Introduction to Engineering Mechanics

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February 16, 2022

STATICS

Statics of Particle

- Introduction to Mechanics - Fundamental Principles - Laws of Mechanics, Lame's theorem, Parallelogram and triangular Law of forces, Coplanar forces - Free body diagram - Equilibrium of particles - Equilibrium of particle in space

Statics of Rigid Body and Friction

- Single equivalent force - Free body diagram - Types of supports and their reactions - requirements of stable equilibrium - Moments and Couples - Moment of a force about a point and about an axis -Varignon's theorem - Equilibrium of Rigid bodies in two dimensions. Characteristics of dry friction - Problems involving dry friction - Ladder - Wedges.

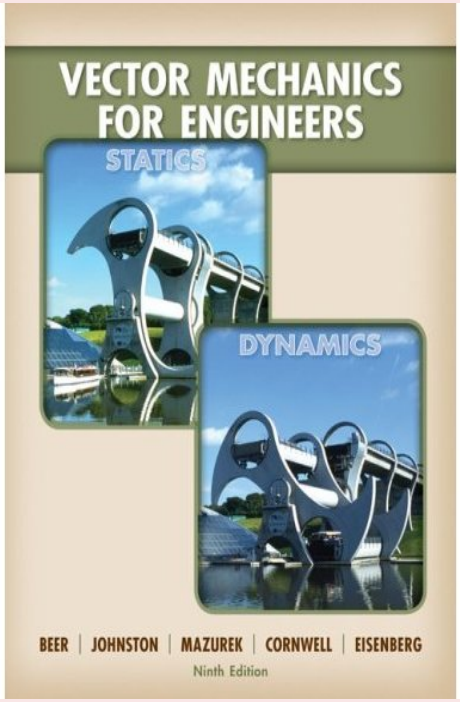
Properties of Sections

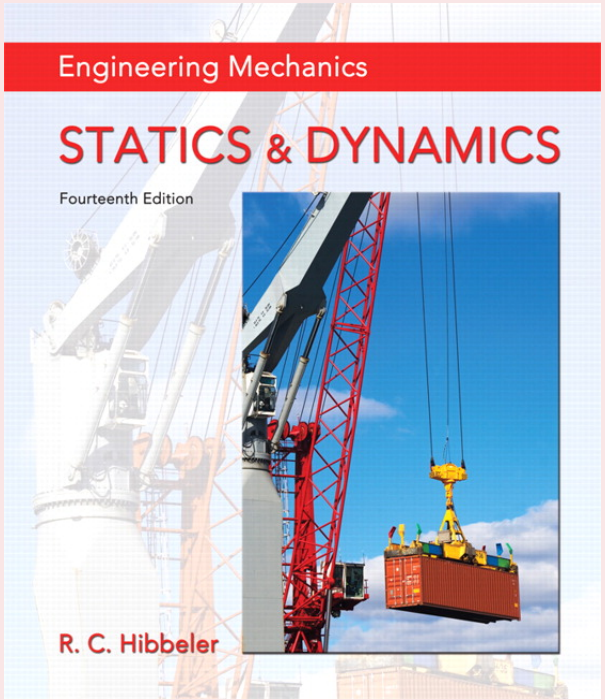
- Centroid - First moment of area - Theorems of Pappus and Guldinus - Second moment of area - Moment and Product of inertia of plane areas - Transfer Theorems - Polar moment of inertia - Principal axes - Mass moment of inertia- Derivation of mass moment of inertia for rectangular section prism, sphere from first principle - relation to area moments of inertia

DYNAMICS

- ## Dynamics of Particles
  - Displacements, Velocity and acceleration, their relationship - relative motion - Curvilinear motion - Newton's law - Work Energy Equation of particles - Impulse and Momentum - Impact of elastic bodies- Impact - direct and central impact - coefficient of restitution.
- ## Dynamics of Rigid Bodies
  - General plane motion -Velocity and Acceleration- Absolute and Relative motion method - Equilibrium of rigid bodies in plane motion- Newton's Law- D'Alembert's Principle- Work Energy Principle-Principle of impulse momentum for rigid bodies in plane motion

Books

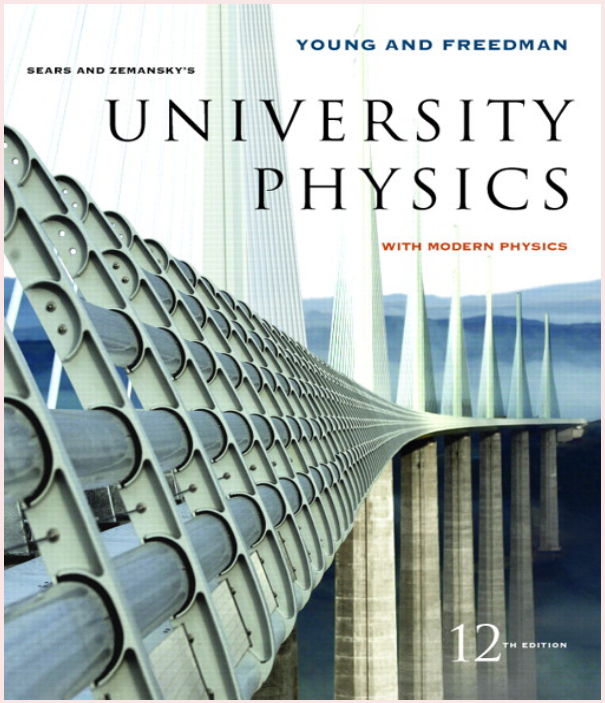

VECTOR MECHANICS FOR ENGINEERS
STATICS
DYNAMICS
BEER | JOHNSTON | MAZUREK | CORNWELL | EISENBERG
Ninth Edition

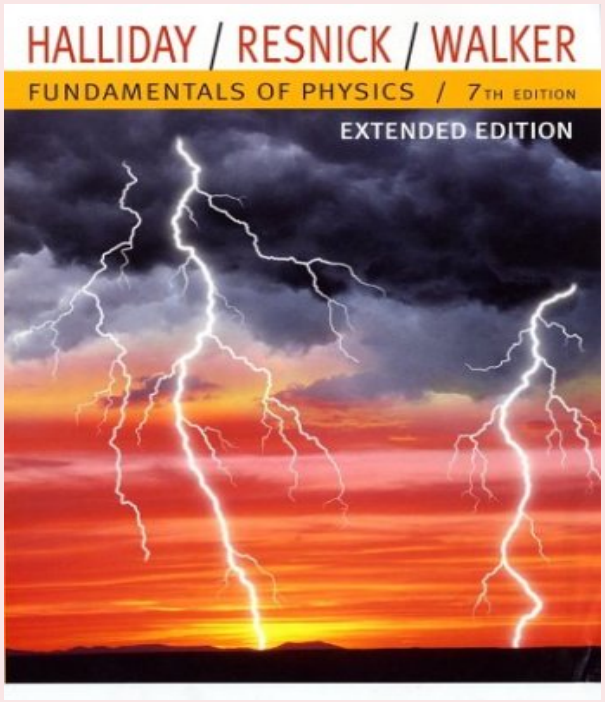

Engineering Mechanics
STATICS & DYNAMICS
Fourteenth Edition
R. C. Hibbeler

Books

- J. L. Meriam and L. G. Kraige, Engineering Mechanics: Statics and Dynamics (6th Edition), Wiley Publishers
- Irving H. Shames, Engineering Mechanics - Statics and Dynamics, Prentice-Hall of India Private limited.
- Timoshenko, Young, and Rao, Engineering Mechanics, Tata McGraw Hill
- K L Kumar, Engineering Mechanics (Third revised Edition), Tata McGraw Hill
- M S Palanichamy and S Nagan Engineering Mechanics Statics and Dynamics, Tata McGraw Hill
- Kottiswaran, Engineering Mechanics, Sri Balaji Publications

You are encouraged to read books like





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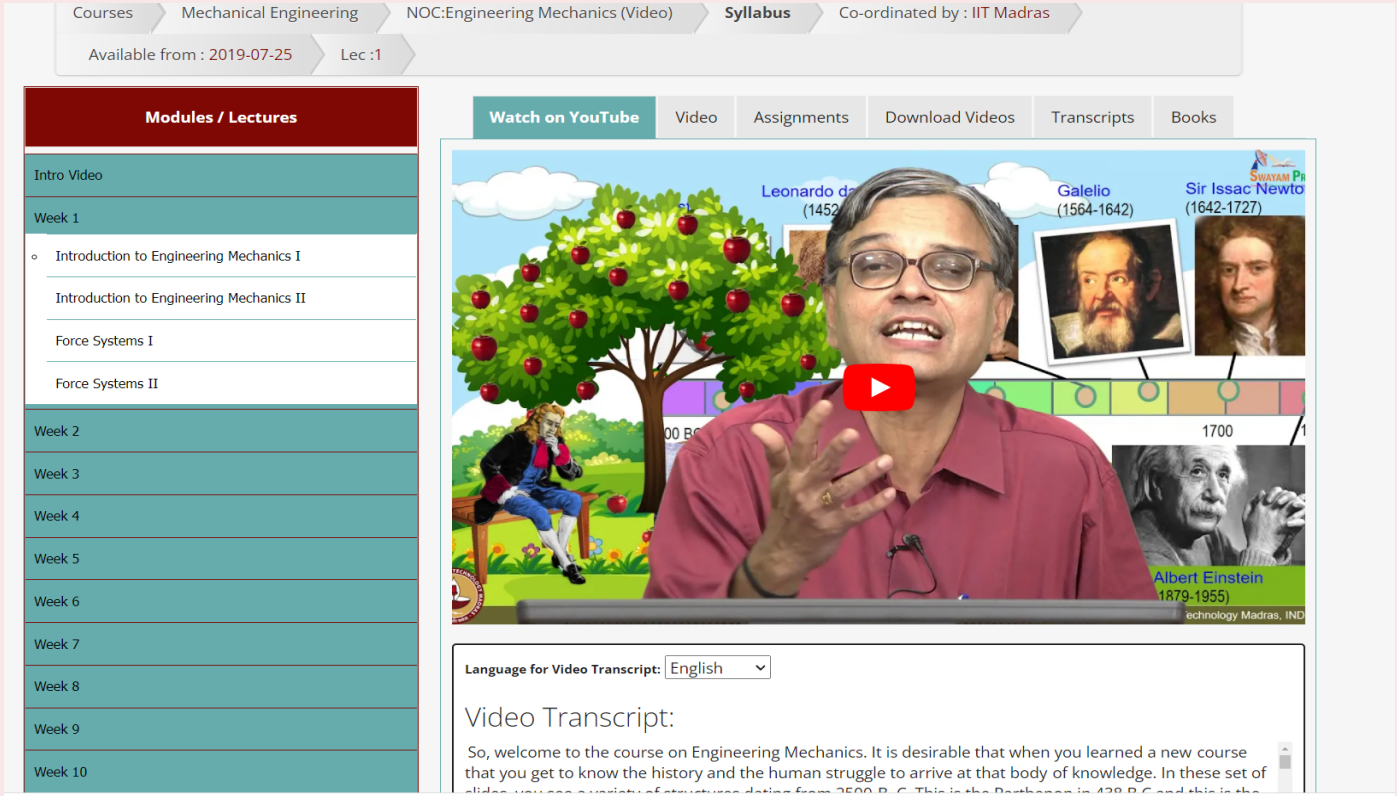

