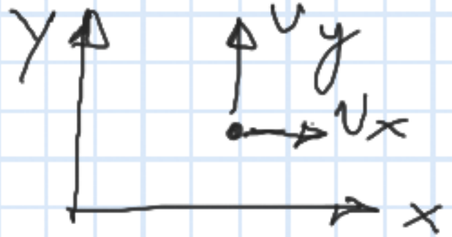
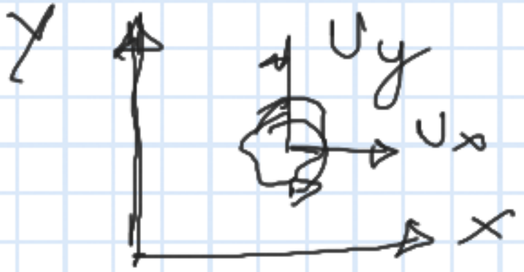
2D



Particle

$\Sigma F_x = 0$

$\Sigma F_y = 0$



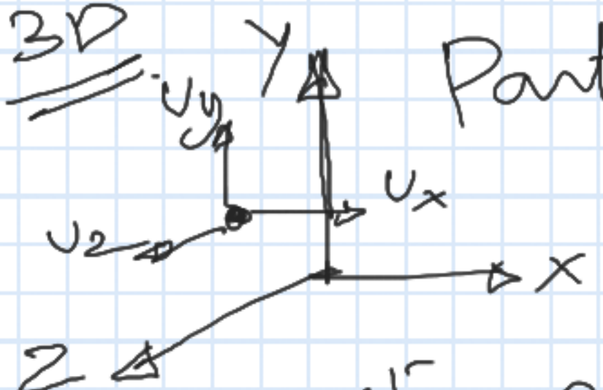
Rigid body

$\Sigma F_x = 0$

$\Sigma F_y = 0$

$\Sigma M = 0$

3D



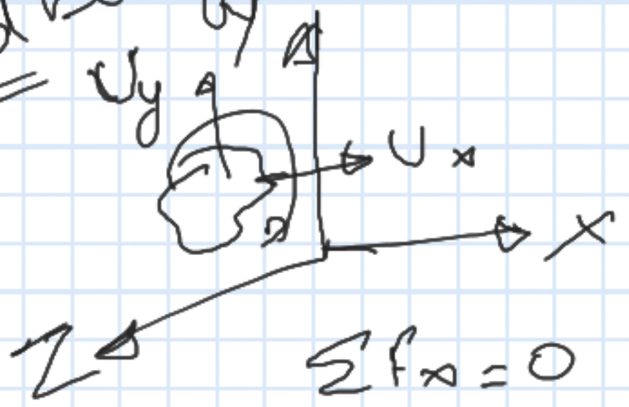
Particle

$\Sigma F_x = 0$

$\Sigma F_y = 0$

$\Sigma F_z = 0$

Rigid body



$\Sigma F_x = 0$ $\Sigma M_x = 0$

$\Sigma F_y = 0$ $\Sigma M_y = 0$

$\Sigma F_z = 0$ $\Sigma M_z = 0$

Engineering Mechanics

Mechanics – Branch of physical science that deals with the state of rest or state of motion of bodies.

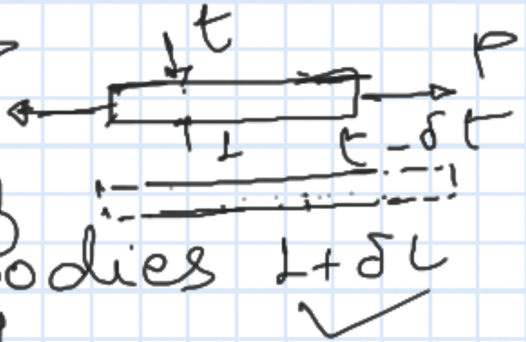
Mechanics – { Classical / Newtonian Mechanics ✓
Relativistic mechanics
Quantum mechanics }

