.12m

$x - intercept = \left|\frac{\Sigma M}{\Sigma Fy}\right| = \left|\frac{60}{20}\right|$ = 3m

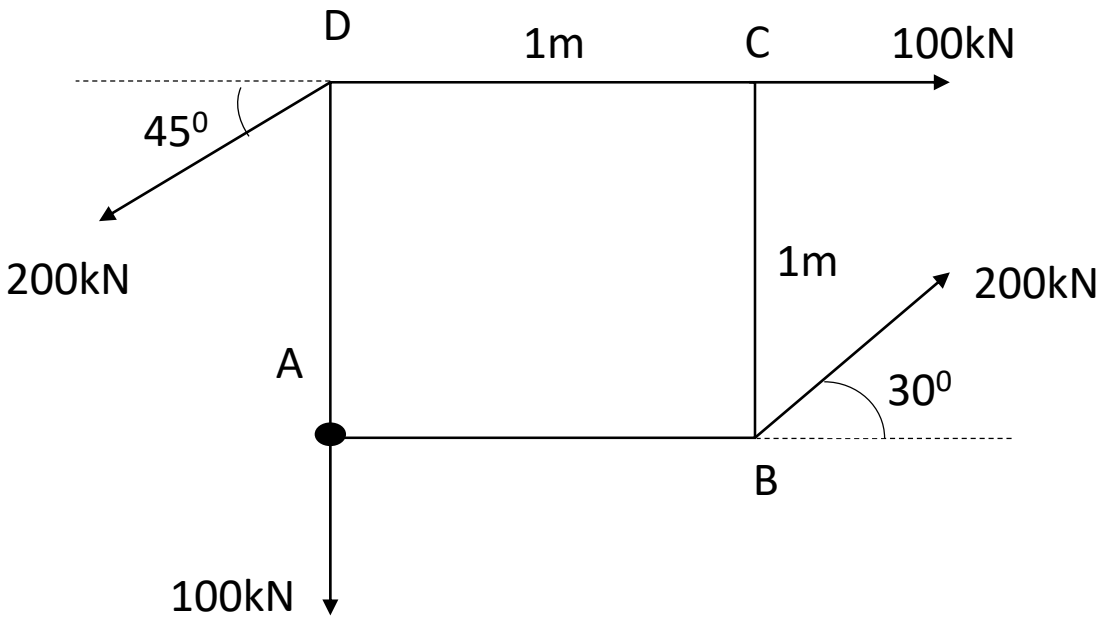
$y - intercept = \left|\frac{\Sigma M}{\Sigma Fx}\right| = \left|\frac{60}{-20}\right|$ = 3m

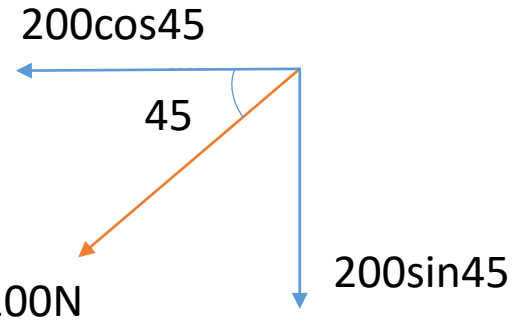


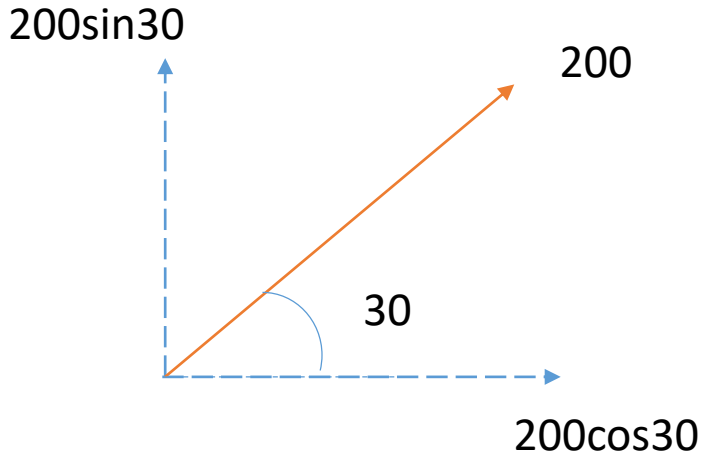


Four forces are acting on a square having 1mX1m as shown in fig. Determine the magnitude, direction & position of resultant force wrt point A

To find: R=?, Θ=?, d=?, x-int=? & y-int=?



