



SNS COLLEGE OF TECHNOLOGY

Coimbatore-35
An Autonomous Institution

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Approved by AICTE, New Delhi & Affiliated to Anna University, Chennai



DEPARTMENT OF AUTOMOBILE ENGINEERING

19AUT203 – Mechanics of Automobile Systems

II YEAR / IV SEM

Unit - 2 - Force Analysis

- In **physics**, a force is any interaction which tends to change the motion of an object.
- In other words, a force can cause an object with **mass** to change its **velocity** (which includes to begin moving from a **state of rest**), i.e., to **accelerate**.
- Force can also be described by intuitive concepts such as a push or a pull.
- A force has both **magnitude** and **direction**, making it a **vector** quantity. It is measured in the **SI unit** of **newtons** and represented by the symbol **F**.
- The original form of **Newton's second law** states that the net force acting upon an object is equal to the **rate** at which its **momentum** changes with time.
- If the mass of the object is constant, this law implies that the **acceleration** of an object is directly proportional to the net force acting on the object, is in the direction of the net force, and is inversely proportional to the **mass** of the object.
- As a formula, this is expressed as:
- Related concepts to force include: **thrust**, which increases the velocity of an object; **drag**, which decreases the velocity of an object; and **torque** which produces **changes in rotational speed** of an object. In an extended body, each part usually applies forces on the adjacent parts; the distribution of such forces through the body is the so-called **mechanical stress**.
- **Pressure** is a simple type of stress. Stress usually causes **deformation** of solid materials, or flow in **fluids**.
- Aristotle famously described a force as anything that causes an object to undergo "unnatural motion"

TYPES OF FORCES

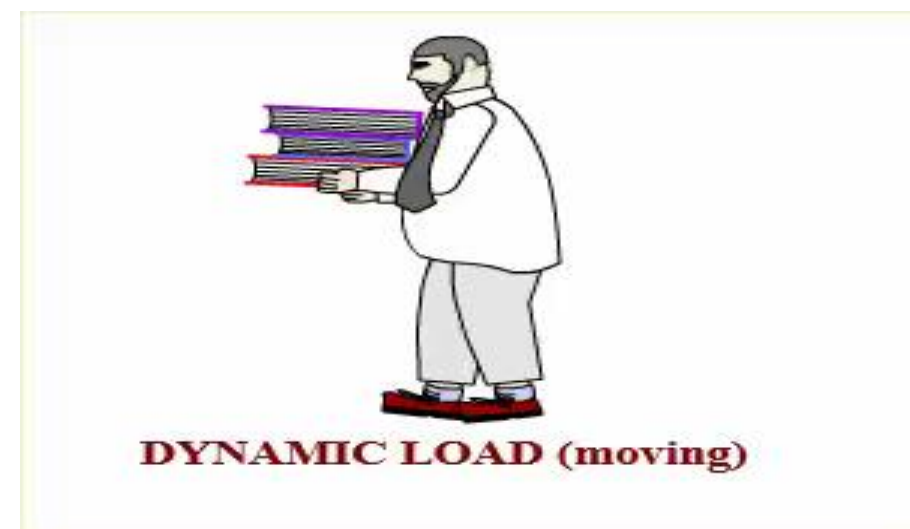
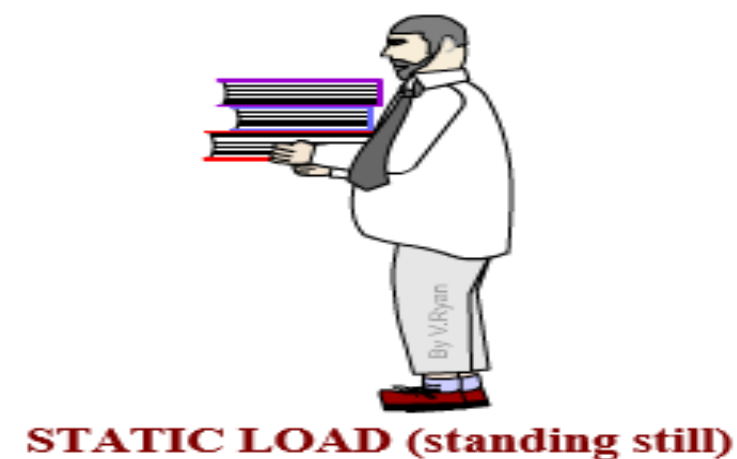
There are different types of forces that act in different ways on structures such as bridges, chairs, buildings, in fact any structure.

The main examples of forces are shown below. Study the diagram and text and then draw a diagram/pictogram to represent each of these forces.