PROF. K. RAMESH

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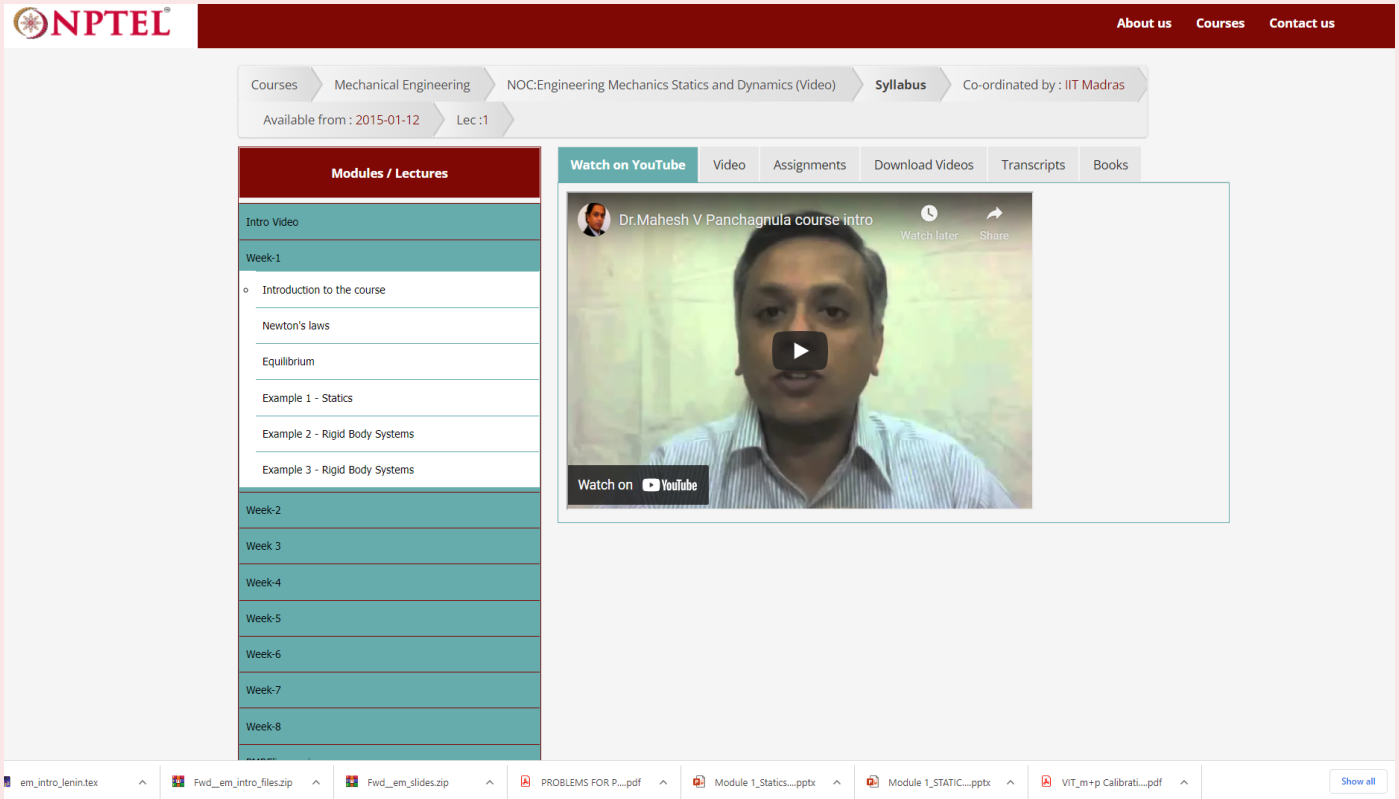
Dr. M. C. Leninbabu

NPTEL Lectures



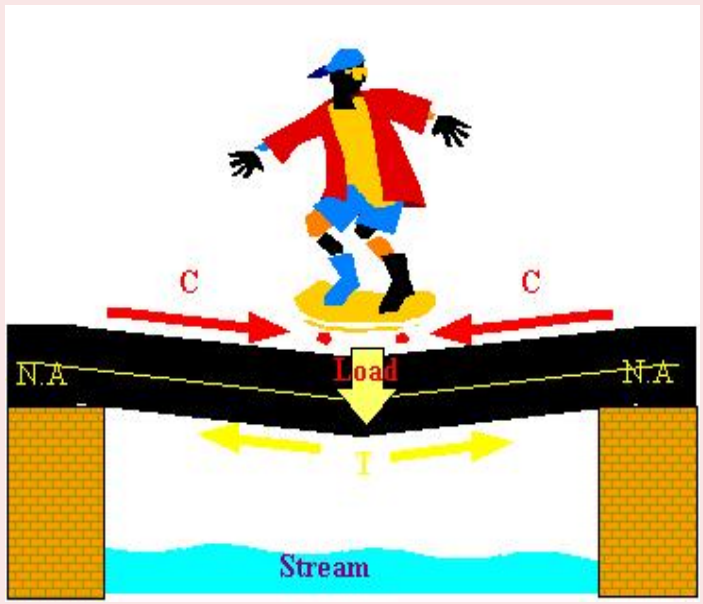
PROF. ANUBHAB ROY

Importance of Mechanics

- Mechanics is the oldest branch of physics and it is the foundation for most of the branches of engineering.
- Many of the topics in such areas as civil, mechanical, aerospace, and agricultural engineering are based upon engineering mechanics only.
- The principles of mechanics are central to research and development in most of the fields of engineering.
- A thorough understanding of mechanics is important to work in most of the engineering applications.
- Although principles of mechanics are few, they have made wide application in engineering.

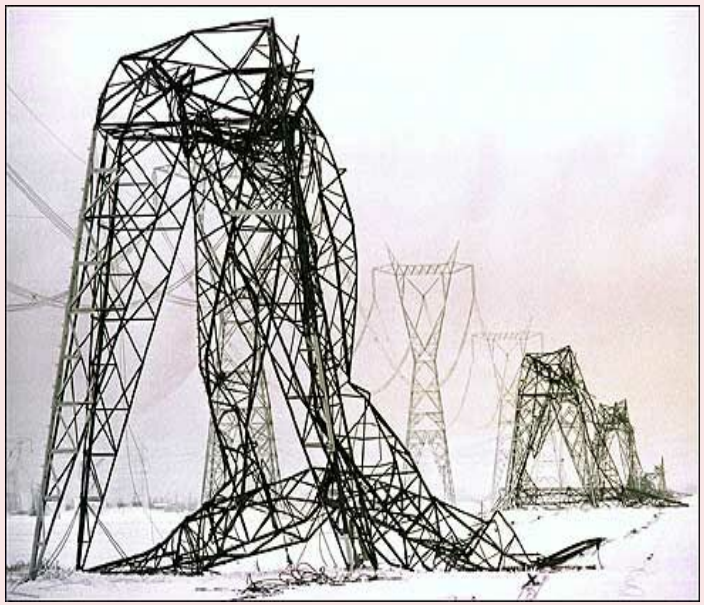
What is Mechanics?

- Mechanics is the physical science which deals with the effects of forces on objects.
- The tasks of mechanics include the description and determination of the motion of bodies and forces associated with the motion.
- Motion in a generalized sense includes the deflection of a bridge or the deformation of a structural element under the influence of a load.



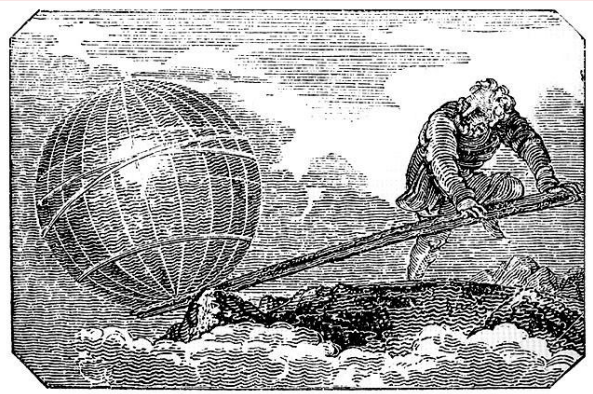
Mechanics

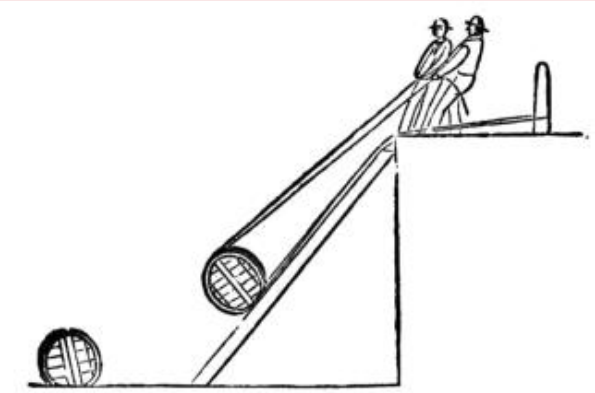
- An important special case is the state of rest; a building, dam or television/mobile phone tower should be constructed in such a way that it does not move or collapse.
- The primary purpose of studying engineering mechanics is to develop the capacity to predict the effects of force and motion while designing a mechanical component.



