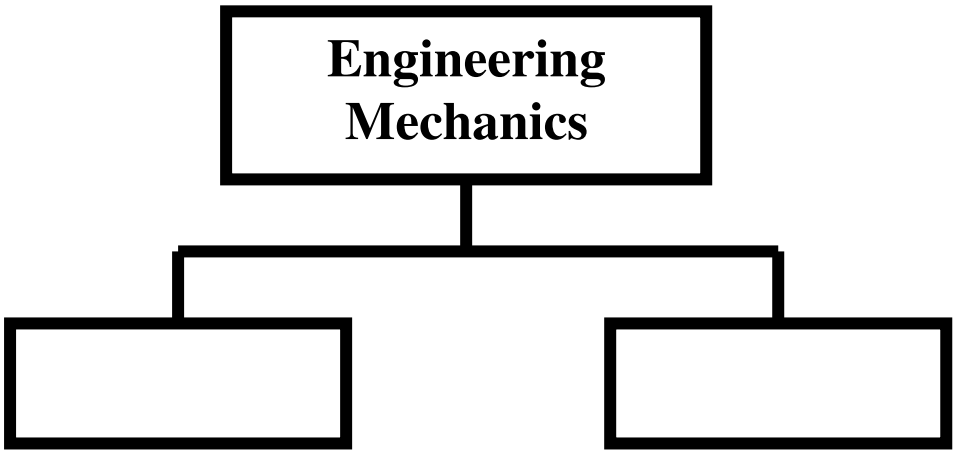
Lecture 1: Introduction to Engineering Mechanics



Engineering mechanics is the physical science which studies _____

_____. The subject is

usually divided into two parts namely _____ and _____.

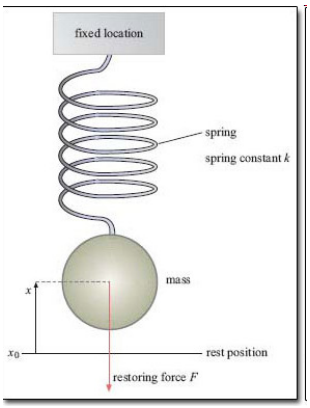
Statics. This branch of mechanics studies the _____ of bodies

under the action of _____.

Examples of static systems include an aeroplane at cruising speed, a hovering

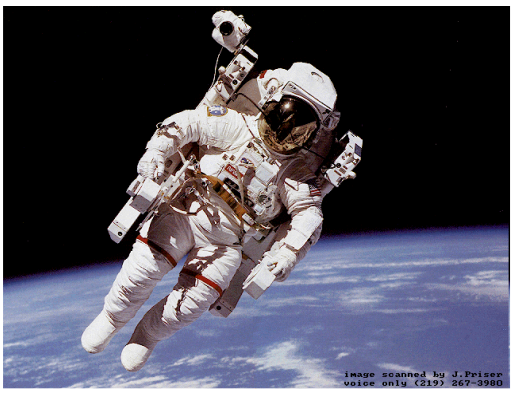
helicopter, a floating ship, etc.

Dynamics. This branch of mechanics studies the _____of bodies, ie. a system where a body is acted upon by an externally applied force which results in a motion. Examples of dynamic systems are a grandfather clock pendulum, a mass-spring system, an accelerating/decelerating vehicle, etc. (This part is not cover in this course.)



Basic terminologies

- A _____ quantity only consists of _____. Mass, time, volume, distance, speed and energy are examples of scalar quantities.
- A _____ quantity consists of both _____ and _____. Weight, displacement, velocity, acceleration, force and moment are examples of vector quantities.



- _____ is the action of one body on another.

- The _____ of force acting on a body depend on the magnitude, direction and the point of application of the force. The resultant effects can be the _____ (translation, rotation) or _____ (bending, denting, breaking, and destruction) of the body.

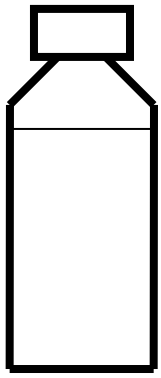
- The _____ of a body is defined as a single point where when a force acts through it, there is no resultant moment.

- _____. When a force is not acting through the centre of gravity of a body, it generates a moment. The effect of the resultant moment is the tendency to _____ or _____ the body.

Free body diagrams

A free body diagram shows an _____ (or a single member of a structure) and _____ acting on it. This is a very powerful tool to help us determine the forces acting on the structures and its members.