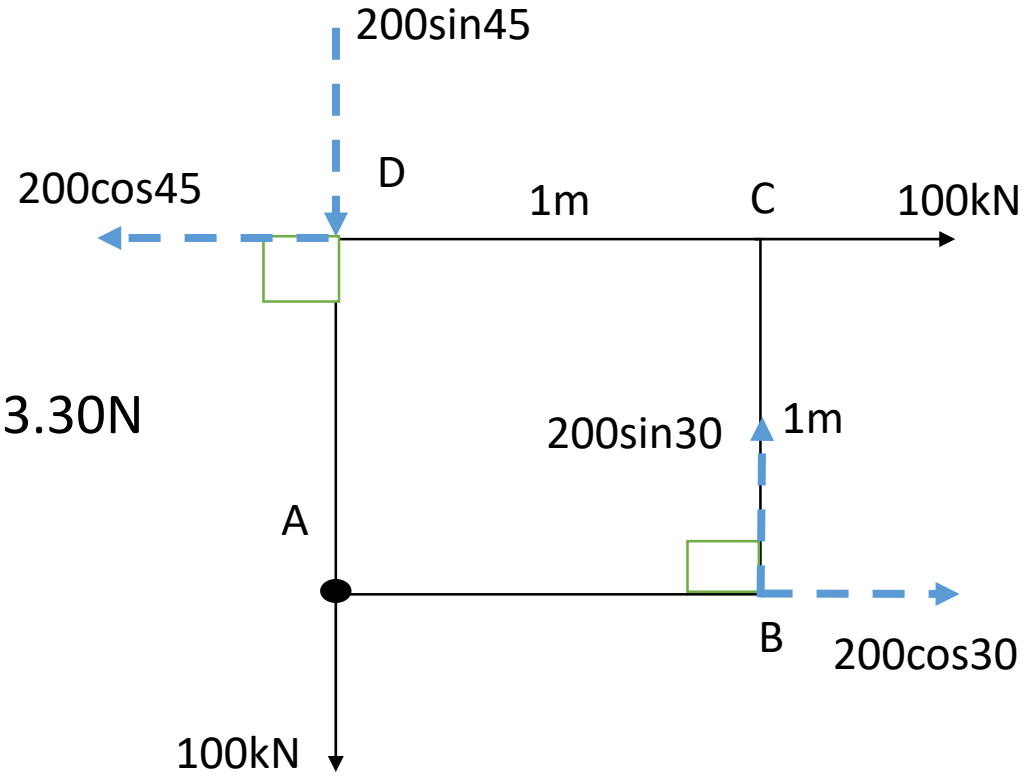




Step 1: $\sum F_x$ = 100 – 200cos30 -200cos45= 131.78kN

Step 2: $\sum F_y$ = -200sin45 + 200sin30 - 100 = -141.42kN

Step 3: Magnitude of resultant



$$R = \sqrt{(\sum F_X)^2+(\sum F_y)^2} = \sqrt{(131.78)^2+(-141.42)^2} = 193.30N$$

Step 4: Direction of resultant

$$\tan\theta = \frac{\sum F_y}{\sum F_x} = \frac{-141.42}{131.78} = -1.073$$

Therefore Θ = $\tan^{-1}$ (-1.073) = -42.02° (Should be marked in clockwise direction)