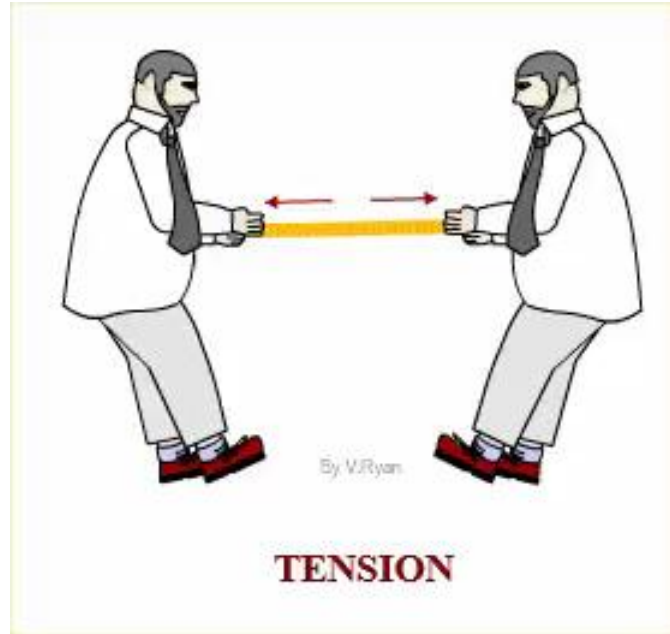
A Static Load : A good example of this is a person seen on the left. He is holding a stack of books on his back but he is not moving. The force downwards is **STATIC**.

A Dynamic Load : A good example of a dynamic load is the person on the right. He is carrying a weight of books but walking. The force is moving or **DYNAMIC**.

Internal Resistance : The person in the diagram is sat on the mono-bicycle and the air filled tyre is under great pressure. The air pressure inside it pushes back against his/her weight.

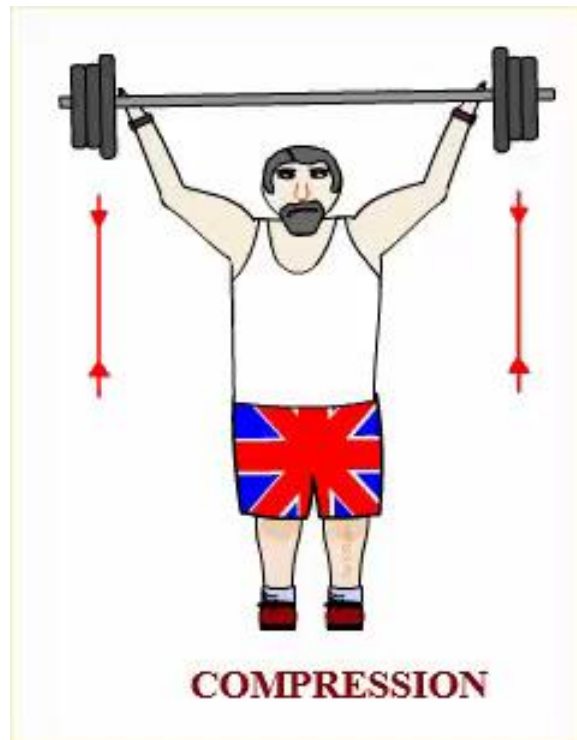
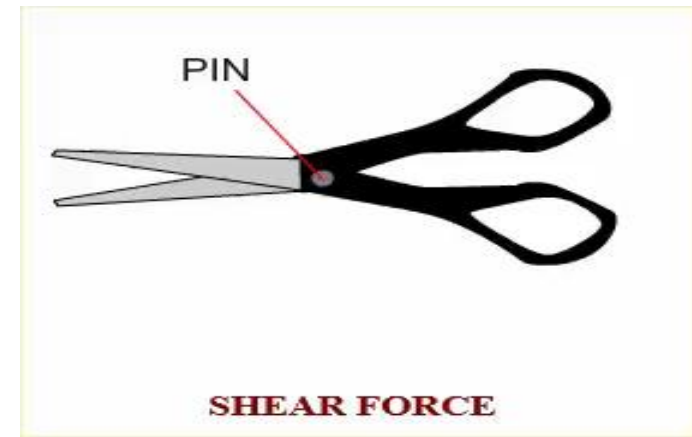


Types of Forces



Tension : The rope is in “tension” as the two people pull on it. This stretching puts the rope in tension.

Compression : The weight lifter finds that his body is compressed by the weights he is holding above his head.



Shear Force : A good example of shear force is seen with a simple scissors. The two handles put force in different directions on the pin that holds the two parts together. The force applied to the pin is called shear force.

Torsion : The plastic ruler is twisted between both hands. The ruler is said to be in a state of torsion.