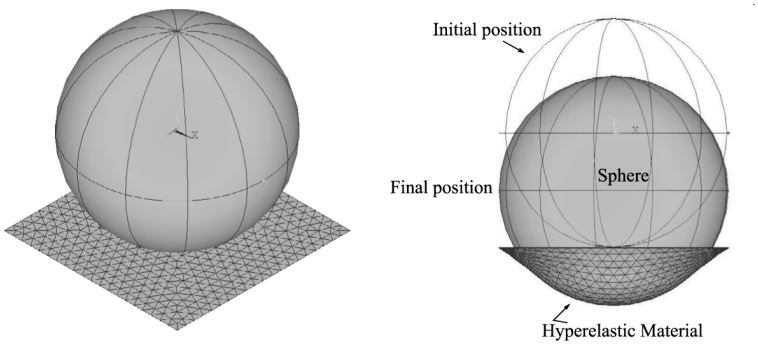
Here is an example of a free body diagram.



The weight of the water acts downward in the direction of the gravity, neglecting the weight of the bottle. The fingers exert horizontal forces on the cap of the bottle and the friction between the fingers and the cap provide the upward forces to counteract the weight of the water.

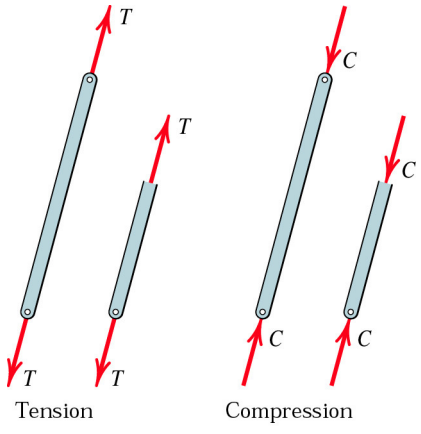
Here are some basic terminologies which are required in order to successfully create free body diagrams.

- A _____ is assumed to undergo negligible change in shape and dimensions when acted upon by a force.



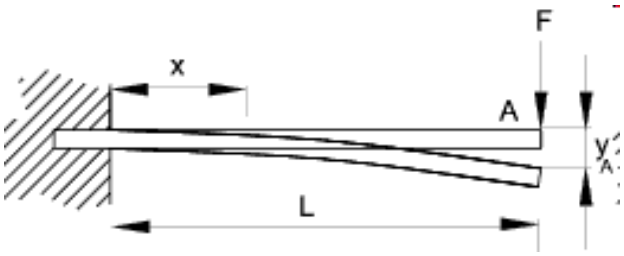
(a) Model 3D **(b)** Nonlinear FEA

- A _____ is a solid member which forms a part of the structure. Bars support both _____ and _____ forces.



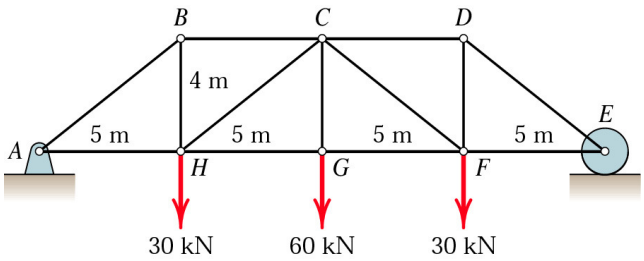
Two-Force Members

- _____ are solid members which can transmit tension and compression longitudinal forces, as well as _____.



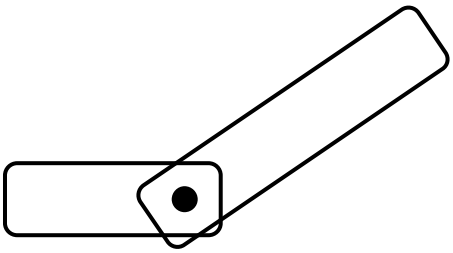
- _____. Only tension can be supported by cables. Without tension, a cable is said to carry zero load.

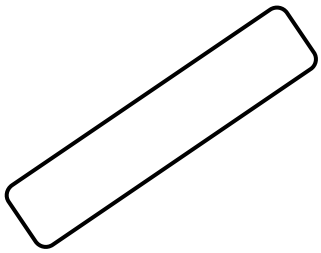
- _____. When several members are joined at their ends to form a rigid framework, it is called a structure or a truss. This part will be covered in Chapter 3.



- _____. When a bar is considered light, its weight is negligible.

