Applied Mechanics

Chapter 1

Introduction to Applied Mechanics

Lecture 1

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Learning Objectives

The main objective of this lecture is to understand about:

- Mechanics and engineering mechanics
- Scope of applied mechanics
- Concept of rigid and deformed body
- Concept of particle and Free body diagram
- Fundamental concepts and principles of mechanics: Newtonian mechanics

1.1 Definition and Scope of applied Mechanics

1.1.1 Definition

Engineering mechanics encompasses the study of mechanical laws and principles as they apply to engineering problems. It involves analyzing how particles and rigid bodies respond to forces, moments, couples, and displacements.

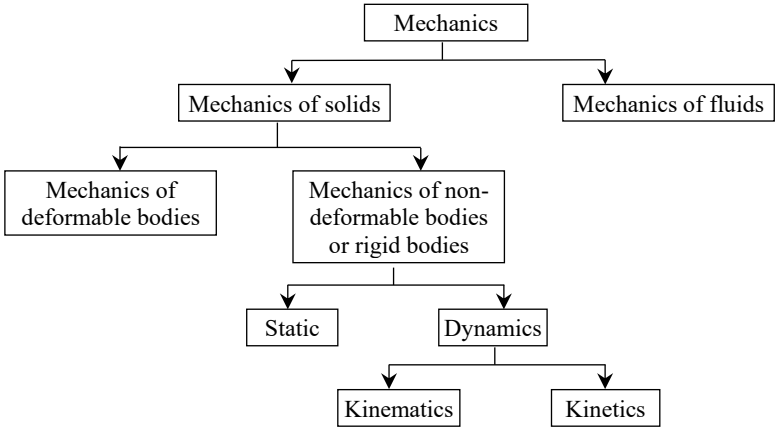


Chart: Branch of mechanics

(a)Statics: Statics focuses on the distribution and effects of forces on bodies at rest or moving with uniform velocity without acceleration.

(b)Dynamics: Dynamics deals with the motion of bodies and how it correlates with the forces acting on them. This includes:

(i) Kinematics, which studies motion without considering the forces involved. (ii) Kinetics, which examines motion alongside the forces causing it.

Mechanics of fluids: Mechanics of fluids, on the other hand, concentrates on the behavior of liquids and gases, whether at rest or in motion.

1.1.2 Scope of applied mechanics

Applied mechanics applies the principles of mechanics to various engineering applications. Its scope includes explaining and predicting natural phenomena, applying equilibrium equations to rigid bodies, designing structural components, analyzing structural stability, understanding tension and compression in members, and predicting the conditions of rest or motion under applied forces. Applied mechanics is crucial in designing structures like towers, chimneys, bridges, and other civil engineering works. Applied mechanics is the application of mechanics. It is the foundation of most engineering sciences. And the other related scope of applied mechanics are as follows:

- To explain and predict natural and physical phenomena.
- For the application of equilibrium equation to rigid bodies.
- For the design of structure part.
- For the analyzing and predicting of the structural stability of the different structural member.
- To know the nature of the member i.e. tension and compression.
- To describe and predicts the condition of rest or motion of bodies under the action of forces. It creates the foundations for engineering application in the field of mechanics.

From the above scope, we can say that applied mechanics is very important in engineering field. Applied mechanics is the basic and advance knowledge to study design and analysis of the structural parts. It is applied to design of tower, chimney, bridges and many civil engineering works.
Hence it is essential to have knowledge of these mechanics.

1.2 Concept of Rigid and Deformed bodies

Rigid body: A Rigid body can be defined as one having specified amount of matter in which all the particles are fixed in position relative to one another or in other words, it is the body which does not deform or distribution of particles are same under the action of an applied force. Principle of transmissibility is applicable in rigid body. Condition of equilibrium is applied in rigid body.
Deformable body: If a body changes its shape and size when it is acted upon by an external force then it is called deformable body. Principle of transmissibility is not applicable, No application of equilibrium.

Q. Why it is necessary to assume a body as perfectly rigid for the study of statics.

Ans: Assuming a body as perfectly rigid is necessary for statics because it simplifies analysis. While real bodies may deform under load, for analytical purposes, we focus only on the external effects of forces, neglecting deformations that are usually minor compared to the body's overall size.