Application of laws of mechanics to field problems –

Engineering mechanics

EM

- Mechanics of solids
  - Mechanics of Rigid bodies
    - Statics
    - Dynamics
      - Particle
        - 2D
        - 3D
      - Rigidbody
        - Kinematics
        - Kinetics
  - Mechanics of deformable bodies
    - Theory of elasticity
      - Static
      - Dynamics
    - Theory of Plasticity
- Mechanics of Fluids
  - Ideal fluid
  - Viscous fluid
  - Incompressible fluids



$F = ku$

$F = m\ddot{u} + c\dot{u} + ku$

Basic Terminologies in Mechanics

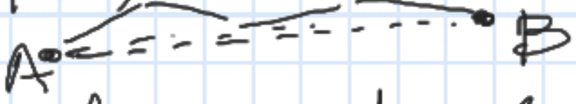
Mass - Quantity of matter possessed by a body (g, kg)

Time - Measure of succession of events (sec, min, hr ...)

Space - Geometric region in which study of body is involved

Length - Concept to measure linear distances (mm, cm, m, km)

Displacement (s) - Distance moved by the body in specified direction (m, km)

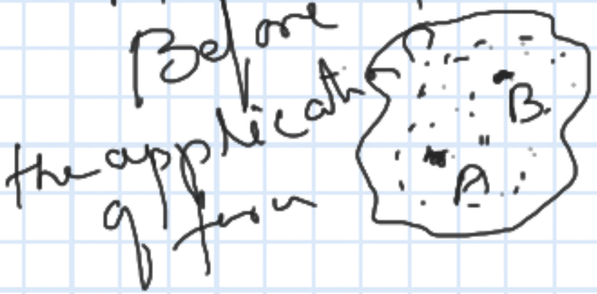


Velocity (v) - Rate of change of displacement (m/s, km/hr)

Acceleration (a) - Rate of change of velocity (m/s^2)

Continuum – A body consisting of several matters

Rigid body – In rigid body the relative positions of any two particles do not change under the action of applied force.



Position of A & B is unaltered.

Particle – Object which has only mass and no specific size

Ex 1. In the study of movement of earth in space, earth is treated as particle

Laws of Mechanics

1. Newton's Law of Motion
2. Newton's Law of Gravitation
3. Law of transmissibility of forces
4. Parallelogram Law of forces

Newton's first law

It states that every body continues in its state of rest or of uniform motion in a straight line, unless it is compelled by an external agency to change the state.

Frames of reference

*Inertial Frame of reference

Newtons first law holds

Either at rest (or) moves with uniform velocity in straight line

ex Train moving in linear track with constant velocity.

*Non-Inertial Frame of reference

Newtons first law does not hold

Accelerating either in linear fashion (or) rotating about some axis

ex A turning car with constant speed.

Newton's second law

It state that rate of change of momentum of a body is directly proportional to the applied force and taken place in the direction of force

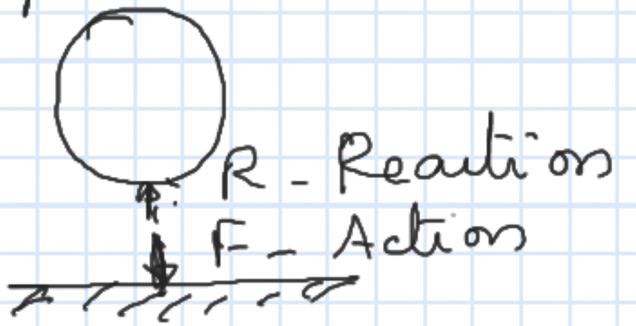
$$F \propto \frac{d}{dt}(mv)$$

$$F \propto m \frac{d}{dt}(v)$$

$$F \propto ma$$

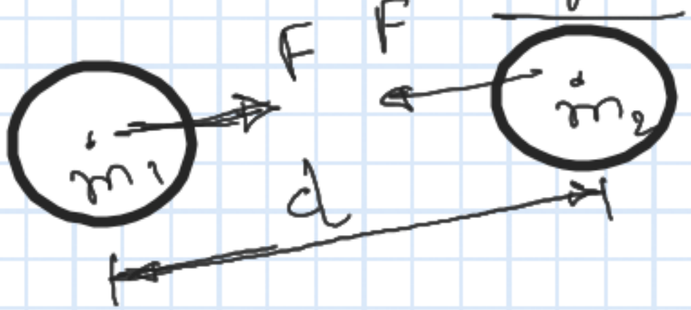
Newton's third law

It state for every action there is an equal and opposite reaction



$F = R$

Newton's law of Gravitation



$$F \propto \frac{m_1 m_2}{(d)^2}$$

$$F = G \frac{m_1 m_2}{(d)^2}$$

G - constant of proportionality / constant of gravitation.