- _____ surface or contact. Friction is negligible at the contact between two smooth surfaces.
- _____ surface. Friction is present at the contact between rough surfaces. Its direction is tangential to the surfaces.
- _____. Usually a simplified structure consists of a number of members pin jointed together. As the connected members are free to rotate at the pin joint, only forces are resisted but not moment.

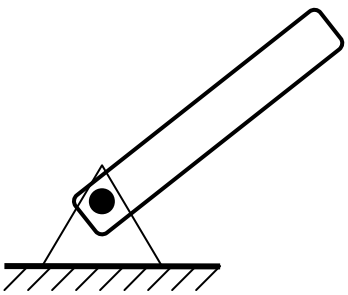


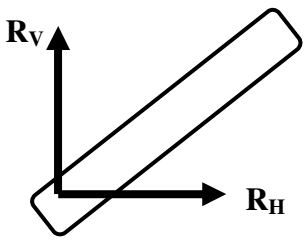


- _____. Structures cannot be suspended in mid-air and therefore must be connected to the ground or wall by means of supports. There are several types of supports as shown below.

1. _____.

   This type of support resists movement of the connected member but allows rotation about the pin joint.

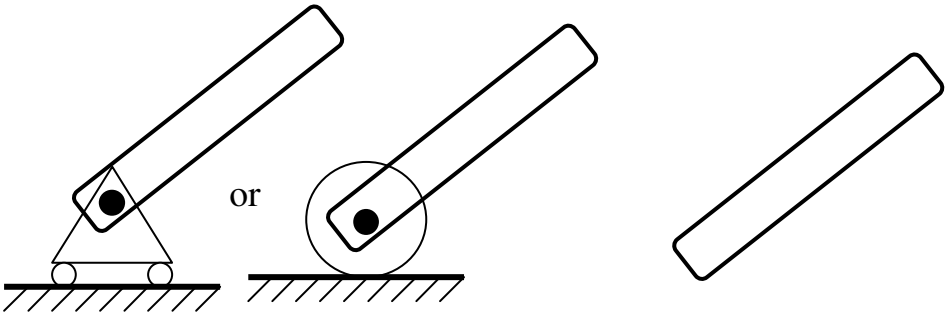




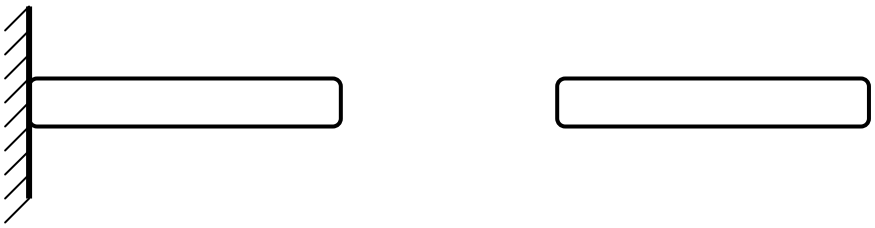
2. _____.

   This type of support allows for movement in the direction parallel to the surface. Hence, the reaction force on the member is always perpendicular

to the surface. Moment is never present.

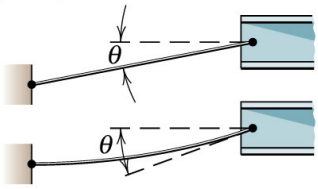
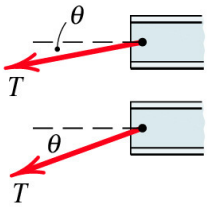
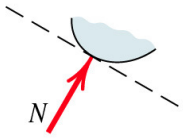
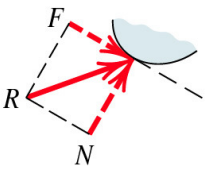
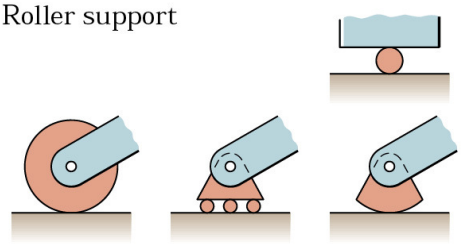
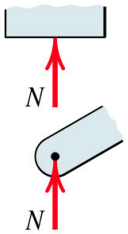
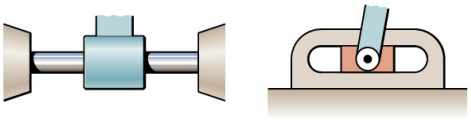
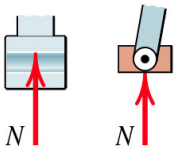