MOMENT OF INERTIA

Moment of inertia is the mass property of a rigid [body](#) that determines the torque needed for a desired [angular acceleration](#) about an axis of rotation.

Moment of inertia depends on the shape of the body and may be different around different axes of rotation. A larger moment of inertia around a given axis requires more torque to increase the rotation, or to stop the rotation, of a body about that axis.

Moment of inertia depends on the amount and distribution of its mass, and can be found through the sum of moments of inertia of the masses making up the whole object, under the same conditions.

For example, if $m_a + m_b = m_c$, then $I_a + I_b = I_c$.

In [classical mechanics](#), moment of inertia may also be called mass moment of inertia, rotational inertia, polar moment of inertia, or the angular mass.

When a body is rotating around an axis, a torque must be applied to change its angular momentum. The amount of torque needed for any given change in angular momentum is proportional to the size of that change.

Moment of inertia may be expressed in terms of kilogram-square metres (kg·m²) in SI units and pound-square feet (lbm·ft²) in imperial or US units.

INTRODUCTION

Inertia force is an imaginary force, which when acted upon rigid body to brings it into equilibrium position. Here magnitude is equal to acceleration but opposite in direction.

$$F_i = -ma$$

Where, m = mass of rigid body
, a = linear acceleration

INTRODUCTION

The inertia force arises due to mass of the rotating or reciprocating parts of a machine. If the magnitude of inertia force is negligible as compared to other externally force or load and hence it is neglected and the analysis as compared of mechanism is called as **STATIC FORCE ANALYSIS.**

NEWTON'S LAWS OF MOTION

NEWTON'S FIRST LAW

Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it.

NEWTON'S SECOND LAW

Acceleration is produced when a force acts on a mass. The greater the mass (of the object being accelerated) the greater the amount of force needed (to accelerate the object).

NEWTON'S THIRD LAW

every force there is a reaction force that is equal in size, but opposite in direction. That is to say that whenever an object pushes another object it gets pushed back in the opposite direction equally hard.

NEWTON'S LAW

Newton's first two laws can be summarized by the following equilibrium

$$\sum F_{ij} = m_j a_{Gj}$$

Which is called the equation of motion of a body j.

APPLIED AND CONSTRAINT FORCES

A pair of actions and reaction forces which constrain two connected bodies to behave in a particular manner depending upon the nature of connection are known as constraint forces. Whereas forces acting from outside on a system of bodies are called applied force.

APPLIED AND CONSTRAINT FORCES

CONSTRAINT FORCES

As the constraint forces at a mechanical occur in pairs. They have no net force effect on the system of bodies. However, for an individual body isolated from the system. Only one of each pair of constraint force has to be considered.

APPLIED FORCE

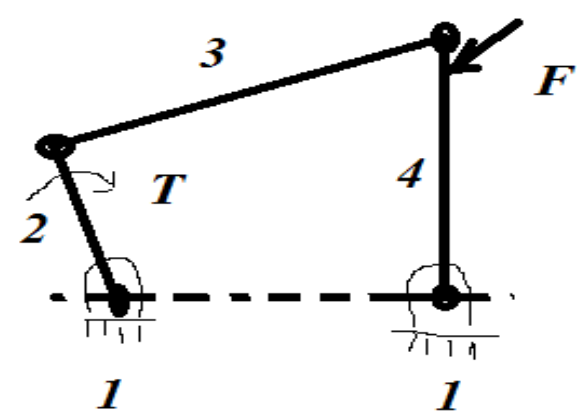
Usually, these forces are applied through direct physical or mechanical contact. However, forces like electric, magnetic and gravitational are applied without actual physical contact.

FREE BODY DIAGRAM

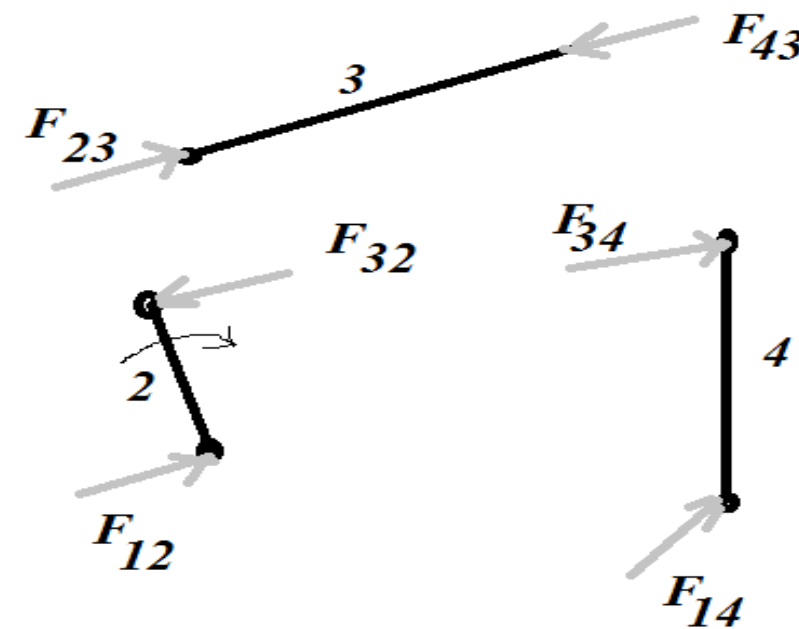
A free body diagram is a sketch or diagram of a part isolated from the mechanism in order to determine the nature of forces acting on it.