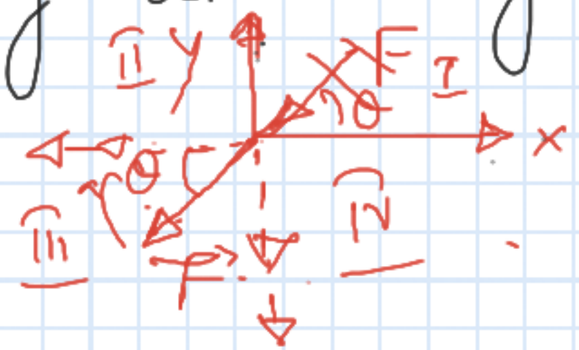
Law of Transmissibility of force.

← Rigidbody

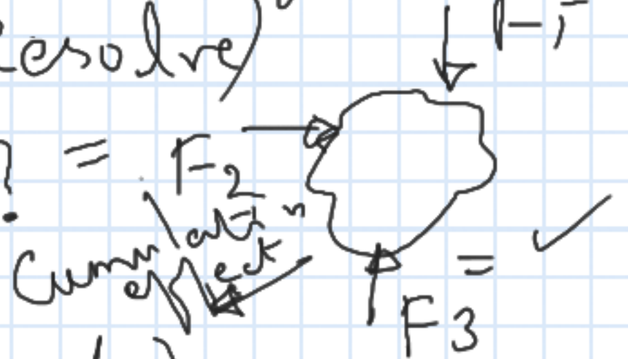
The state of rest or motion of a rigid body is unaltered if a force acting on the body is replaced by another force of same mag

line of action of force

and direction but acting all along the line of action of the replaced force.



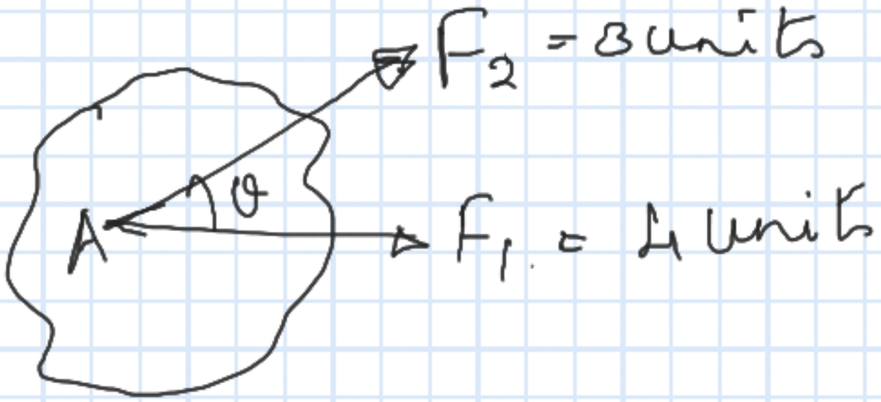
(Resolve)



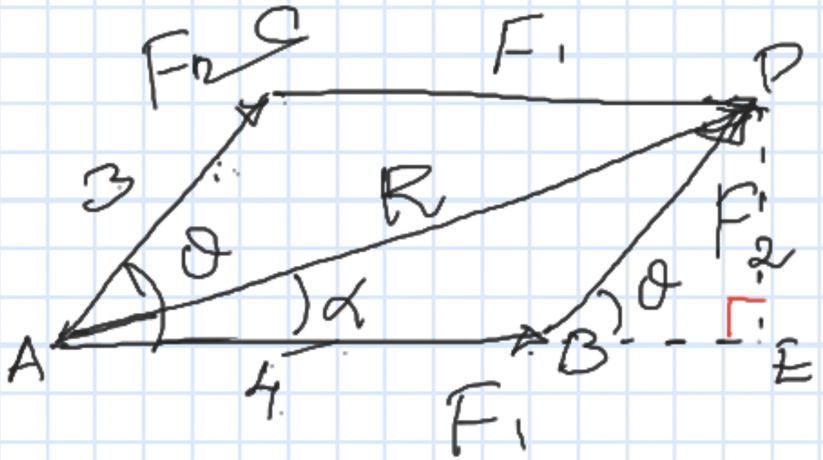
Parallelogram Law of forces (Resultant)