History

- The historical origin of mechanics can be traced to ancient Greece; several cornerstones on statics were laid by the works of **Archimedes** (287-212): lever and fulcrum, block and tackle, center of gravity and buoyancy.
- Studies of the pulley, inclined plane, and wrench are also recorded in ancient writings-at times when the requirements for engineering were limited primarily to building construction.
- Give me a place to stand on, and I will move the Earth-Archimedes





History

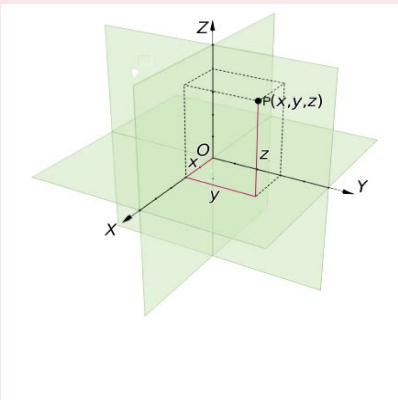
- Substantial progress came later with the formulation of laws of vector combination of forces by Stevinus (1548-1620), who also formulated most of the principles of statics.
- Since the principles of dynamics depend on an accurate measurement of time, this subject developed much later.
- The first investigation of dynamics problem is credited to Galileo Galilei (1564-1642) for his experiments with falling stones.
- The most significant contributions in dynamics, however, were made by **Issac Newton** (1642-1727), who is noted for his formulation of three fundamental laws of motion.
- Shortly after these laws were postulated, important techniques for their application were developed by such notables as Euler, D'Almebert, Lagrange, and others.

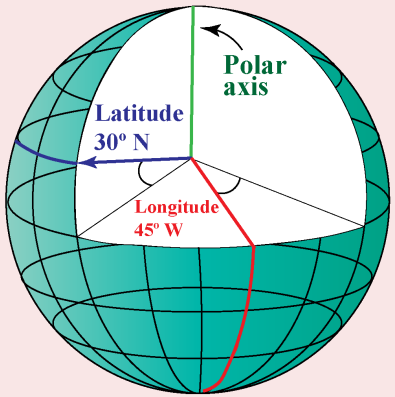
Mass

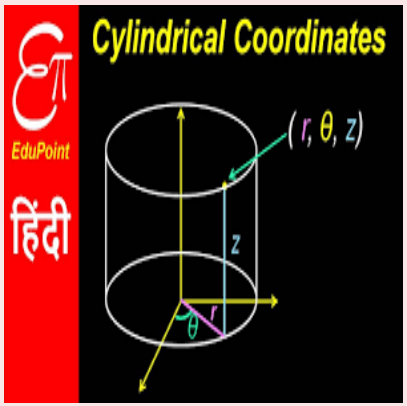
- Mass is a measure of the inertia of a body, which is its resistance to a change of velocity
- Mass can also be thought of as the quantity of matter in a body
- The mass of a body will not change unless the body is damaged and part of it is physically separated.
- When a body is taken out in a spacecraft, the mass will not change but its weight may change due to the change in gravitational force.
- Even the body may become weightless when a gravitational force vanishes but the mass remain the same.

Space

- It is the geometric region occupied by bodies whose positions are described by linear and angular measurements relative to a coordinate system.
- The reference point is called the origin and set of measurements as coordinates.
- If coordinates involve only in mutually perpendicular directions they are known as Cartesian coordinates. If the coordinates involve angle and distances, it is termed as polar coordinate system.



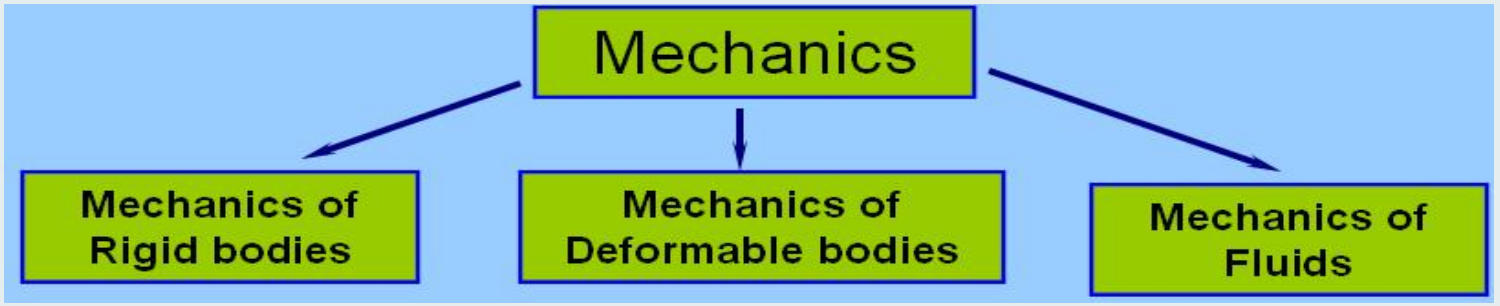




Time

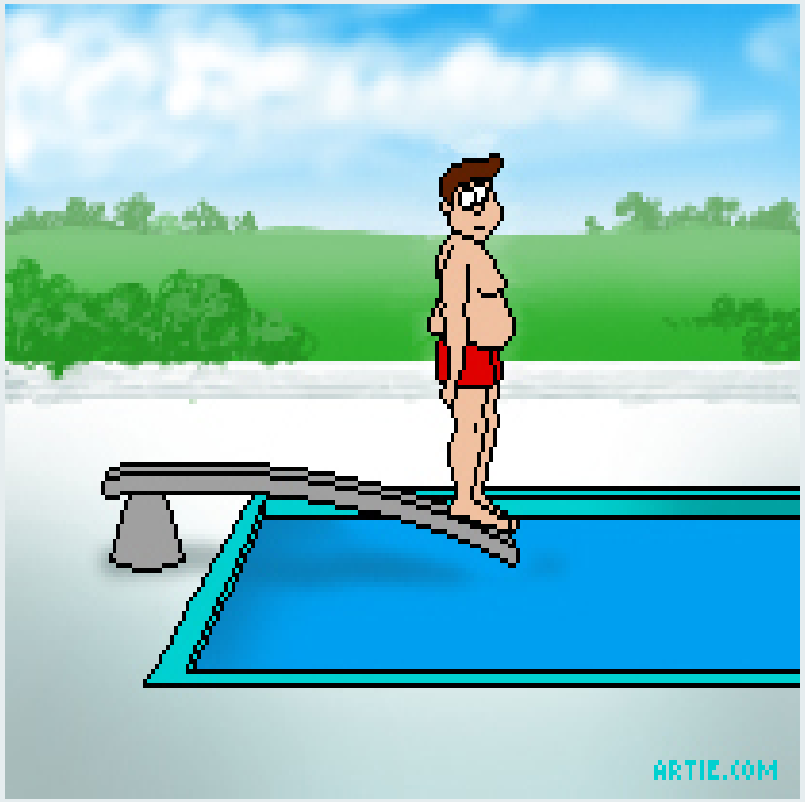
- Time is the measure of the succession of events and is a basic quantity in dynamics
- Time is not directly involved in the analysis of statics problems

Classification

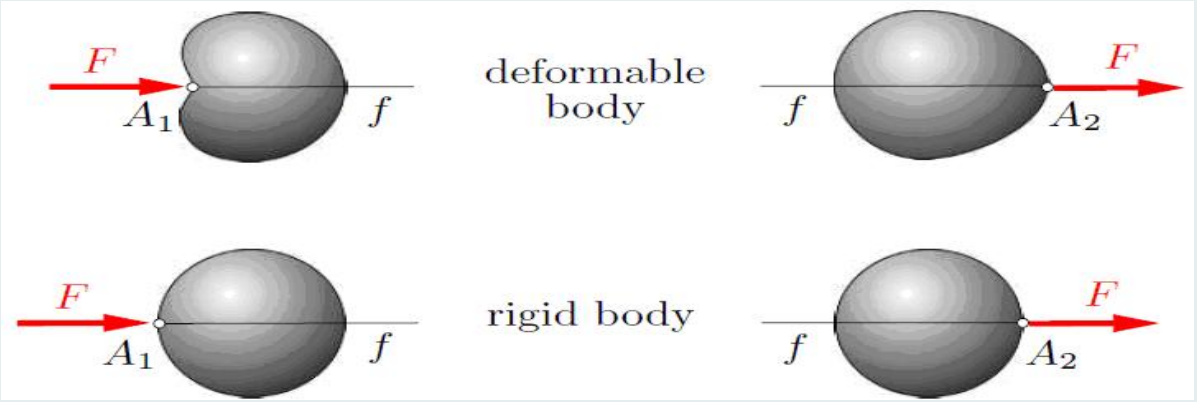


- A **rigid body** can be considered as a combination of a large number of particles in which all the particles remain at a fixed distance from one another, both before and after applying the load.
- Deformation due to force applied is insignificant