For the study of statics, we have to determine different external movement, reaction by considering equilibrium equation which only considers the external effect So, many problems related to motion or rest condition of actual bodies and for the application of different law. It is necessary to assume a body as perfectly rigid.

1.3 Fundamental concepts and principles of mechanics: Newtonian mechanics

1.3.1 Fundamental concepts

Fundamental concepts in mechanics include space (coordinates), time (measure of event succession), force (interaction between bodies), mass (comparing parameter), and motion. In Newtonian mechanics, mass, space, and time are absolute and independent parameters.

So, fundamental units = mass (M)
= Space (L) length, coordinate
= Time (T)

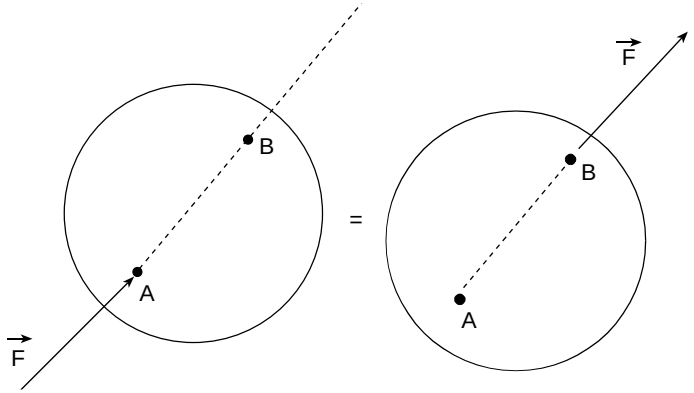
1.3.2 Principles of Mechanics: Newtonion Mechanics

Based on the experiment there are six fundamentals' principles on which Newtonian mechanics rest and the six principles are as follows:

i. The principle of transmissibility of force
ii. The parallelogram law of forces
iii. Newton's law of gravitation
iv. Newton's first law of motion
v. Newton's second law of motion
vi. Newton's third law of motion

i. The principle of transmissibility

The principle of transmissibility, which asserts that the equilibrium or motion of a rigid body remains unchanged if a force acting at one point is replaced by an equal force acting at a different point along the same line of action.



In other words, the equilibrium doesn't disturb if the force acting at a point on the rigid body is shifted by same magnitude direction and same line of action.

Limitations of Principle of transmissibility

The tension forces F is acted at the point A and B which causes the member to be in tension shown by figure 1, or extends. According to the principle of transmissibility, the rightward forces F can be shifted to point A shown in given figure 2. Equal and opposite forces acted in same point means there is no any change in the system shown in figure 3. So we can say that the member is in tension before the application of principle of transmissibility and after there is no any structural change in the member. But the member actually is in tension. So this principle is applicable only at rigid body not in Elastic material.

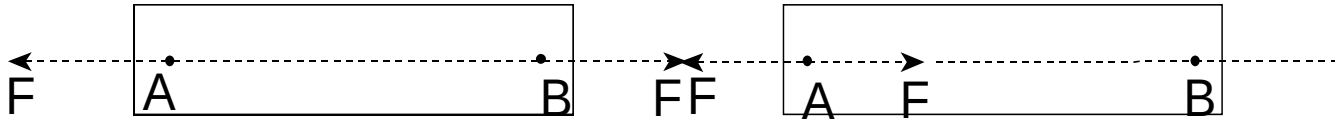


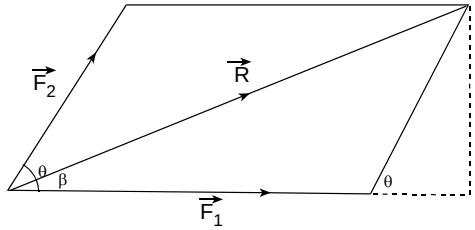
Figure 1

Figure 2

Figure 3

ii. The parallelogram law of forces

It states that when two forces $\vec{F_1}$ and $\vec{F_2}$ acting on a body are represented by two adjacent sides of a parallelogram then the diagonal represents the resultant force $\vec{R}$ in magnitude and direction.