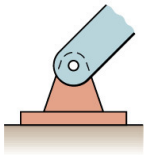
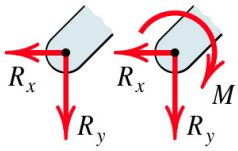
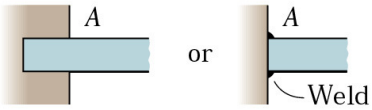
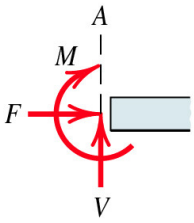
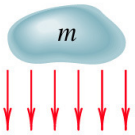
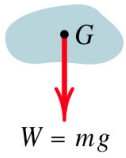
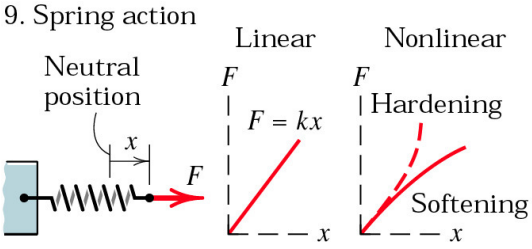
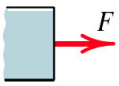
3. _____. This type of support completely resists the movement of the connected member, therefore both forces and moment are present in the free body diagram.



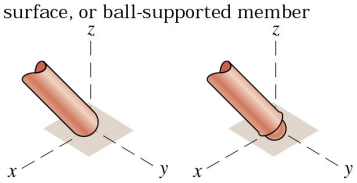
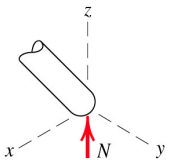
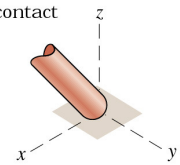
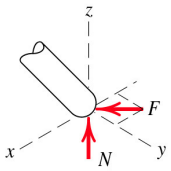
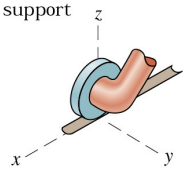
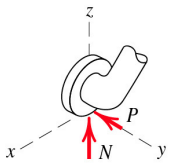
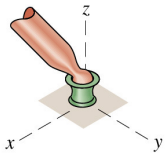
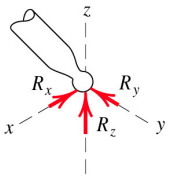
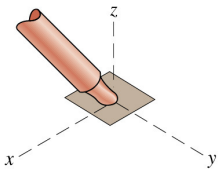
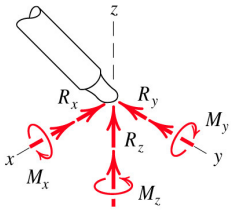
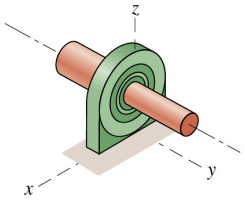
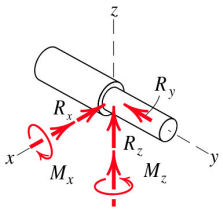
Examples

The following tables are taken from *Meriam* pages 105-106 and 109.