Rigid Vs Deformable body

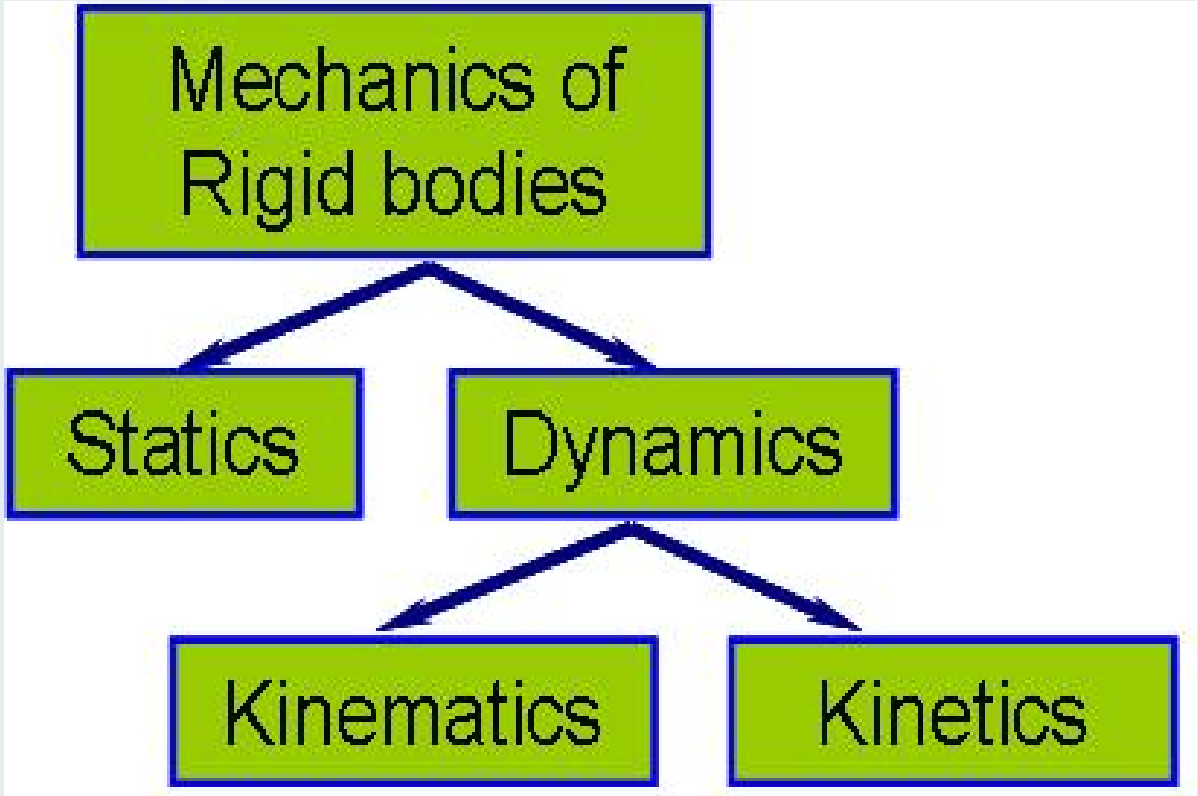


Rigid Vs Deformable body



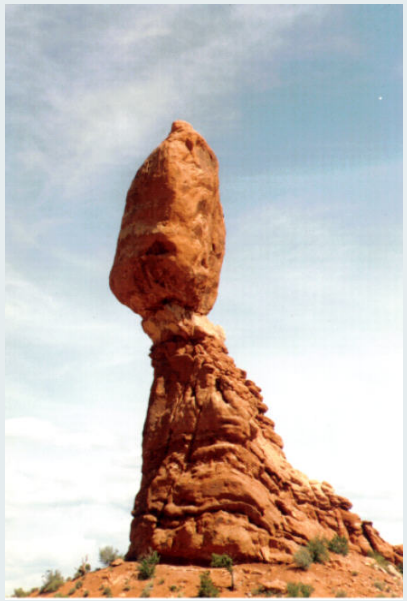
- In the case of a deformable sphere, the effect of the force depends on the point of application. In contrast, for a rigid sphere the effect of the force F on the entire body is the same, regardless of whether the body is pulled or pushed
- In most cases the actual deformations occurring in structures, machines, mechanisms, and the like are relatively small, and the rigid-body assumption is suitable for analysis.

Rigid Body Mechanics-Classification



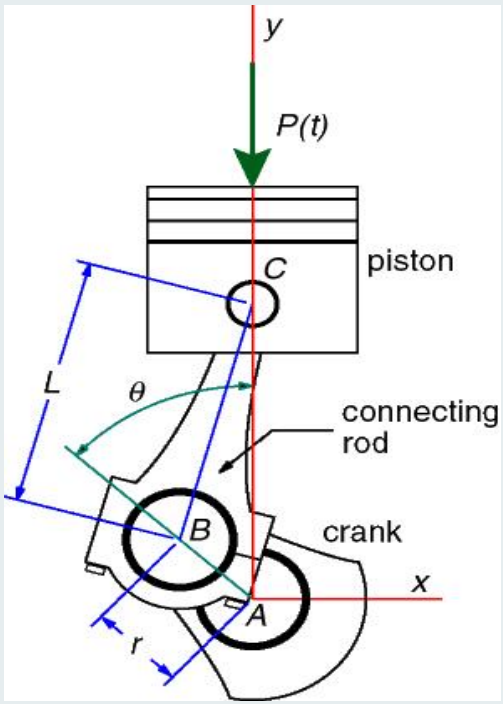
Rigid Body Mechanics

- Rigid body mechanics further classified as statics and dynamics
- **Statics** (Latin: Status = standing) deals with bodies in the state of rest subjected to forces.
- **Dynamics** (Greek: dynamis = force) deals with accelerated motion of bodies. Statics can be considered as a special case of dynamics, in which the acceleration is zero.



Dynamics

- Dynamics subdivided into kinematics and kinetics.
- Kinematics (Greek: kinesis = movement) investigates the motion of bodies without referring to forces as a cause or result of motion.
- Kinematics deals with the geometry of the motion in time and space.
- Kinetics relates the forces involved and the motion.

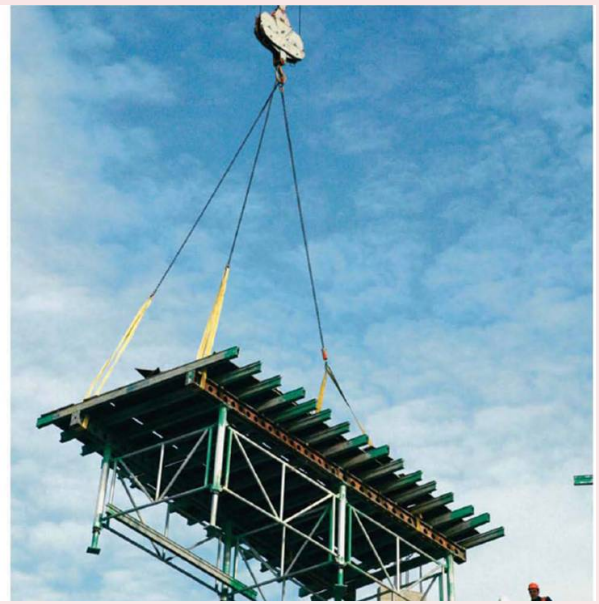


Force

- Force is considered as a push or pull exerted by one body on another.
- This interaction can occur when there is direct contact between bodies or it can occur through a distance when the bodies are physically separated.
- Examples
  - Direct contact - A person pushing on a wall.
  - At a distance - Gravitational, electrical and magnetic forces
- Although forces cannot be seen or directly observed, we are familiar with their effects.
  - Helical spring stretches when it is pulled, muscle tension conveys a qualitative feeling of the force in the spring.

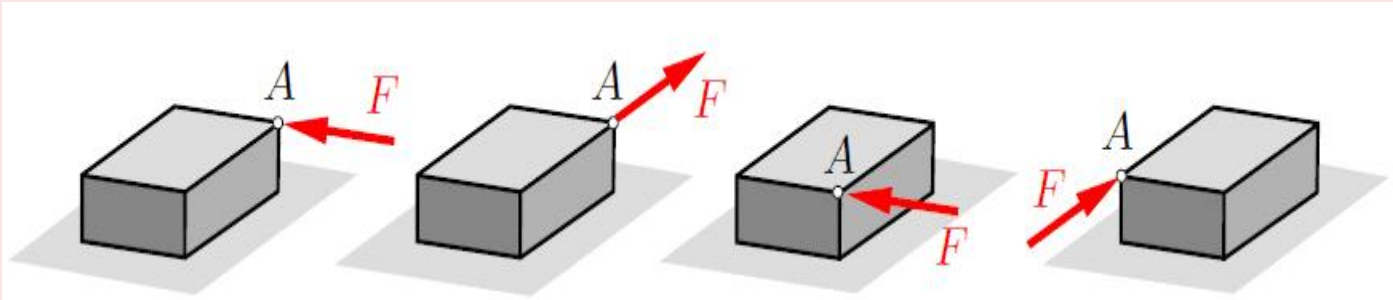
Concentrated force

- A single force with a line of action and a point of application.
- It is an idealization that in reality does not exist and it is almost realized when a body is loaded over a thin wire or a needlepoint.
- We can represent a load by a concentrated force, provided the area over which the load is applied is very small compared to the overall size of the body.
- Examples: Contact force between the wheel and rail, tension in each rope on the hook

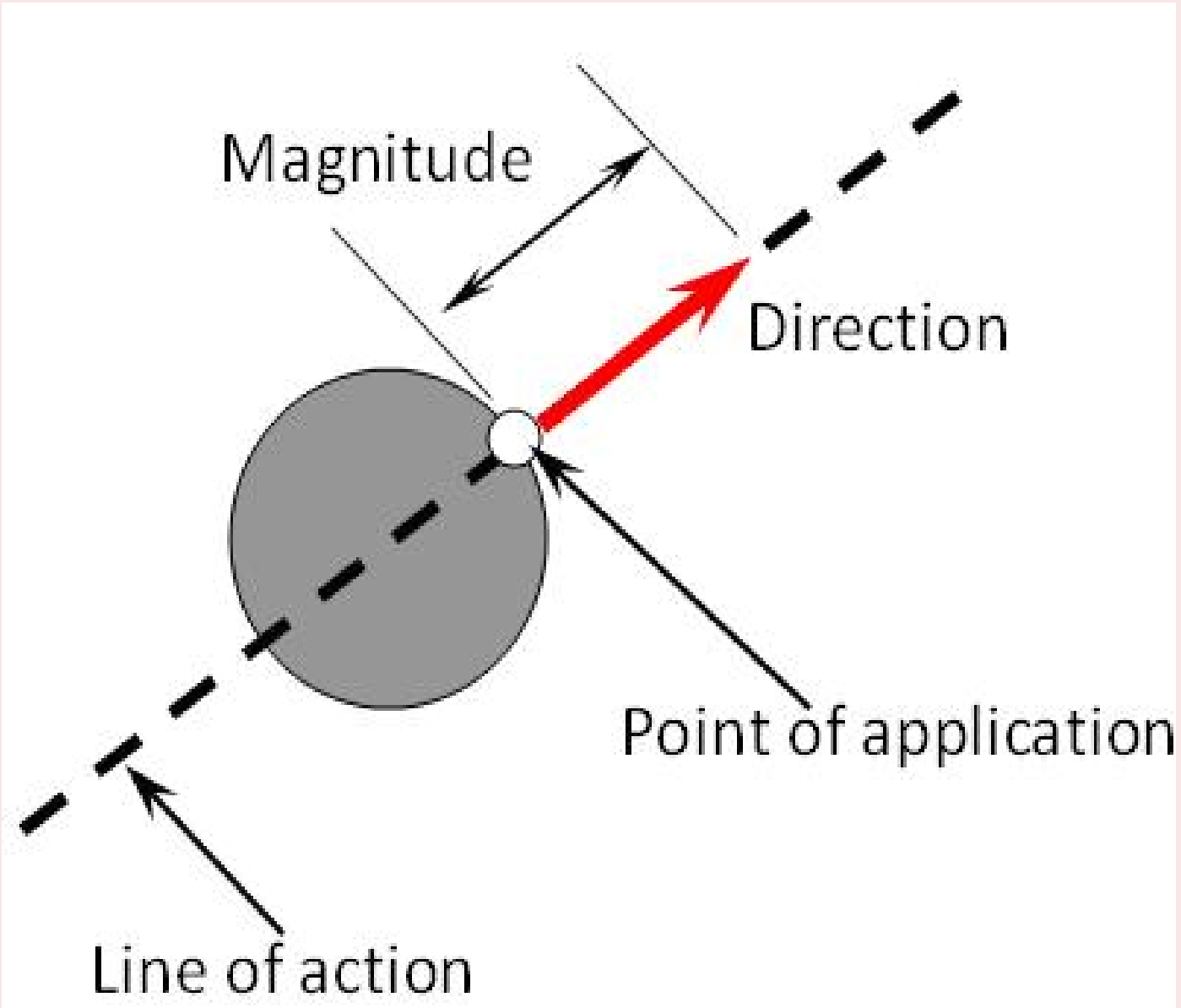


Representation of a Force

- The quantitative effect of a force is given by its magnitude.
  - we feel different muscle tensions when we lift different bodies
- Force has a direction
  - we can press against a tabletop in a perpendicular or in an inclined manner.
  - The direction of the force can be described by its line of action and its sense of direction (orientation)is indicated by the arrow
- A single force acts at a certain point of application
  - Depending on the location of point A, the force will cause different movements of the box.