(Only two forces are acting)

This law states that if two forces acting simultaneously on a body are represented in mag & dir by two adjacent sides of a parallelogram, their resultant is represented in mag & dir by the diagonal of the parallelogram which passes through the point of intersection of the two sides representing the forces.



Magnitude and direction of the resultant force.



$\angle BDE = \theta$

$BD = F_2$

$BE = F_2 \cos\theta$

In $\triangle^{le}$ ADE

$$AD = \sqrt{(AE)^2 + (DE)^2}$$

$$= \sqrt{(AB + BE)^2 + (DE)^2}$$

$$\cos\theta = \frac{x}{F_2}$$

$$x = F_2 \cos\theta$$

$$\sin\theta = \frac{y}{F_2}$$

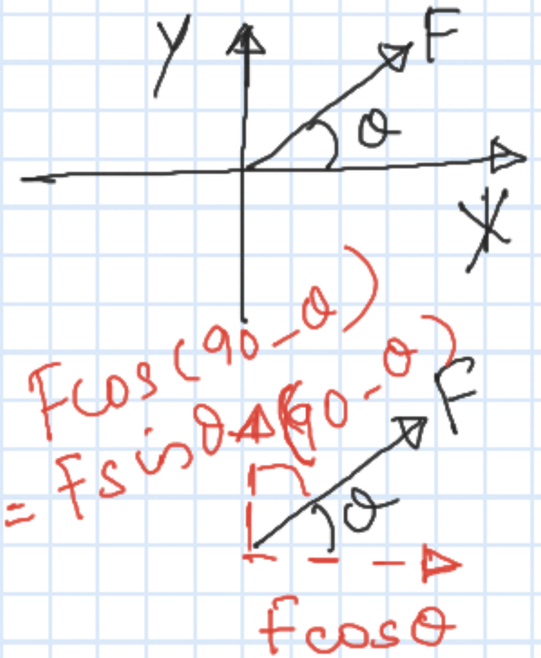
$$y = F_2 \sin\theta$$

$$DE = F_2 \sin\theta$$

$$AD = \sqrt{(F_1 + F_2\cos\theta)^2 + (F_2\sin\theta)^2}$$

$$= \sqrt{F_1^2 + F_2^2\cos^2\theta + 2F_1F_2\cos\theta + F_2^2\sin^2\theta}$$

$$= \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$$



$(\because \sin^2\theta + \cos^2\theta = 1)$

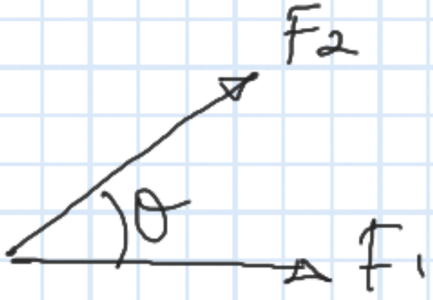
Magnitude

$$R = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$$

Direction

$$\tan\alpha = \frac{DE}{AE} = \frac{F_2\sin\theta}{(F_1 + F_2\cos\theta)}$$

$$\alpha = \tan^{-1}\left(F_2\sin\theta / (F_1 + F_2\cos\theta)\right)$$



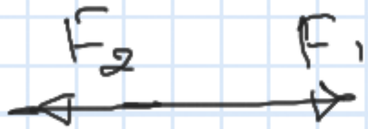
If $\theta = 0^\circ$

$R = F_1 + F_2$

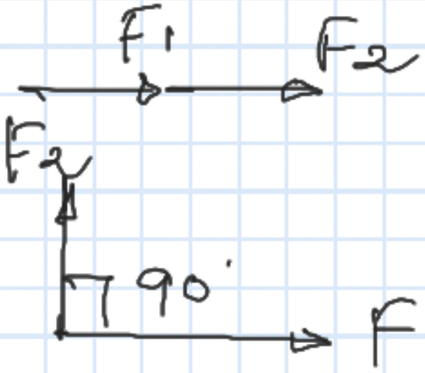
If $\theta = 90^\circ$

$R = \sqrt{F_1^2 + F_2^2}$ → Triangle law of forces.