Figure (a) shows a four-link mechanism.

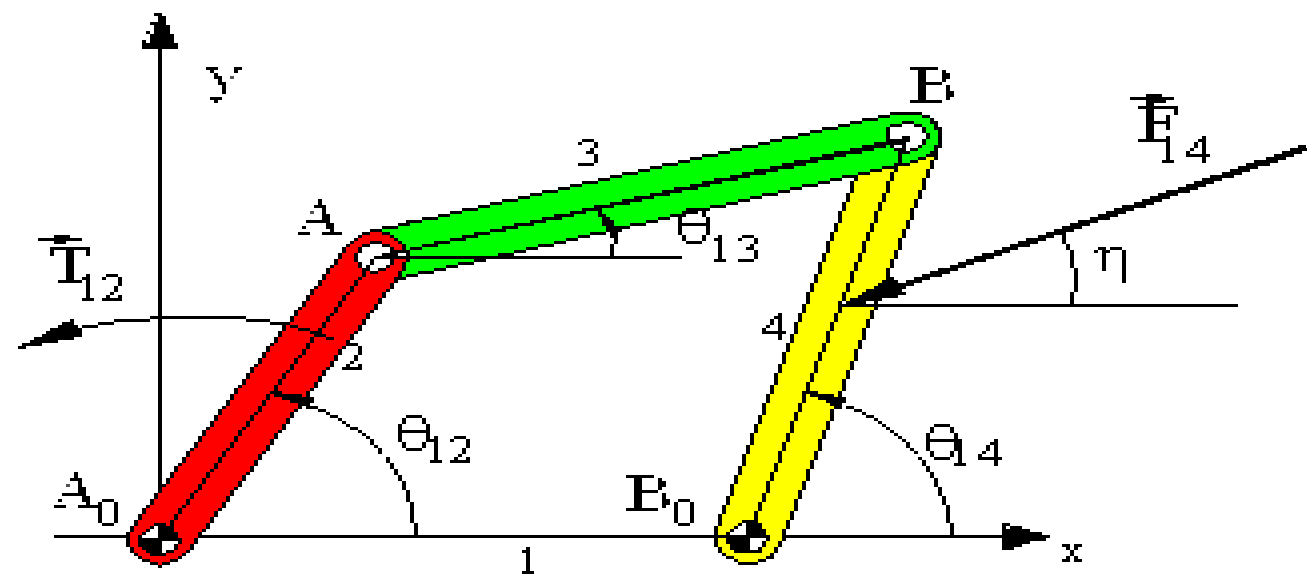
- The free-body diagrams of its members 2, 3 and 4 are shown in Figs. (b), (c) and (d) respectively.
- Various forces acting on each member are also shown.
- As the mechanism is in static equilibrium, each of its members must be in equilibrium individually.