Step 1: $\sum F_x$ = 100 – 200cos30 -200cos45= 131.78kN

Step 2: $\sum F_y$ = -200sin45 + 200sin30 - 100 = -141.42kN

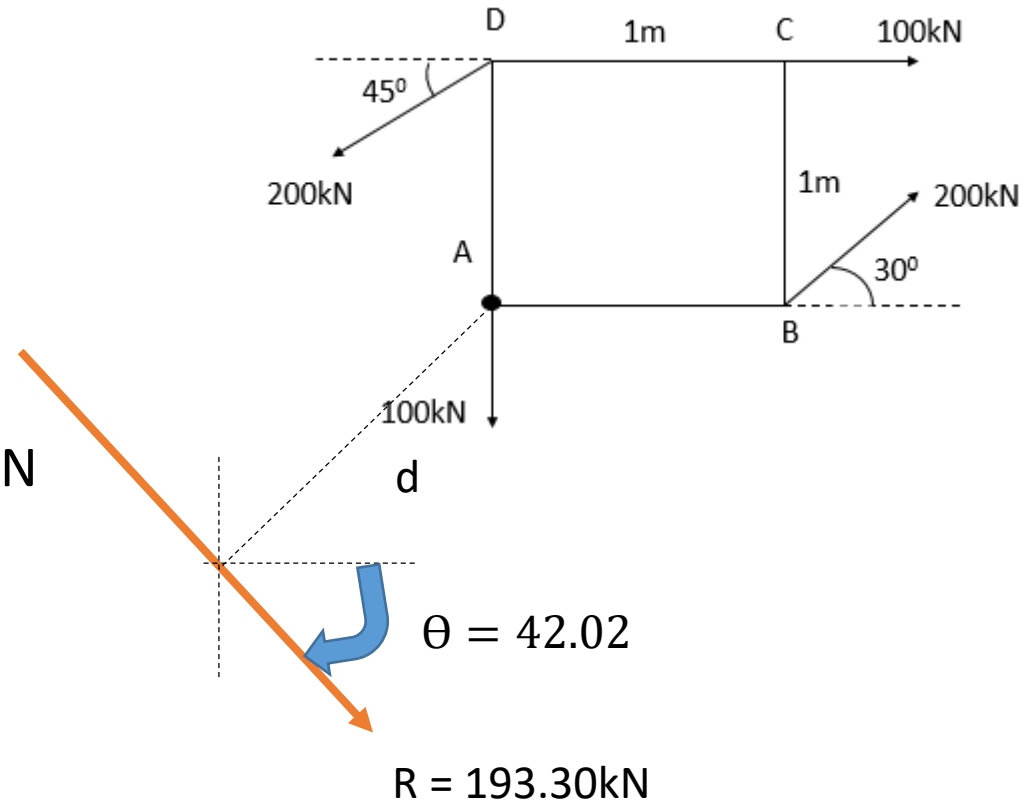
Step 3: Magnitude of resultant

$$R = \sqrt{(\sum F_X)^2+(\sum F_y)^2} = \sqrt{(131.78)^2+(-141.42)^2} = 193.30N$$

Step 4: Direction of resultant

$$\tan\theta = \frac{\sum F_y}{\sum F_x} = \frac{-141.42}{131.78} = -1.073$$

Therefore Θ = $\tan^{-1}$ (-1.073) = -42.02° (Should be marked in clockwise direction)