Representation of a Force

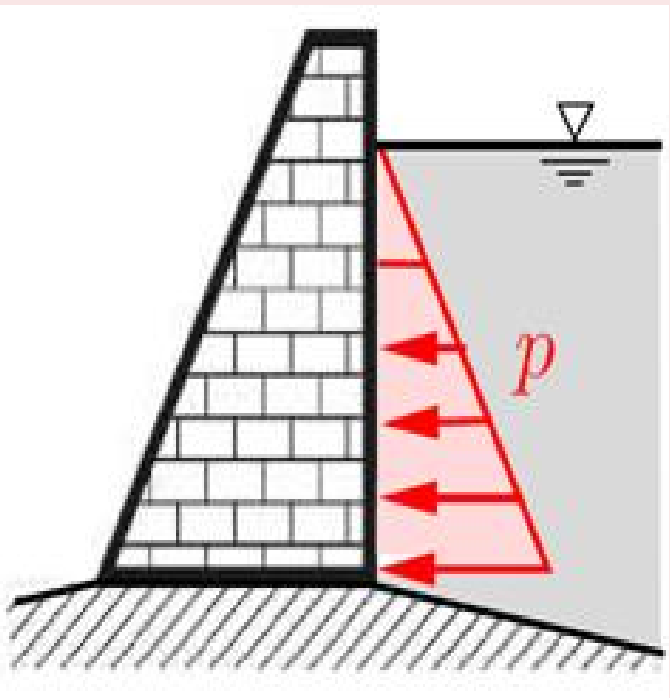


Volume force

- is a force that is distributed over the volume of a body or a portion thereof.
- Examples
  1. Weight
  2. Magnetic force
  3. Electrical force

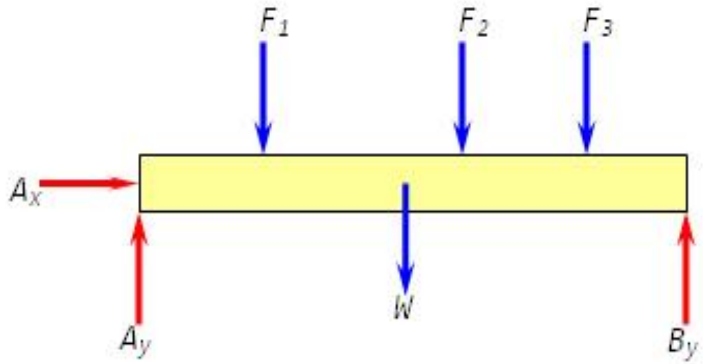
Area force

- Area forces occur in the regions where two bodies are in contact.
- Examples
  1. Water pressure p at a dam
  2. The snow load on a roof, Rain on the roof
  3. pressure of a body on a hand



Active and Reactive forces

- Active forces refer to the physically prescribed forces in a mechanical system.
- Reactive forces are generated if the freedom of movement of a body is constrained.
- Example: Forces in blue are active while Forces in red are reactive



Newton's Law

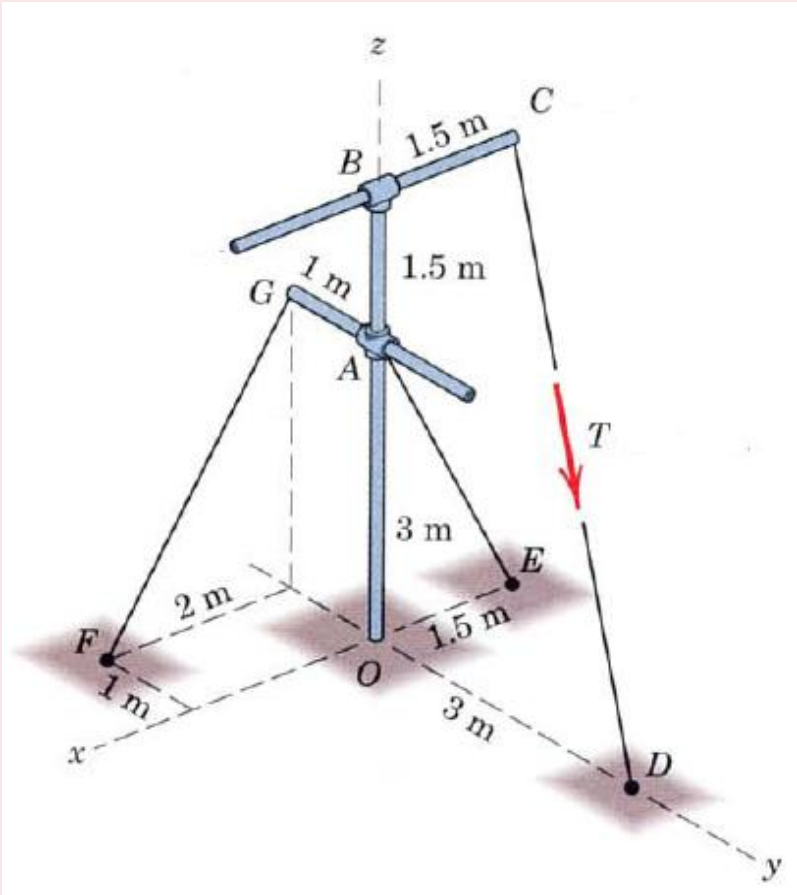
- First Law
  - An object at rest remains at rest, and an object in motion remains in motion at constant speed and in a straight line unless acted on by an unbalanced force.
- Second Law
  - The acceleration of an object depends on the mass of the object and the amount of force applied.
- Third Law
  - forces act in equal and opposing pairs.
  - every action has an equal and opposite reaction.

Coplanar Forces

- Forces lying in the same plane are called coplanar forces
- Line of action of coplanar forces lie in a single (same) plane
- Forces in each cables (on one side of the bridge) will constitute a coplanar force system

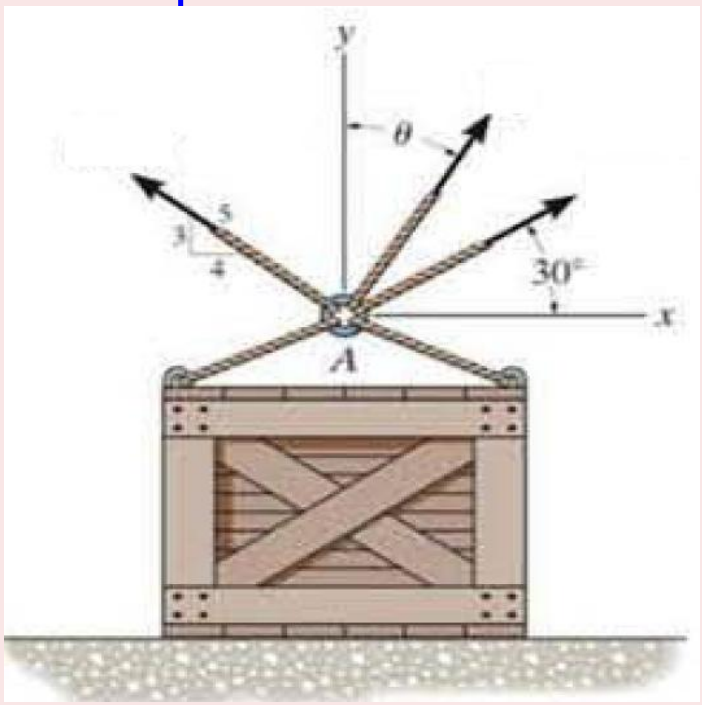
Non Coplanar Forces

- Forces lying in different planes
- Line of action of coplanar forces will not lie in a single/same plane
- Tension in ropes AE, GF and CD will constitute a non coplanar force system

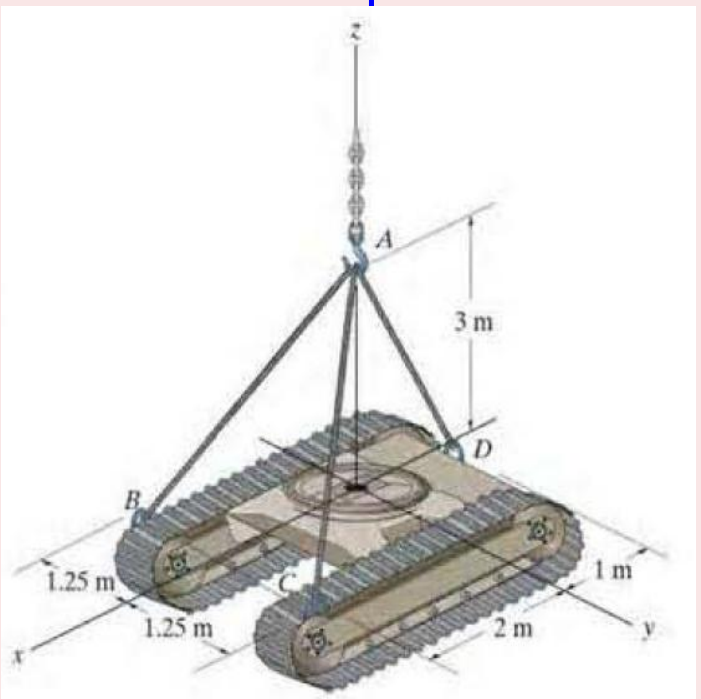


Concurrent Forces

- Systems of concentrated forces that have a common point of application
- Forces acting on a body do not have to have the same point of application; it is sufficient that their lines of action intersect at a common point
- Coplanar