If $\theta = 180^\circ$

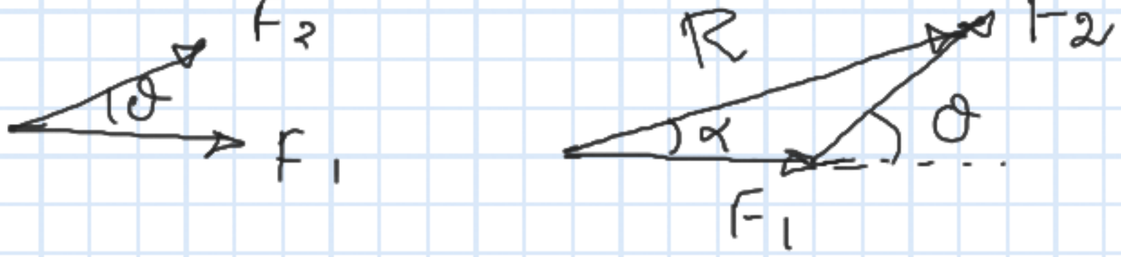


$R = F_1 - F_2$



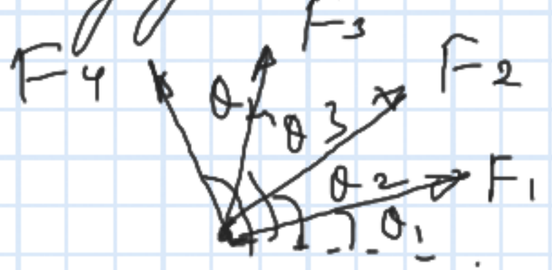
Triangle law of forces

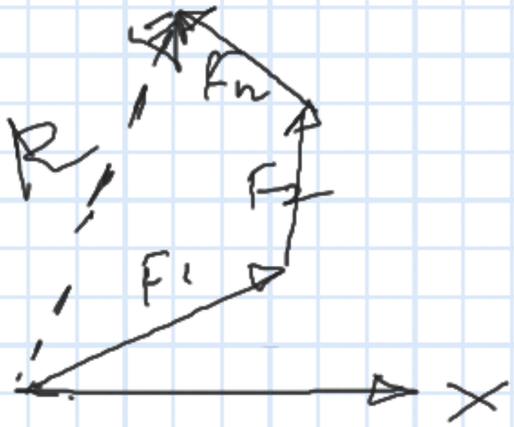
It states that if two forces acting on a body simultaneously are represented one after another by the sides of a triangle, their resultant is represented by the closing side of the triangle taken in opposite order

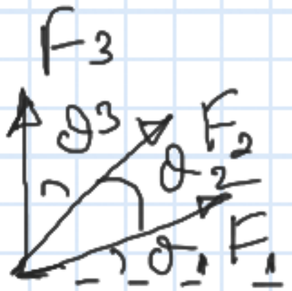


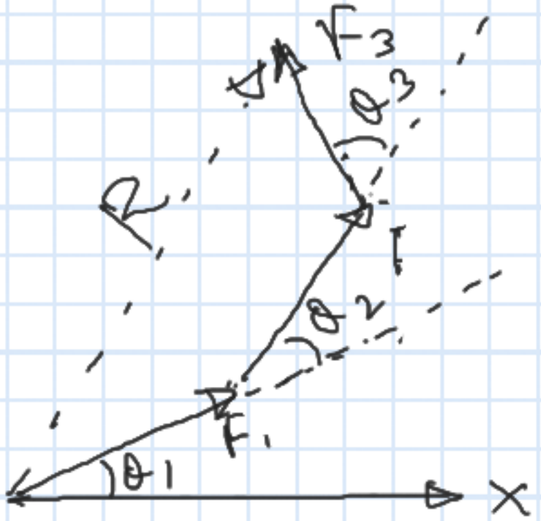
Polygon law of forces

It states that if a number of forces acting simultaneously on a body are represented in magnitude and direction by the sides of a polygon taken in order, the resultant is represented in magnitude and direction by the closing side of the polygon taken in opposite order