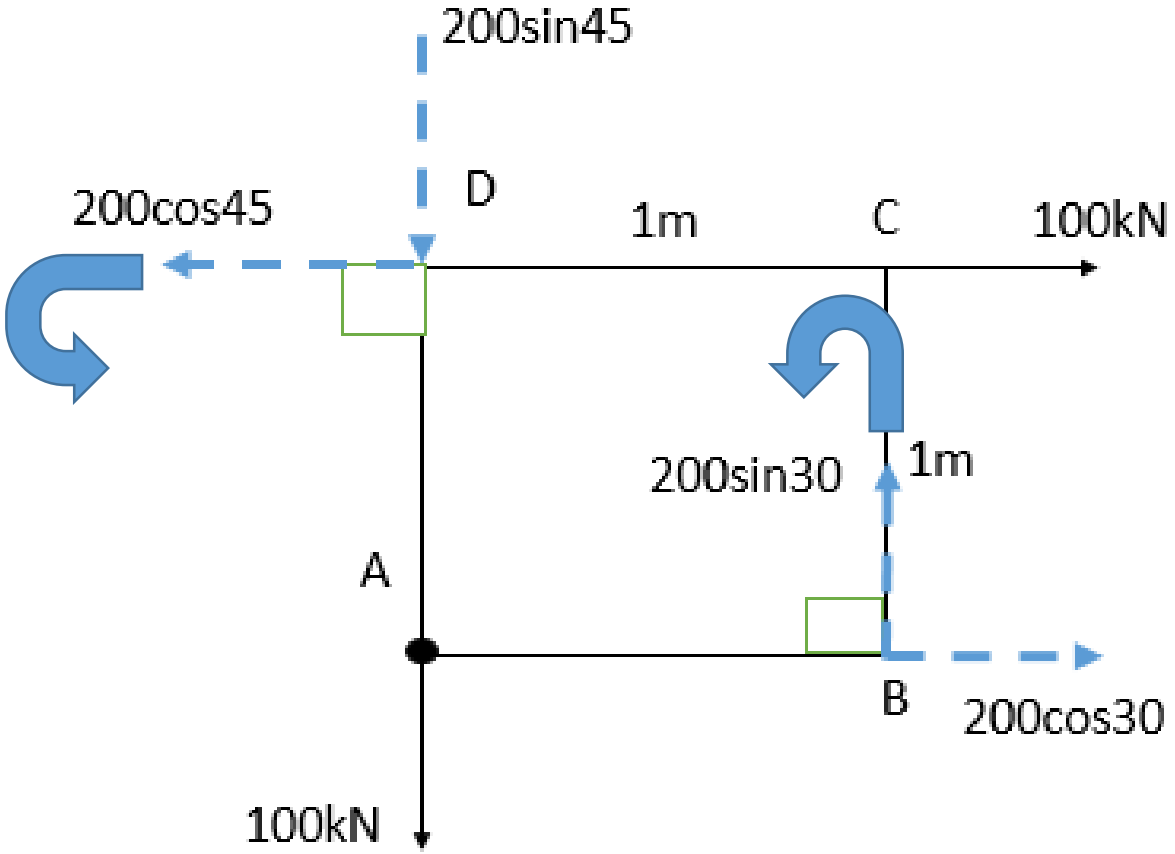


Taking Moment of all the forces about point A

$\sum M_A$ = (100 X 1) + (200cos30 X 0) + (100 X 0)

= - (200cos45 X 1) + (200sin45 X 0)