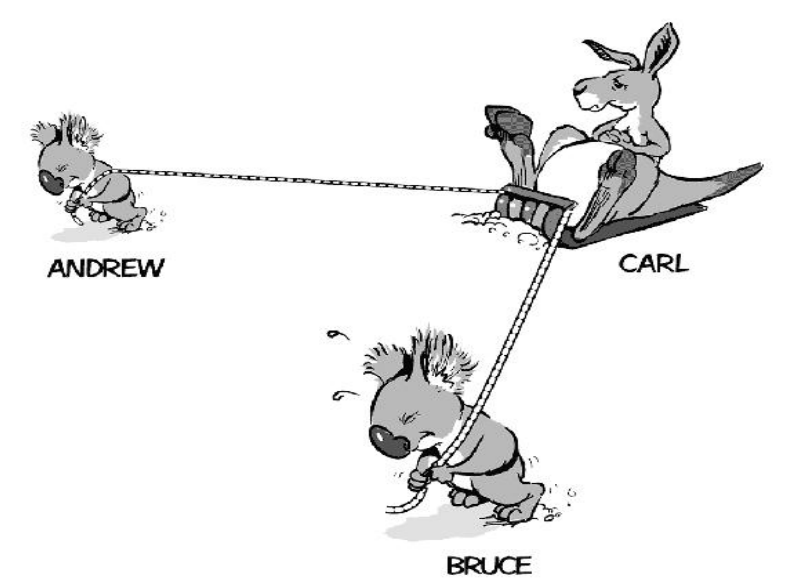


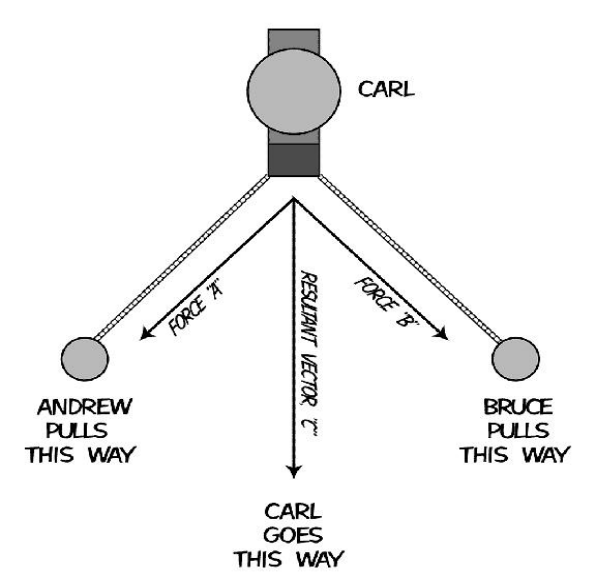
Non coplanar



Resultant Force

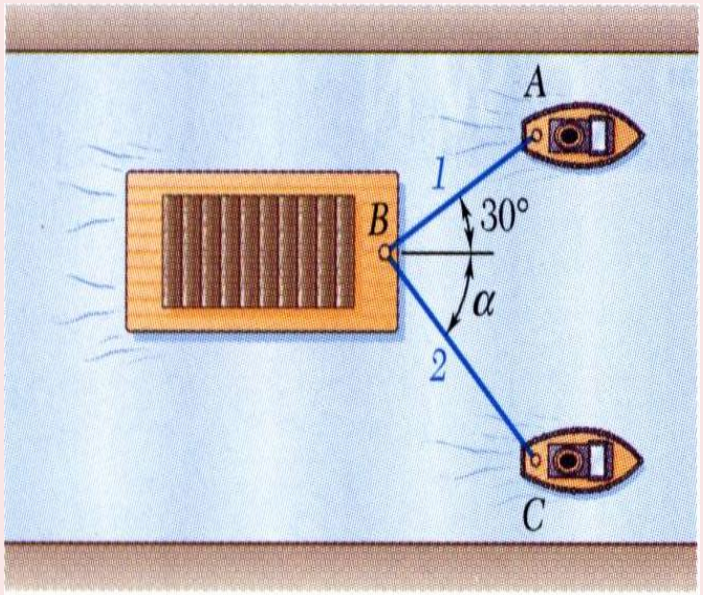
- Resultant of a system of forces is the single force that replaces the original forces and produces the same external effect of the system on the body





Resultant Force-One more example

- A barge is pulled by two tugboats. The resultant of the forces exerted by the tugboats is 5000 N directed along the axis of the barge while tension in ropes AB and AC are 3660 N and 2590 N respectively.

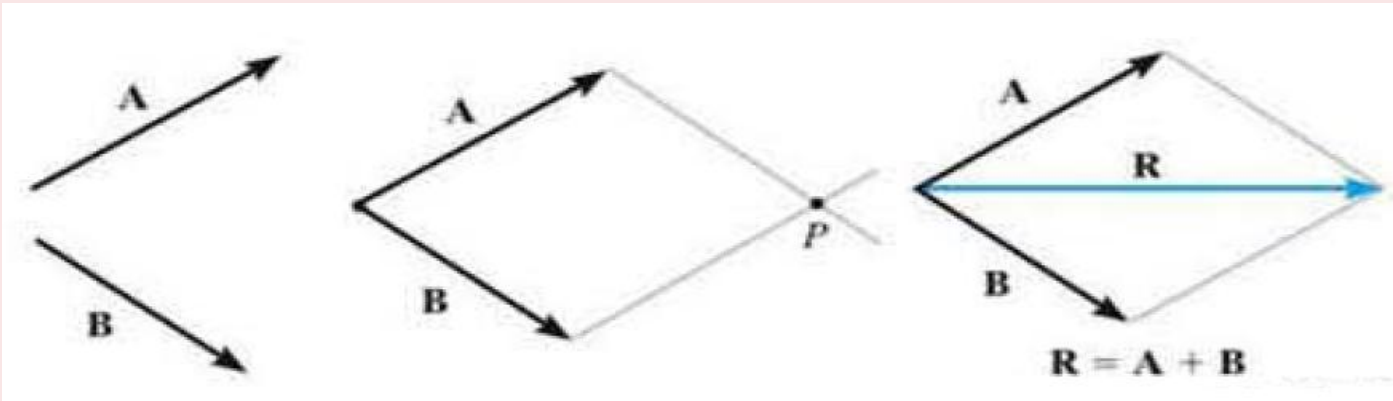


Resultant of Two Forces-Parallelogram Law

- If two co-planar concurrent forces acting on a particle are represented by the two adjacent sides of a parallelogram, then, the diagonal of the parallelogram gives the resultant of the two forces.

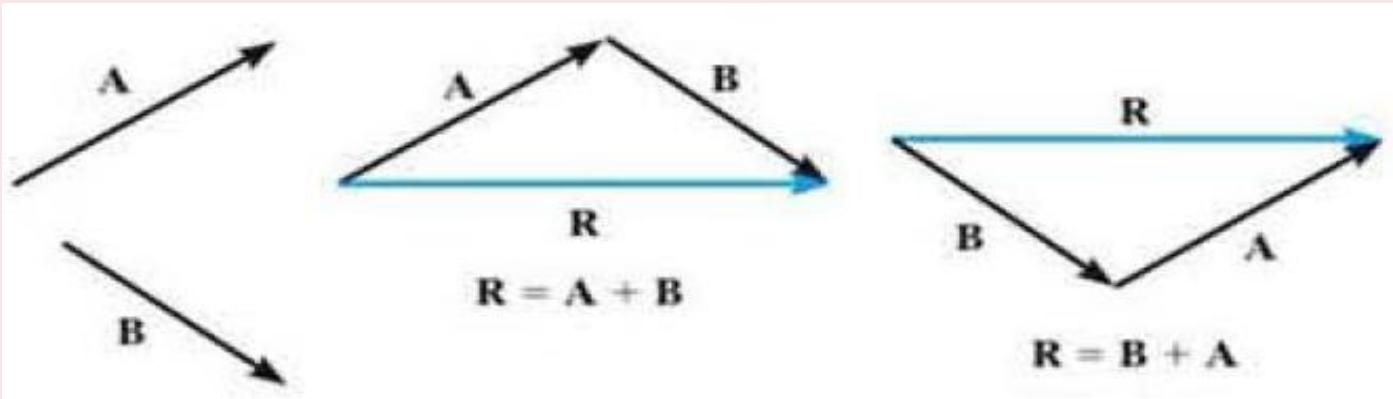
Resultant of Two Forces-Parallelogram Law

- If two co-planar concurrent forces acting on a particle are represented by the two adjacent sides of a parallelogram, then, the diagonal of the parallelogram gives the resultant of the two forces.
  - Join the tails of the forces at a point
  - From the head of B, draw a line parallel to A. Draw another line from the head of A that is parallel to B. These two lines intersect at point P
  - The diagonal of the parallelogram will represent the resultant vector R
  - A and B are also known as component vectors of R



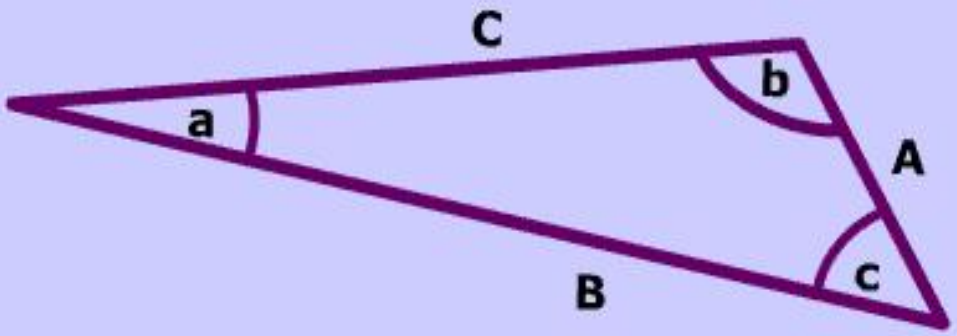
Resultant of Two Forces-Triangle Law

- If two co-planar concurrent forces acting on a particle are represented by the two adjacent sides of a triangle, then, the third side of the triangle will give the resultant.
  - Vector B is added to vector A in a head-to-tail fashion, i.e., by connecting the head of A to the tail of B
  - The resultant R extends from the tail of A to the head of B