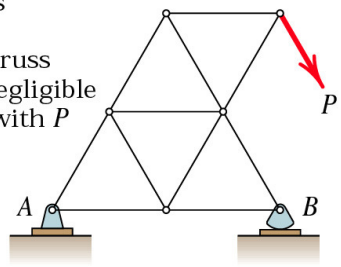
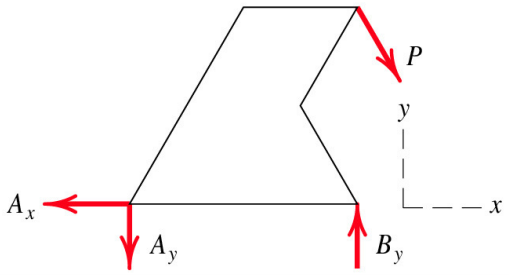
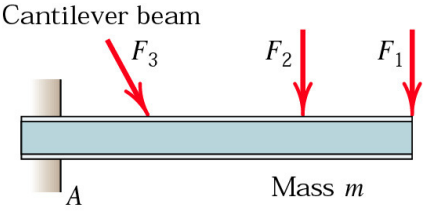
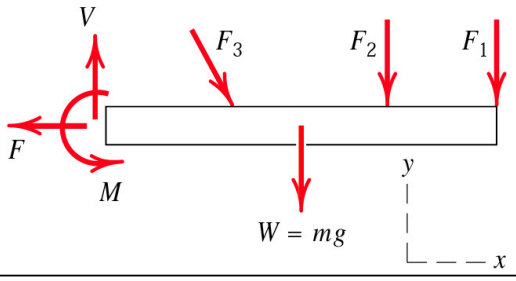
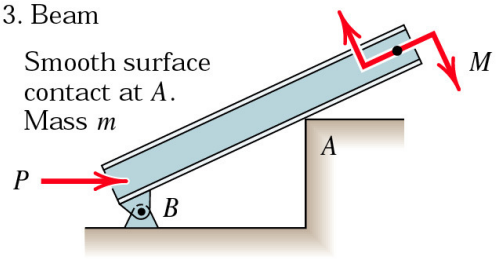
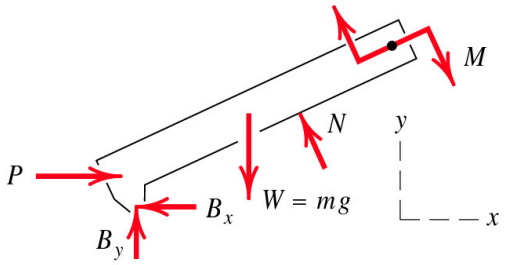
MODELING THE ACTION OF FORCES IN TWO-DIMENSIONAL ANALYSIS	
Type of Contact and Force Origin	Action on Body to Be Isolated
1. Flexible cable, belt, chain, or rope Weight of cable negligible Weight of cable not negligible 	 Force exerted by a flexible cable is always a tension away from the body in the direction of the cable.
2. Smooth surfaces 	 Contact force is compressive and is normal to the surface.
3. Rough surfaces 	 Rough surfaces are capable of supporting a tangential component F (frictional force) as well as a normal component N of the resultant contact force R.
4. Roller support 	 Roller, rocker, or ball support transmits a compressive force normal to the supporting surface.
5. Freely sliding guide 	 Collar or slider free to move along smooth guides; can support force normal to guide only.

MODELING THE ACTION OF FORCES IN TWO-DIMENSIONAL ANALYSIS (*cont.*)		
Type of Contact and Force Origin	Action on Body to Be Isolated	
6. Pin connection 	Pin free to turn / Pin not free to turn 	A freely hinged pin connection is capable of supporting a force in any direction in the plane normal to the axis; usually shown as two components R_x and R_y. A pin not free to turn may also support a couple M.
7. Built-in or fixed support 		A built-in or fixed support is capable of supporting an axial force F, a transverse force V (shear force), and a couple M (bending moment) to prevent rotation.
8. Gravitational attraction 		The resultant of gravitational attraction on all elements of a body of mass m is the weight $W = mg$ and acts toward the center of the earth through the center mass G.
9. Spring action 		Spring force is tensile if spring is stretched and compressive if compressed. For a linearly elastic spring the stiffness k is the force required to deform the spring a unit distance.

MODELING THE ACTION OF FORCES IN THREE-DIMENSIONAL ANALYSIS

Type of Contact and Force Origin	Action on Body to Be Isolated
1. Member in contact with smooth surface, or ball-supported member 	 Force must be normal to the surface and directed toward the member.
2. Member in contact with rough surface 	 The possibility exists for a force F tangent to the surface (friction force) to act on the member, as well as a normal force N.
3. Roller or wheel support with lateral constraint 	 A lateral force P exerted by the guide on the wheel can exist, in addition to the normal force N.
4. Ball-and-socket joint 	 A ball-and-socket joint free to pivot about the center of the ball can support a force **R** with all three components.
5. Fixed connection (embedded or welded) 	 In addition to three components of force, a fixed connection can support a couple **M** represented by its three components.
6. Thrust-bearing support 	 Thrust bearing is capable of supporting axial force R_y as well as radial forces R_x and R_z. Couples M_x and M_z must, in some cases, be assumed zero in order to provide statical determinacy.

SAMPLE FREE-BODY DIAGRAMS

Mechanical System	Free-Body Diagram of Isolated Body
1. Plane truss Weight of truss assumed negligible compared with P 	
2. Cantilever beam 	
3. Beam Smooth surface contact at A. Mass m 	
4. Rigid system of interconnected bodies analyzed as a single unit