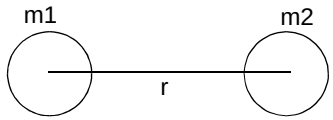
$\vec{R}=\vec{F_1}+\vec{F_2}$

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

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

iii. Newton's law of gravitation:

It states that, the force of attraction or gravitational force between the two masses m_1 and m_2 is directly proportional to the product of their mass and inversely proportional to the square of the distance between them.



$$F = \frac{Gm_1 m_2}{r^2}$$

Where G is gravitational constant and its value is $6.67 \times 10^{-11}\ Nm^2/kg^2$

iv. **Newton's first law:** Everybody continues in its state of rest or of uniform motion in a straight line unless it is compelled to change that state by forces acting on it.

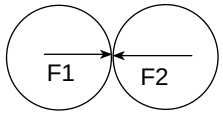
v. **Newton's second law**: The rate of change of momentum of a anybody is directly proportional to the force acting on that body and takes place in the direction of application of force.
In mathematical form

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

$$\left[\vec{F} = m\vec{a}\right]$$

Where $\vec{F}$ represents the resultant of a system of forces acting on a particle, m is the mass of particle and $\vec{a}$ is its acceleration.

vi. **Newton's Third law:** To every action there is always an equal and opposite reaction.
e.g. If we stand up on the ground, the ground exerts a reaction equal to our weight in opposite direction.



1.4 Concept of particle and free body diagram

1.4.1 Particles:

The particle is smallest material body whose dimension can be neglected in comparison to the other dimensions which are attached in the system. The particle has a mass which can be considered to be concentrated at a point e.g. the earth may be treated as a particle as the dimensions of the earth can be neglected in comparison to the whole system.

1.4.2 Free Body Diagram

Free body diagrams are diagrams used to show the relative magnitude and direction of all forces acting upon an object in a given situation. In other words, FBD is a graphical illustration of the isolated figure used to visualize and to show the applied forces, movements and resulting developed reaction on a body in a given condition.

1.4.2.1 Importance/Necessity of the free body diagram

The major importance of F.B.D are as follows:

- It helps to visualize all the forces acting on a single object including self-weight.
- Net external force acting on the object can be obtained in order to apply Newton's second law of the motion of the object.
- It helps to determine the unknown forces and moments.
- It helps to analyze a problem in statics or dynamics.
- F.B.D is used to determine shear force and bending moments for a component of a structure.
- Can easily apply equilibrium equation on F.B.D of the system.
- Acceleration is calculated from the net force.

1.4.2.2 Principles/Point to be considered on drawing F.B.D

- The size of the arrow reflects the magnitude of the force.
- The direction of the arrow shows the direction that the force is acting.
- All the dimensions should be indicated including the inclination of line.
- Each force arrow in the diagram is labeled to indicate the exact type of force.
- Applied and developed reaction with an arrow head along with labeling should be used.
- If the body is attached to a spring, then a restoring force must be shown acting on the body in the direction opposite to that on which the body tries to move.
- The self-weight should be indicated with vertical downward arrow FBDS have no external support or no any external connections.

Note: *The forces shown in the free-body diagram are the forces exerted on the body by the members attached to it or in contact with it, and not the forces exerted by the body on the other members.*

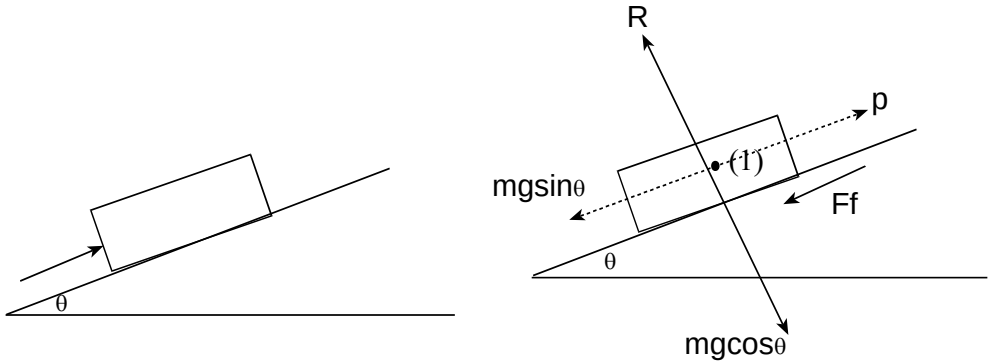
1.4.2.3 Steps to be followed while Drawing Free Body Diagrams