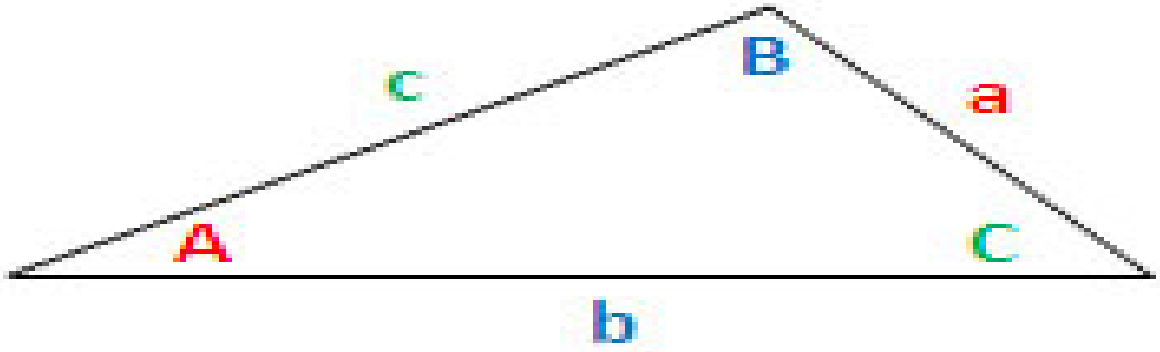
Law of Sines

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



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

Law of cosines



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

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

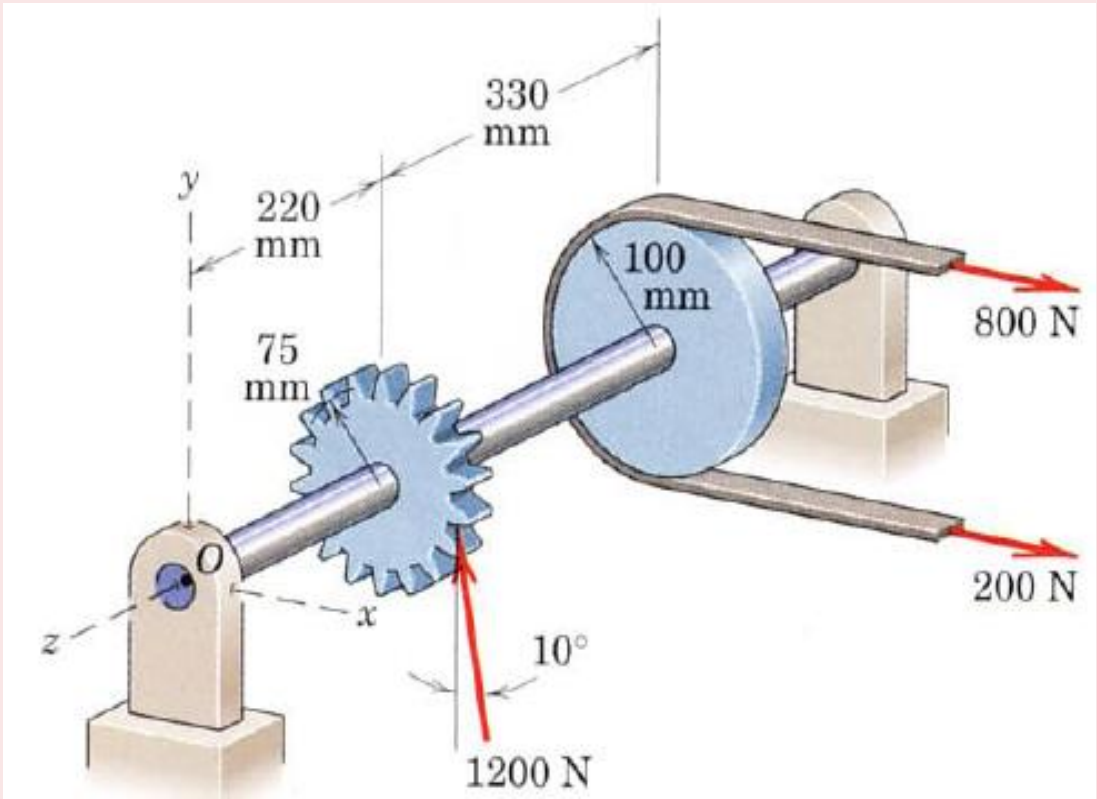
$$c^2 = a^2 + b^2 - 2ab\cos C$$

Components of a force

- Effect of a force on a particular direction
- A single force has infinity number of components
- Component of a force in a direction perpendicular to the line of action of a force is zero

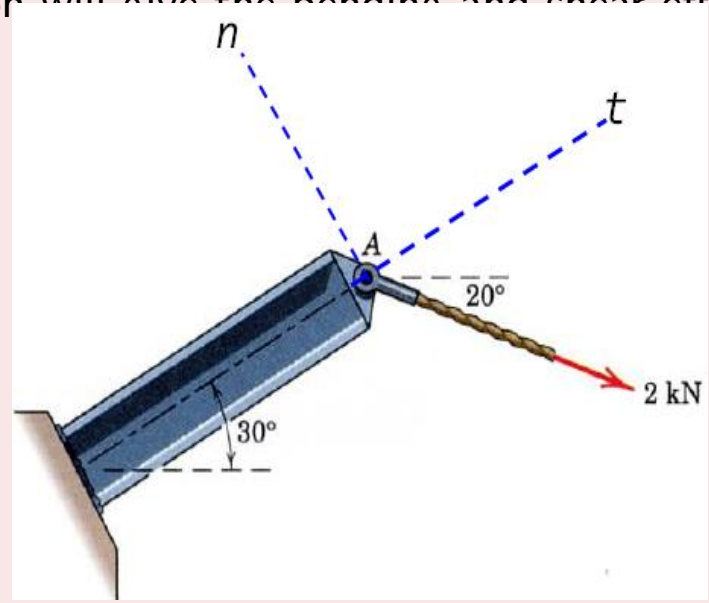
Components of a force

- The design of bearing at O and shaft (selection of material and diameter) will be influenced by the forces in the belt (i.e., 800 N and 200 N) and component of 1200 N force acting on the gear along x direction
- So it is important to be familiar with components of a force



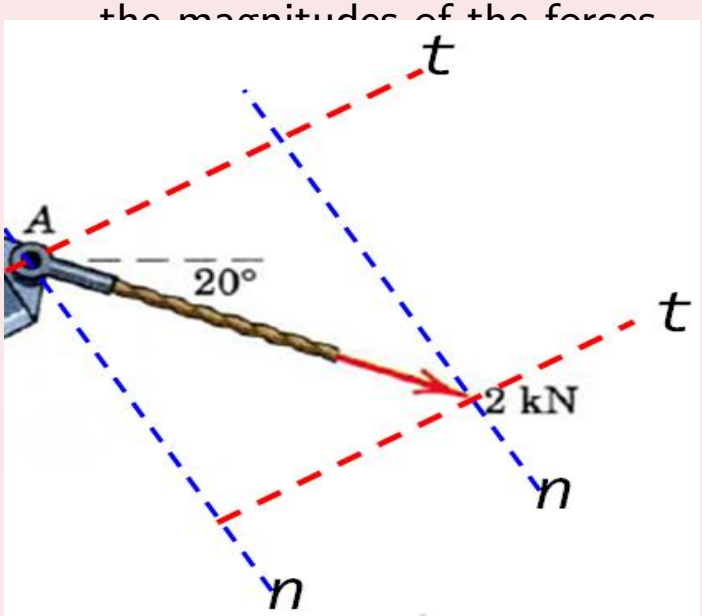
Finding the components of a force

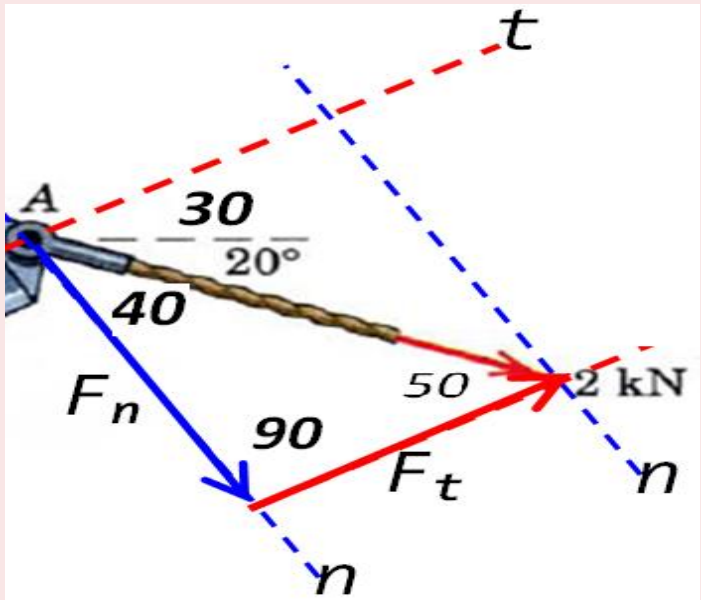
- Sometimes it is necessary to resolve a force into two components in order to study its pulling or pushing effect in two specific directions.
  - For example, F is to be resolved into two components along parallel (t) and perpendicular (n) to the beam.
  - Component of F along parallel direction will give the effect of tension on the beam while component of F along perpendicular direction will give the bending and shear effect on the beam



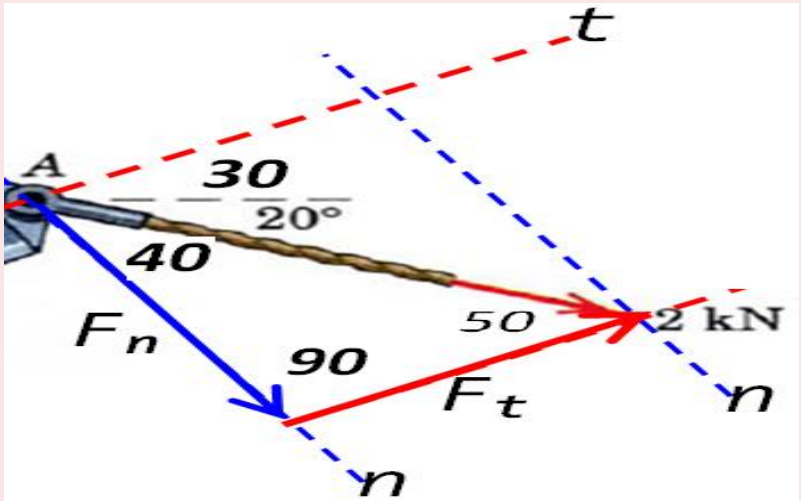
Finding the components of a force

- For this, a parallelogram is constructed first, by drawing lines starting from the tip of F, one line parallel to t, and the other line parallel to n. These lines then intersect with the t and n axes, forming a parallelogram
- Establish the force components
- Reduce the parallelogram to a triangle and apply law of sines to obtain the magnitudes of the forces