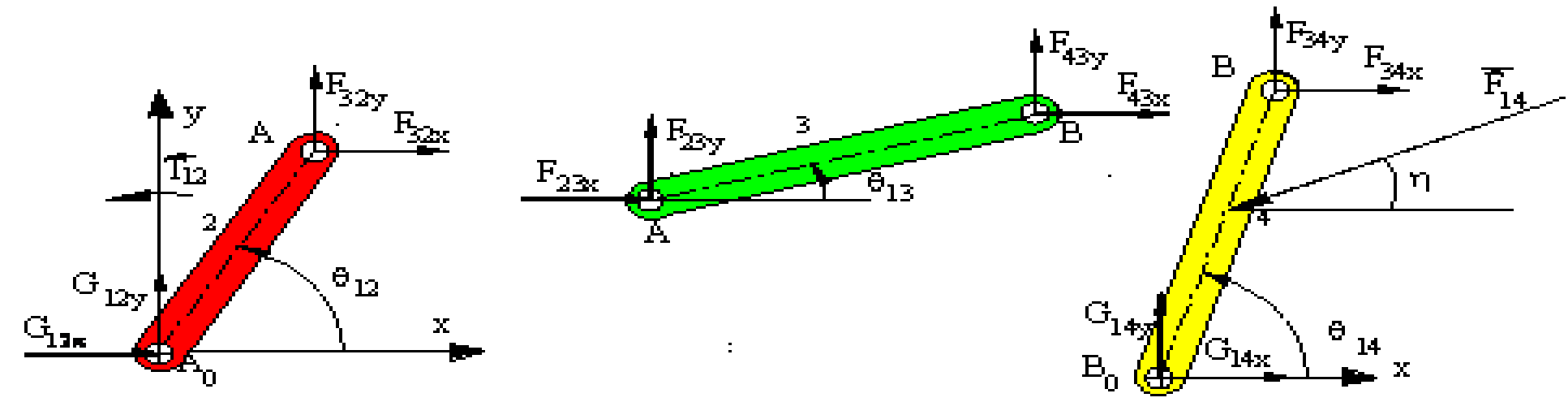
a) *Four bar chain*



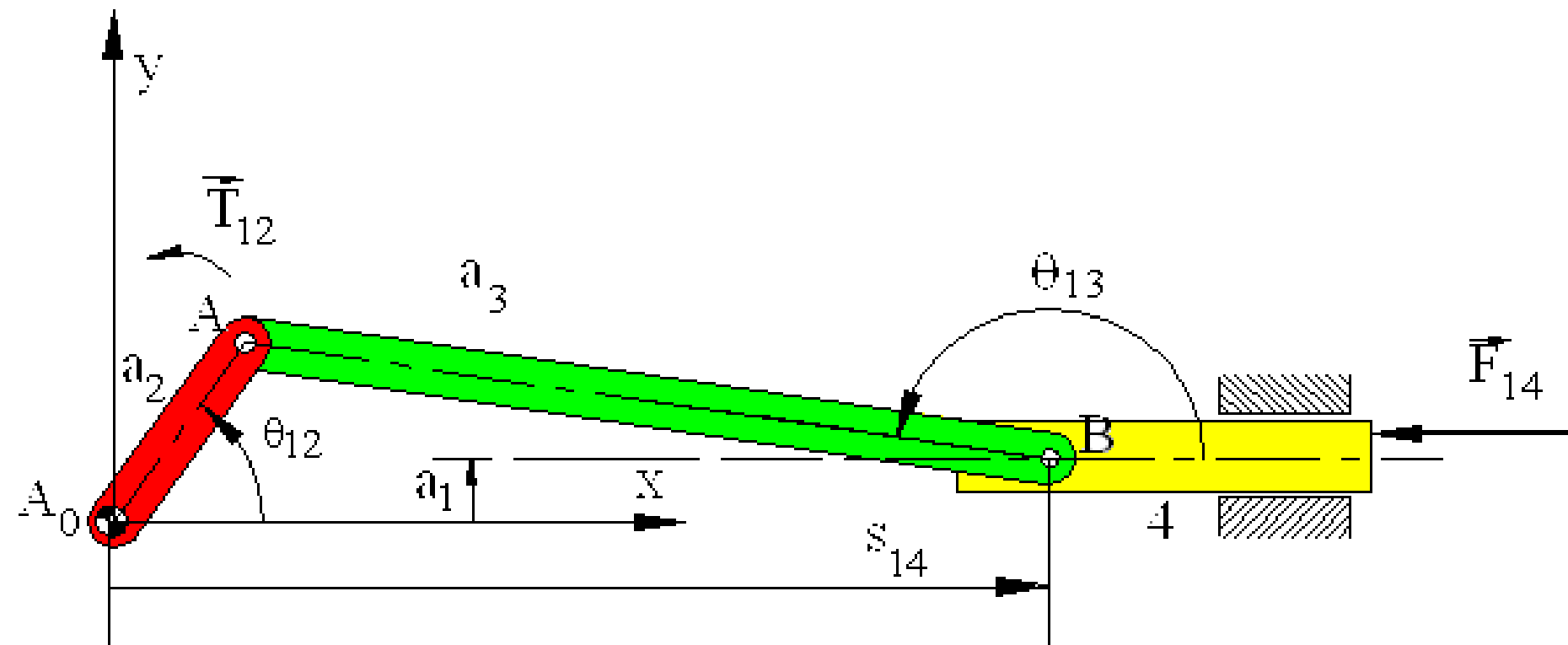
b) *F.B.D of four bar chain*



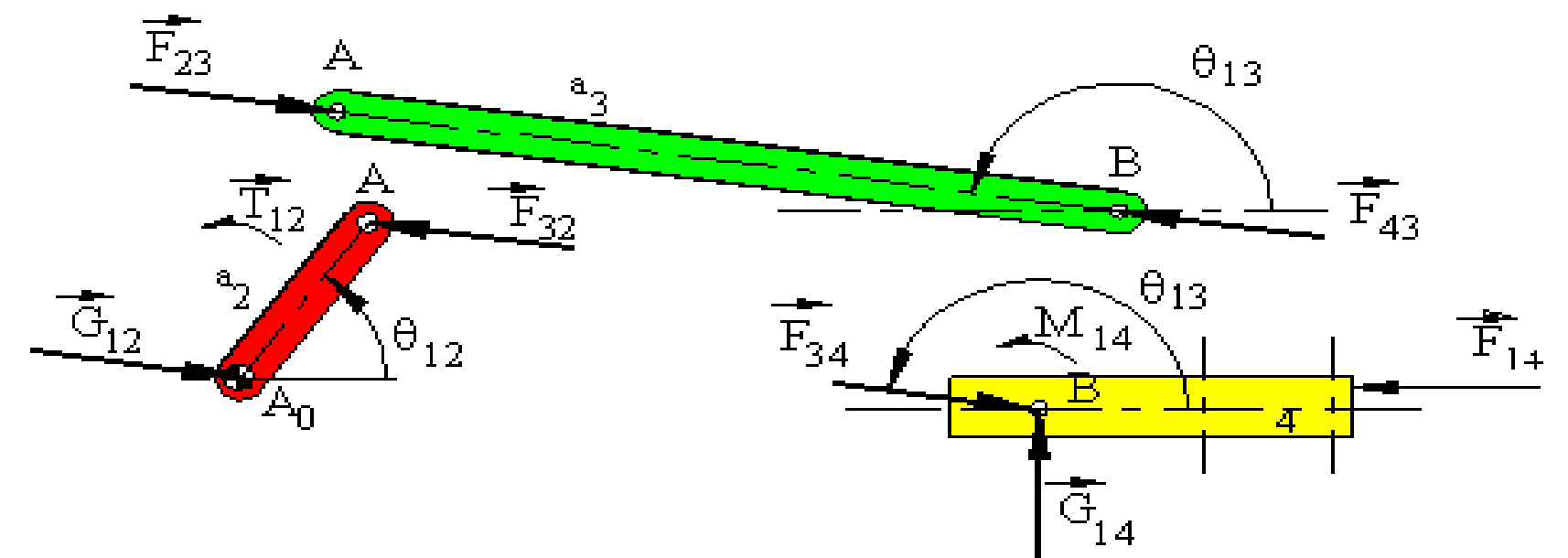
(a) Four bar chain mechanism



(b) F.B.D of four bar mechanism



(c) Slider crank mechanism



(b) F.B.D of slider crank mechanism

EQUILIBRIUM CONDITIONS

STATIC EQUILIBRIUM

A body is in static equilibrium if it remains in its state of rest or motion. If the body is at rest, it tends to remain at rest and if in motion, it tends to keep the motion.

DYNAMIC EQUILIBRIUM