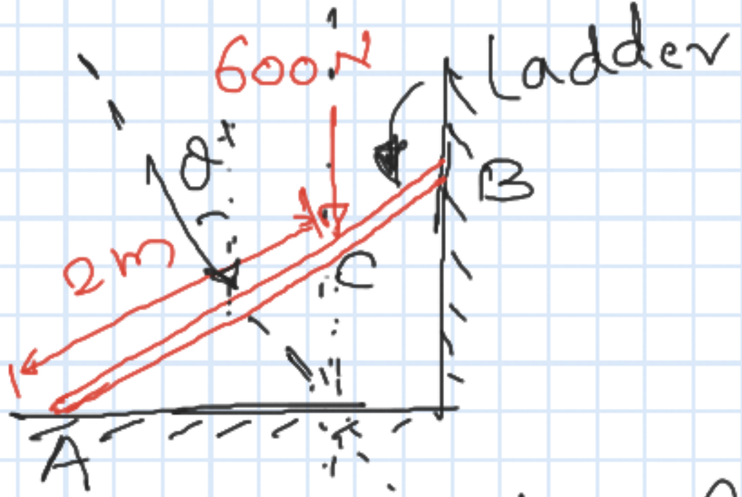


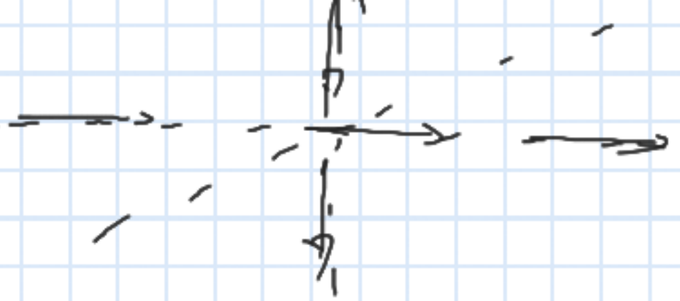
Characteristics of a force.

Force - An agency which tries to change the state of rest or uniform motion of a body

- It is required to produce unit acceleration in a body of 1 kg mass. (1 Newton)
- It is completely specified only when the following characteristics are specified

- Magnitude
- Point of application
- Line of action
- Direction





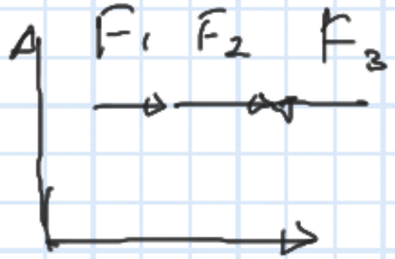
The force applied by the person on the ladder has the following characteristics

- Magnitude (600N)
- Point of application (C which is 2m from A)
- Line of action (vertical)
- Direction (downward)

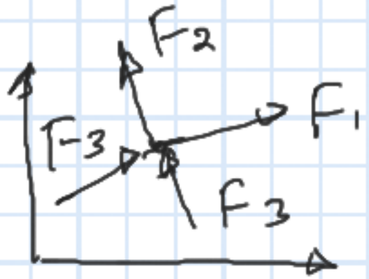
System of forces

- Force system
  - Coplanar (plane)
    - Collinear (a)
    - Concurrent (b)
    - parallel (c)
    - Non Concurrent Non-parallel (d)
  - Non-coplanar (space)
    - concurrent (e)
    - parallel (f)
    - Non concurrent Non parallel (g)

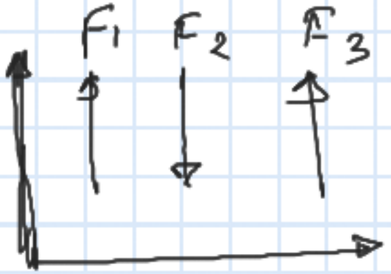
(a)