Apply Law of Sines

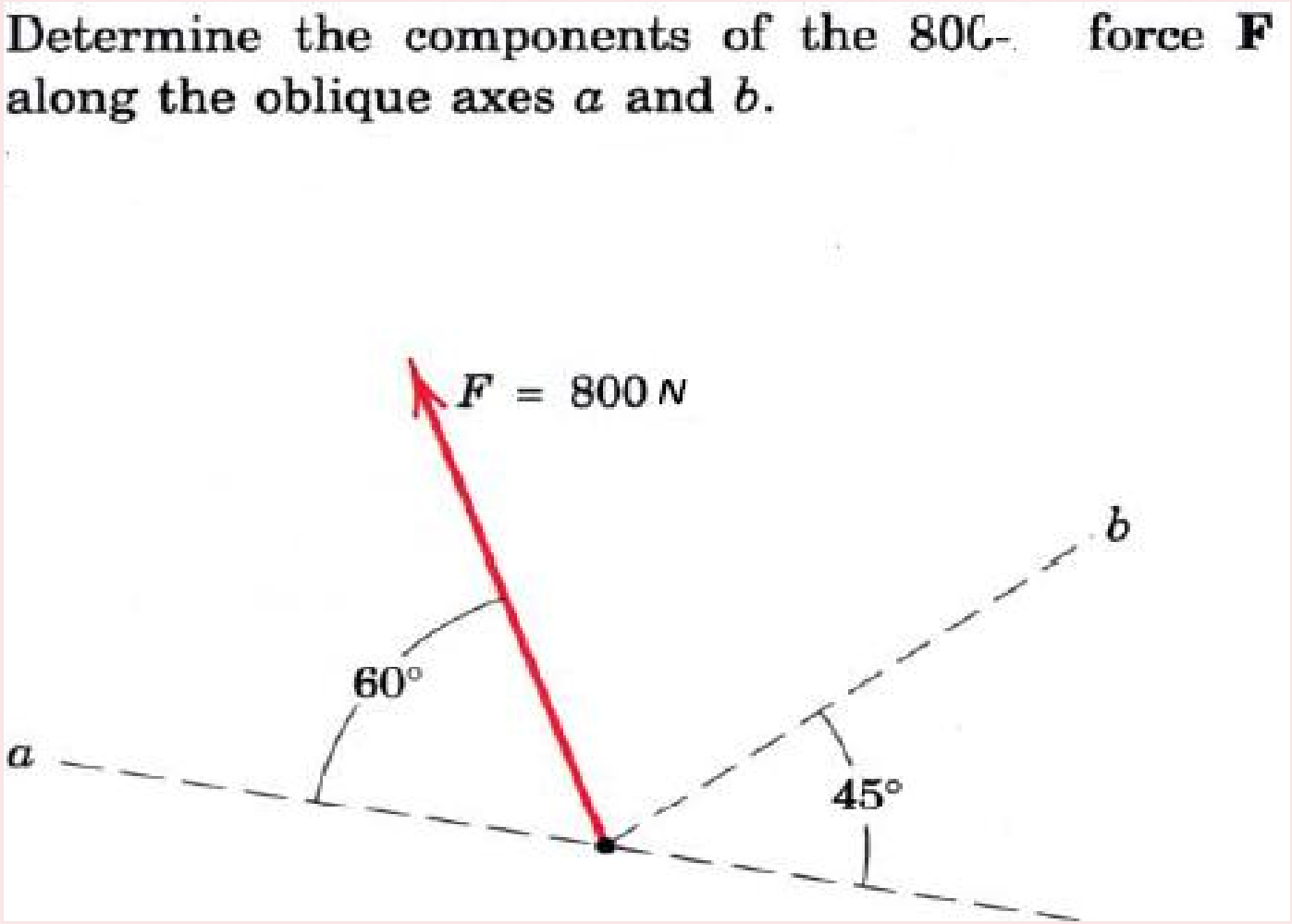


- $$\frac{F_t}{sin40} = \frac{F_n}{sin50} = \frac{2000}{sin90}$$

- F_t= 1286 N and F_n= 1532 N

Problem 1

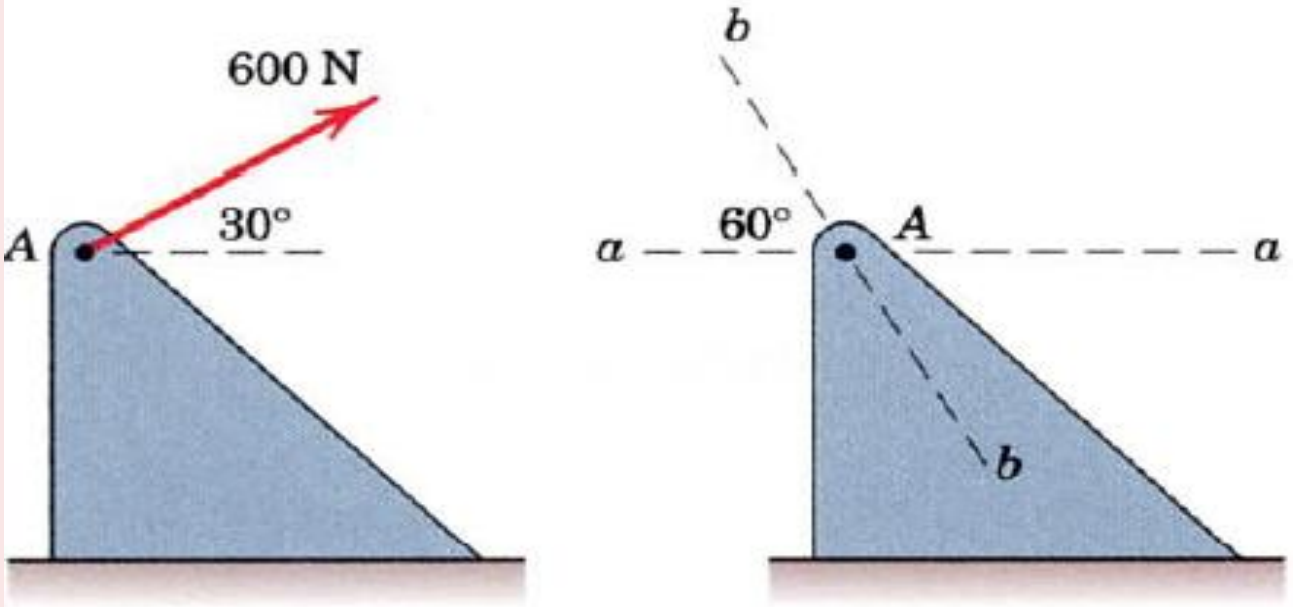
Determine the components of the 800- force **F** along the oblique axes a and b.



- F_{aa}=1093 N and F_{bb}= 980 N

Problem 2

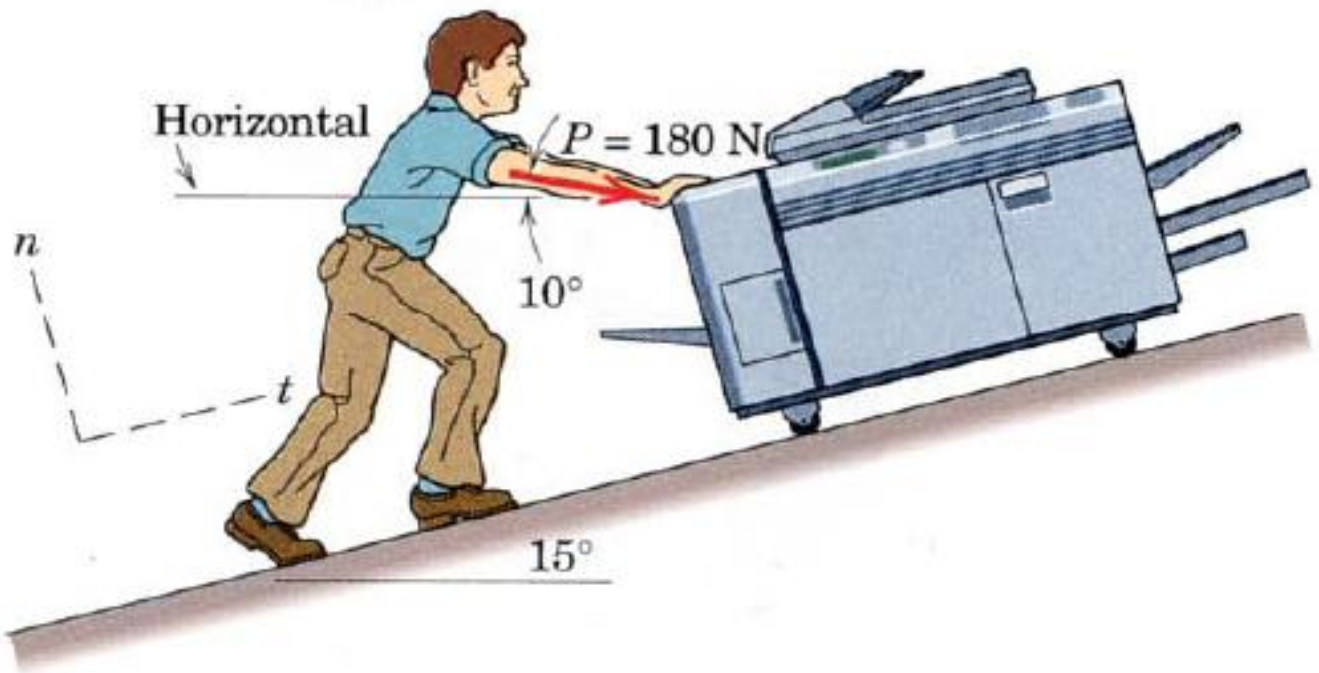
The 600-N force applied to the bracket at A is to be replaced by two forces, F_a in the a-a direction and F_b in the b-b direction, which together produce the same effect on the bracket as that of the 600-N force. Determine F_a and F_b.



- F_{aa}= 693 N and F_{bb}= 346 N

Problem 3

While steadily pushing the machine up an incline, a person exerts a 180-N force **P** as shown. Determine the components of **P** which are parallel and perpendicular to the incline.



- F_{aa}=163 N and F_{bb}= 76 N