If body in motion, it tends to keep in motion. It simply that the velocity do exist but remain constant that system in dynamic equilibrium

$$\begin{aligned}\Sigma \mathbf{F} &= \mathbf{0} \\ \Sigma \mathbf{T} &= \mathbf{0}\end{aligned}$$

$$\begin{aligned}\Sigma F_x &= 0 \\ \Sigma F_y &= 0 \\ \Sigma T_z &= 0\end{aligned}$$

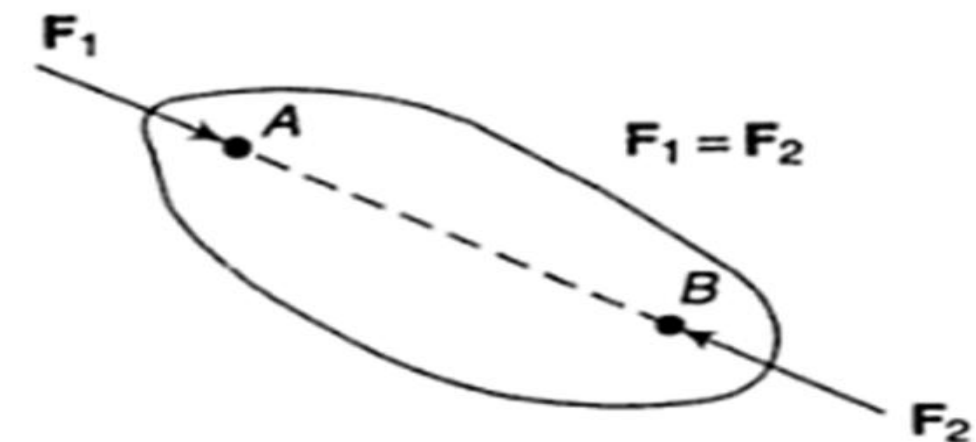
EQUILIBRIUM OF 2,3 FORCE SYSTEM

A member under the action of two forces will be in equilibrium if

- the forces are of the same magnitude,
- the forces act along the same line, and
- the forces are in opposite directions.