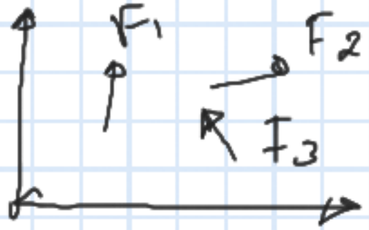
(b)



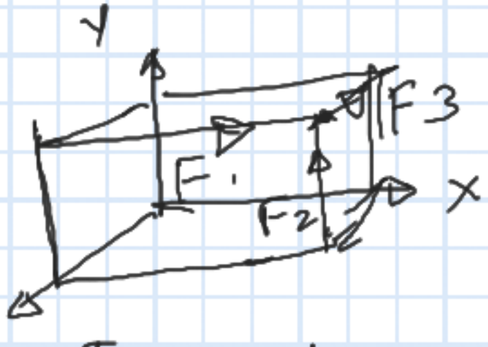
(c)



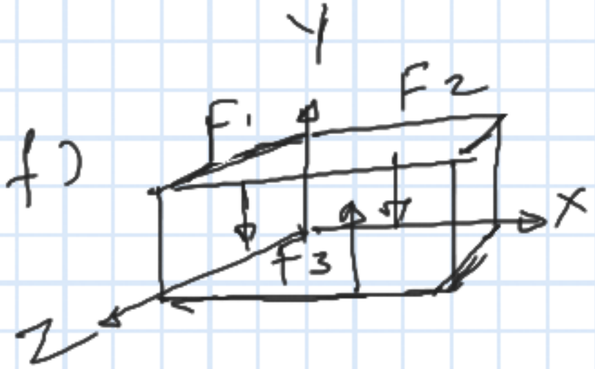
(d)



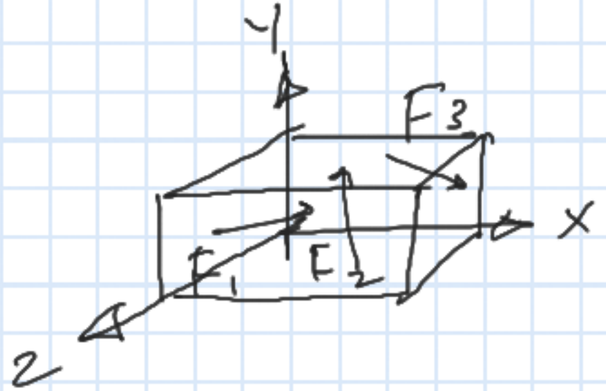
(e)



(f)

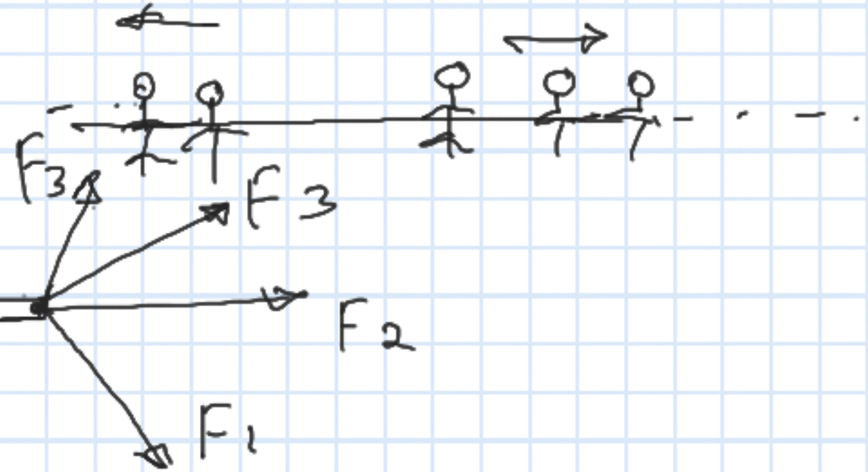


(g)



