Lecture 1: Introduction

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1.1 What is mechanics?

Mechanics can be defined as the science which describes and predicts the conditions of rest (**statics**) or motion (**dynamics**) of bodies under the action of forces.

It is divided into 3 parts:

- Mechanics of rigid bodies → this course
- Mechanics of deformable bodies
- Mechanics of fluids

Bodies are *assumed* to be perfectly rigid

- In reality, things are *never absolutely rigid* and deform slightly when acted upon by a force
- These deformations are minute and do not effect the equilibrium of the structure
- Deformations are important considerations with respect to the resistance of the structure to failure + functionality

Mechanics is the foundation of most engineering sciences. It is an applied science. **The purpose of mechanics is to explain and predict physical phenomena and thus to lay the foundations for engineering applications**.

1.2 Fundamental concepts and principles

- Sir Isaac Newton (late 17th century) first formulated fundamental principles of mechanics
- These principles were later modified by d'Alembert, Lagrange, and Hamilton
- The study of mechanics actually goes back to the days of Aristotle (4th century B.C. and Archimedes (3rd century B.C.)

The basic concepts of mechanics are:

- Space
- Time
- Mass
- Force

These concepts cannot be truly defined, but they should be accepted on the basis of our intuition and experience

The concept of **space**:
- Associated with the notion of the position of a point P
- This position can be defined by 3 lengths measured from a certain reference point (origin) in three directions (x,y,z) - **coordinates**

The concept of **time**:
- Defining space is not enough, an event requires the time it occurred

The concept of **mass**:
- Used to characterize and compare bodies on the basis of certain fundamental mechanical experiments
- Example: Two bodies of the same mass will be attracted to the earth by the same manner. They will also offer the same resistance to a change in translational motion.

The concept of **force**:
- Action of one body on another
- Exerted by actual contact or from a distance (eg. Gravitational &

magnetic forces)
    - A force is characterized by its point of application, its magnitude, and its direction
    - Represented by a vector

Other terms:

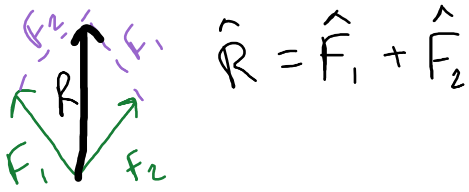
→ A **particle** is a very small amount of matter which is assumed to occupy a single point in space

→ A **rigid body** is many particles occupying fixed positions with respect to each other

Therefore, the study of the mechanics of particles is a prerequisite to that of rigid bodies.

Parallelogram Law for the Addition of Forces

- 2 forces acting on a particle may be replaced by a single force, called their **resultant**, obtained by drawing the diagonal of the parallelogram which has sides equal to the given forces



The Principle of Transmissibility

- The conditions of **equilibrium** or of motion of a **rigid body** will remain **unchanged** if a force acting at a given point of the rigid body is replaced by a force of the **same magnitude** and **same direction**, but acting at a different point, provided that the two forces have the same line of action.

Newton's 3 Fundamental Laws

First law:

- If the **resultant** force acting on a particle is zero, the particle will **remain at rest** (if originally at rest) or will move with constant speed in a straight line (if originally in motion)
    - Therefore, if an object is at rest, the resultant force is zero!

Second law:

- If the **resultant force** acting on a particle is **NOT zero**, the particle will have an acceleration proportional to the magnitude of the resultant and in the direction of this resultant force.
- This law can be stated as follows:
    - **F=ma**
        - F=resultant force
        - m=mass of particle
        - a=acceleration of particle [expressed in a consistent system of units]

Third law:

- The forces of **action** and **reaction** between bodies in contact have the same magnitude, same line of action, and opposite sense

Newton's law of gravitation

Two particles of mass *M* and *m* mutually attracted with equal and opposite forces *F* and *-F* of magnitude F given by the formula:

$$F = G\frac{Mm}{r^2}$$

r=distance between the two particles

G=universal constant called the constant of gravitation

Newton's law of gravitation introduces the idea of a force exerted at a distance

and furthers Newton's third law.
Attraction of the Earth on a particle located on its surface:

- The force *F* exerted by the Earth on the particle is defined as the weight *W* of the particle. Taking *M* equal to the mass of the Earth, *m* equal to the mass of the particle, and *r* equal to the radius *R* of the Earth, and introducing the constant:
  $$g = \frac{GM}{R^2}$$
  the magnitude *W* of the weight of a particle of mass *m* may be expressed as:
  $$W = mg$$

The value of *R* is dependent on location (latitude) since the Earth isn't perfectly spherical

- therefore, the value of *g* varies with the position of the point considered

As long as the point remains on, or near, the surface of the Earth, it is **sufficient accurate** in **most engineering computations** to assume that g=9.81m/s^2

1.3 System of Units

Kinetic units quantify each of the 4 fundamental concepts above
Units for length, time, and mass are defined arbitrarily and are called **base units**
The SI unit of force is **derived** because it's obtained from the equation F=ma

- the **Newton** (**N**)
- one newton is a force that gives an acceleration of 1m/s^2 to a mass of 1kg

This forms a **consistent system of units**

International System of Units (SI Units):

- base units: length (metres, m), mass (kilograms, kg), time (seconds, s)
- all three are arbitrarily defined but internationally accepted
- this system is called an **absolute system of units**
  - 3 base units are **independent** of location where measurements are made (ie. even on a different planet they'd have the same significance)
- prefixes form multiples of the base units (kilo, milli, mega, etc. for kg and m, min, h, d, a for time)
- for angles, Si uses radian (rad), but degrees are permitted as well