Figure shows such a member.

- A member under the action of three forces will be in equilibrium if
 - the resultant of the forces is zero, and
 - the lines of action of the forces intersect at a point (known as *point of concurrency*).

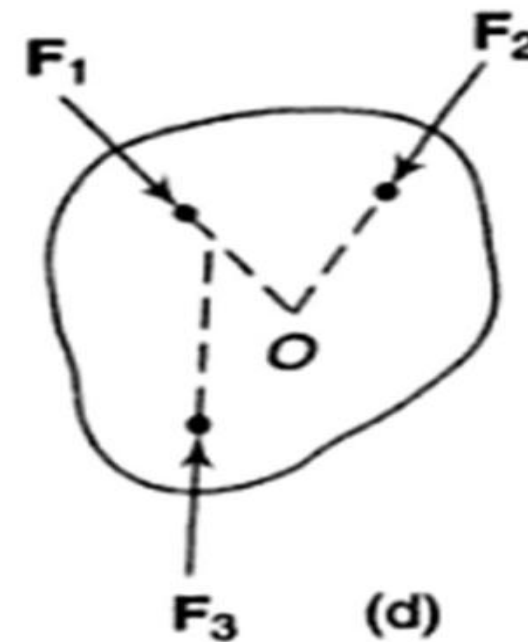
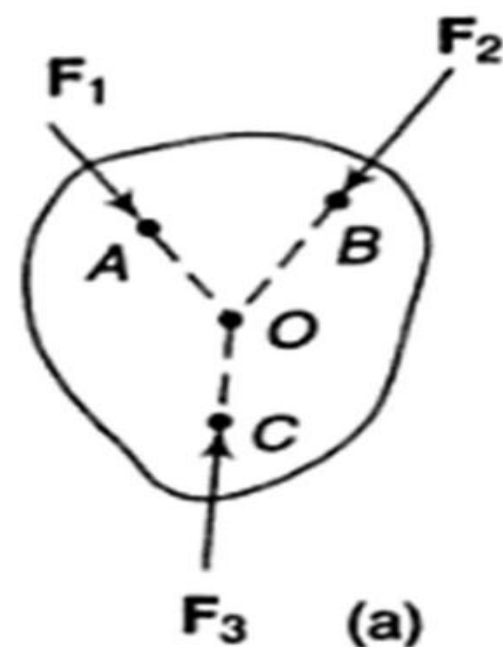


EQUILIBRIUM OF TWO AND THREE-FORCE MEMBERS

Figure (a) shows a member acted upon by three forces F_1 , F_2 and F_3 and is in equilibrium as the lines of action of forces intersect at one point O and the resultant is zero.

- This is verified by adding the forces vectorially [Fig.(b)].
- As the head of the last vector F_3 meets the tail of the first vector F_1 , the resultant is zero.
- Figure (d) shows a case where the magnitudes and directions of the forces are the same as before, but the lines of action of the forces do not intersect at one point.
- Thus, the member is not in equilibrium.

PROBLEM.