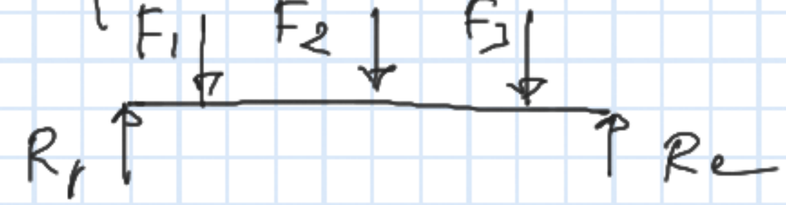
Examples

(a) Forces on a rope in a tug of war



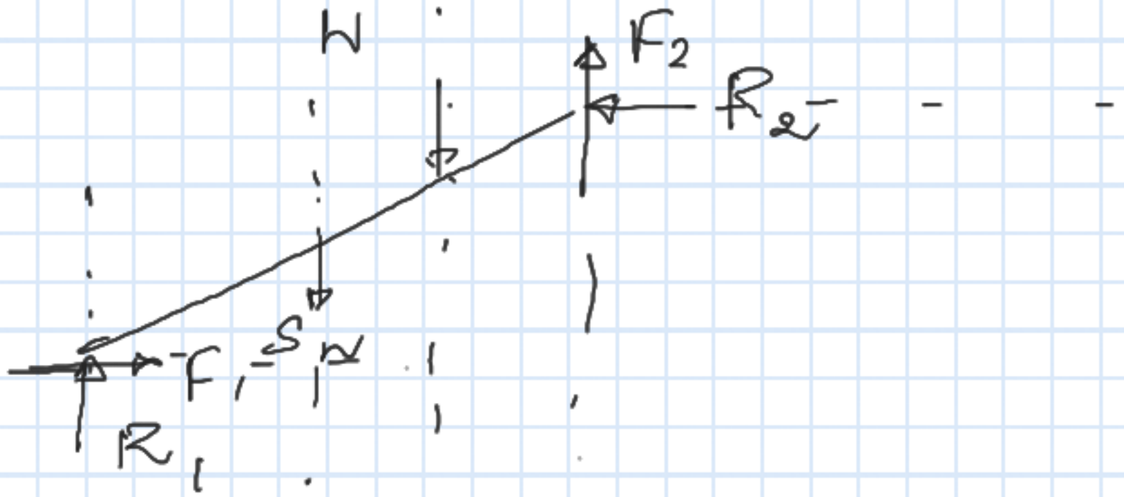
(b) Forces on a rod resting against a wall

(c) Forces acting on a beam subjected to vertical load

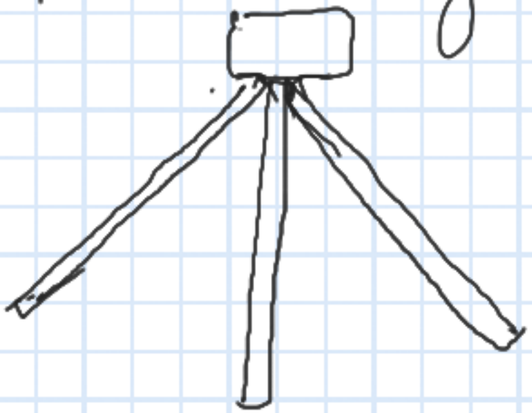


Unlike parallel

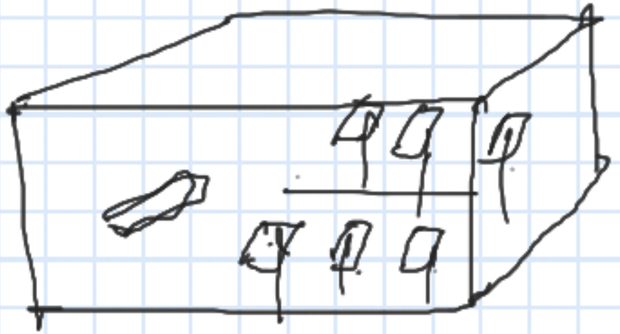
(d) Forces on ladder



(e) A tripod carrying an instrument



(f) The weight of benches in a classroom



(g) Force acting on a moving bus

2S 3D

Scalars and vectors.

Scalar - A quantity is said to be scalar, if it is completely defined by its magnitude alone.

Ex Length, mass, area, time

Vector - A quantity is said to be vector, if it is completely defined by its magnitude and direction

Ex Velocity, acceleration, momentum etc.