The following conceptual steps can be followed to drawing free body diagram in a system:

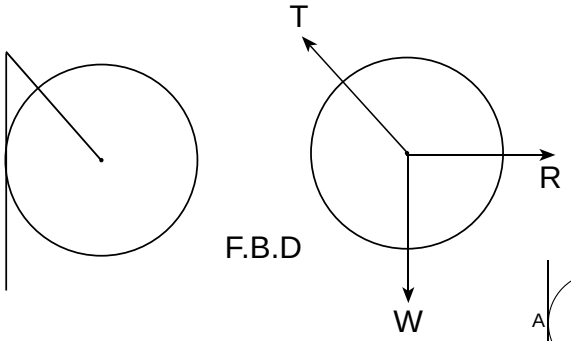
1. Identify the body or bodies for which F.B.D must be drawn to analyze the structural system.
2. Isolate the body from all its attachments in the structure system.
3. Draw a sketch of the isolated body and show all the applied and developed forces acting on the body by vectors including self-weight of the body.
4. If the body is in contact with table, channel, wall etc. then the normal reaction must be shown at the point of contact in the direction perpendicular to the tangential plane at that point.
5. If the body is attached with string, cable rope etc. then the tension is produced along the line of string (rope) and show in away from the body.

6. Frictional force shown in the direction opposite to that in which the body tries to move.
7. When all the applied or developed forces are shown in the F.B.D, we then proceed to analyze its equilibrium.

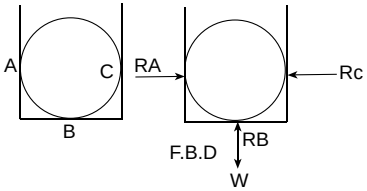
Some examples of FBD



A sphere tied with wire in vertical wall



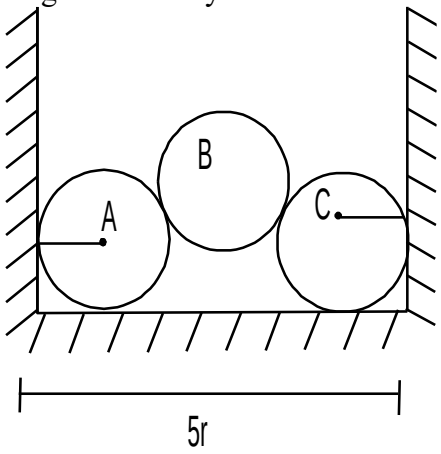
E.g. A sphere resting in a channel

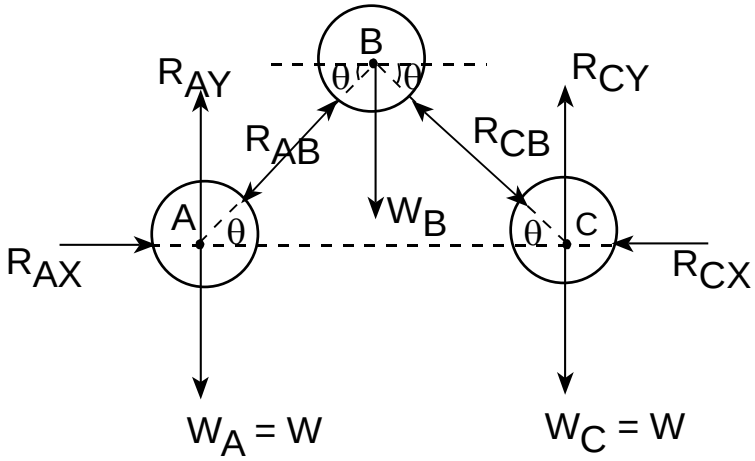


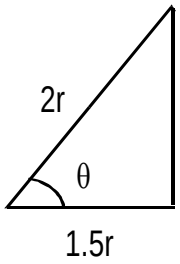
Draw Free body diagram of the given system.

Radius of each cylinder=r

Weight of each cylinder=W







Thank You!!!