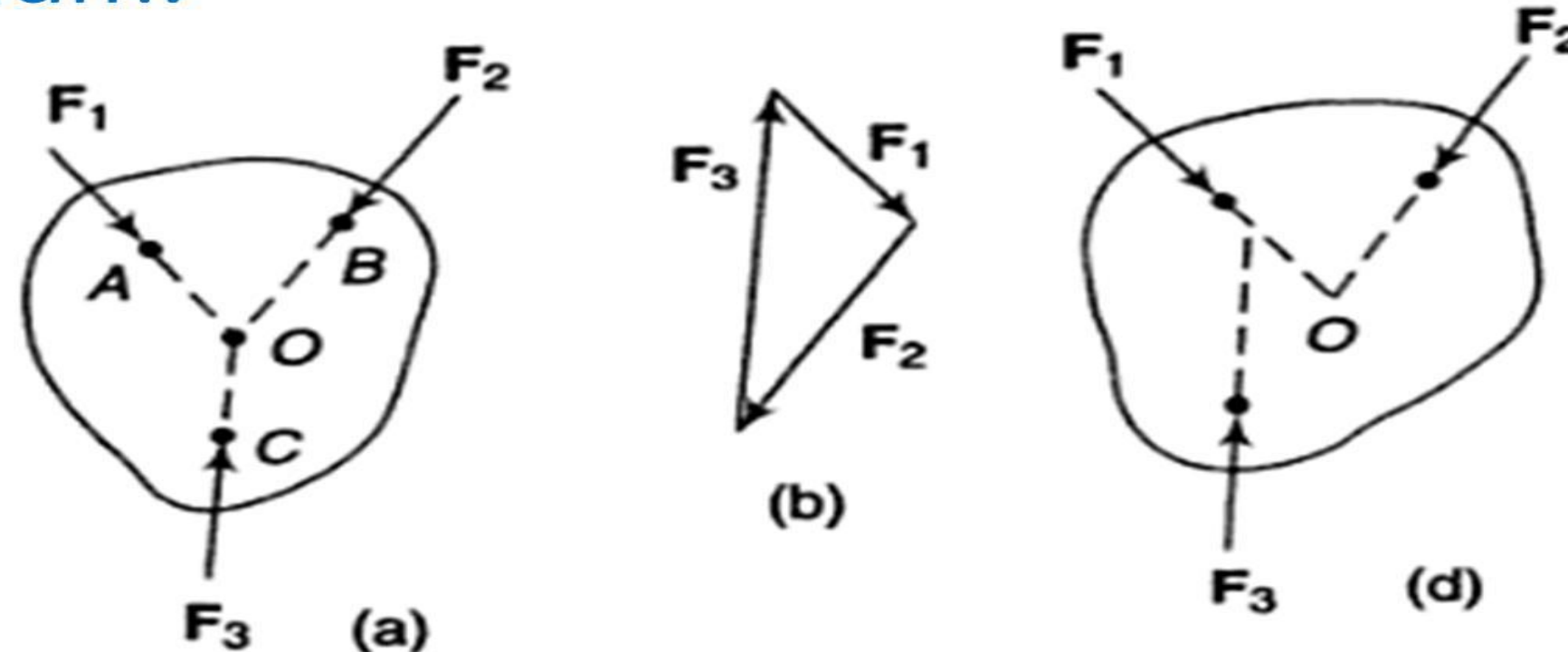


EQUILIBRIUM OF TWO AND THREE-FORCE MEMBERS

Consider a member in equilibrium in which force F_1 is completely known, F_2 known in direction only and F_3 completely unknown.

- The point of applications of F_1 , F_2 and F_3 are A , B and C respectively.
- To solve such a problem, first find the point of concurrency O from the two forces with known directions, i.e. from F_1 , and F_2 .
- Joining O with C gives the line of action of the third force F_3 .
- To know the magnitudes of the forces F_2 and F_3 , take a vector of proper magnitude and direction to represent the force F_1 .
- From its two ends, draw lines parallel to lines of action of the forces F_2 and F_3 forming a force triangle [Fig.].
- Mark arrowheads on F_2 and F_3 so that F_1 , F_2 and F_3 are in the same order.

Diagram.



DYNAMIC FORCE ANALYSIS

Dynamic forces are associated with accelerating masses. In situations where dynamic forces are dominant or comparable with magnitudes of external forces and operating speeds are high, dynamic analysis has to be carried out.

D' Alembert's Principle: The inertia forces and couples and the external forces and torques on a body together give statical equilibrium.

Inertia is a property of matter by virtue of which a body resists any change in velocity.

Inertia force $F_i = -ma$

Where m = mass of body, a = acceleration of center of mass of the body.

Negative sign indicates that the force acts in the opposite direction to that of acceleration.

Dynamic Analysis of Four bar Mechanism:

A **four-bar linkage** or simply a **4-bar** or **four-bar** is the simplest movable linkage. It consists of four rigid bodies (called bars or links), each attached to two others by single joints or pivots to form closed loop. Four-bars are simple mechanisms common in mechanical engineering machine design and fall under the study of kinematics.

- ◆ Dynamic Analysis of Reciprocating engines.
- ◆ Inertia force and torque analysis by neglecting weight of connecting rod.
- ◆ Velocity and acceleration of piston.
- ◆ Angular velocity and Angular acceleration of connecting rod.
- ◆ Force and Torque Analysis in reciprocating engine neglecting the weight of connecting rod.
- ◆ Equivalent Dynamical System
- ◆ Determination of two masses of equivalent dynamical system

FORCE ANALYSIS

Principle of Super Position:

Sometimes the number of external forces and inertial forces acting on a mechanism are too much for graphical solution. In this case we apply the method of superposition. Using superposition the entire system is broken up into (n) problems, where n is the number of forces, by considering the external and inertial forces of each link individually. Response of a linear system to several forces acting simultaneously is equal to the sum of responses of the system to the forces individually. This approach is useful because it can be performed by graphically.

Thank you