= 58.57kN-m



Assuming the position of resultant towards left of

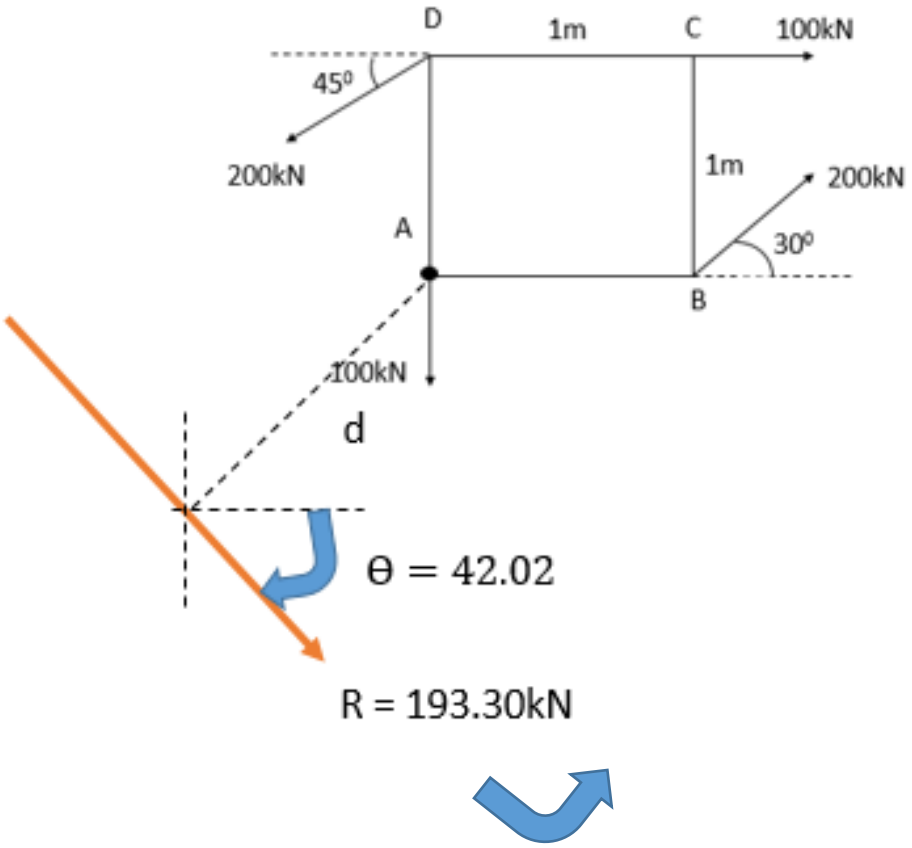
Point A - (R * d) = $\sum M_A$

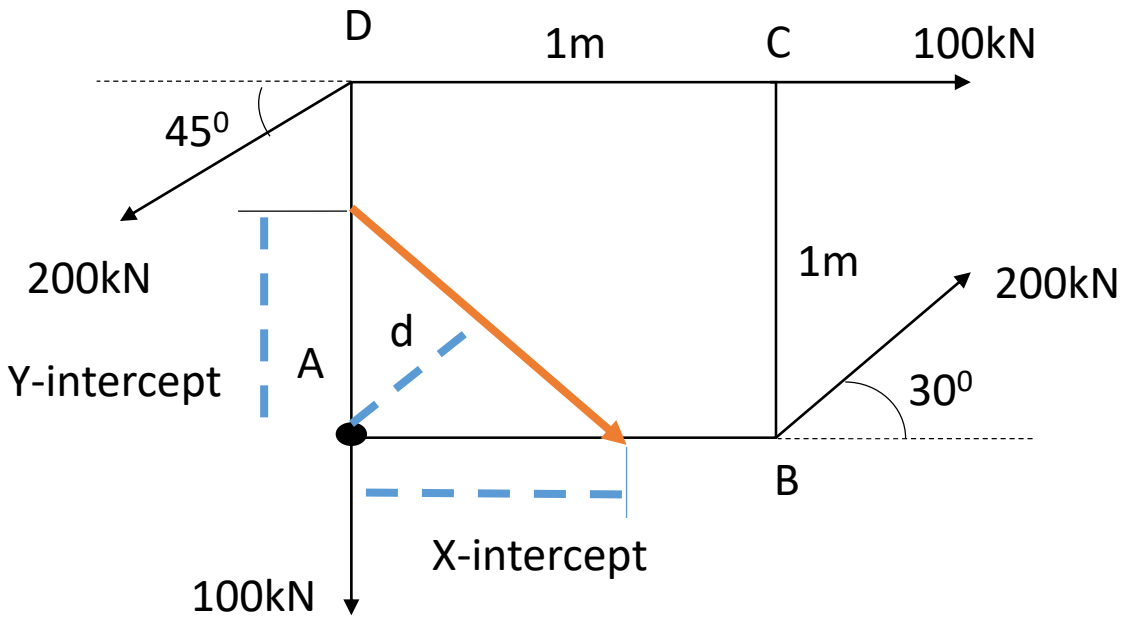
d = - $\frac{\sum M}{R} = \frac{58.57}{193.30}$ = - 0.30m

Therefore resultant is acting to the right of A

$x - intercept = \left|\frac{\Sigma M}{\Sigma Fy}\right| = \left|\frac{58.57}{141.48}\right|$ = 0.414m

$y - intercept = \left|\frac{\Sigma M}{\Sigma Fx}\right| = \left|\frac{58.57}{131.78}\right|$ = 0.414m




D
1m
C
100kN
45⁰
200kN
1m
200kN
d
A
Y-intercept
30⁰
B
X-intercept
100kN