Palestine Technical University- Kadoorie (PTUK)

Mechanical Engineering Department

12210244: Dynamics

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This is an explanation of the Dynamics course

offered at Palestine Technical University - Kadoorie

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Textbook:

Engineering Mechanics: Dynamics, 7th Edition

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J.L. Meriam and L.G. Kraige, 2013

Chapter One:

Introduction to Dynamics

1 Chapter One

1.2 Basic Concepts

1.2.1 Mechanics

Kinematics

- Kinematics is the branch of mechanics that deals with the **motion** of objects **without** considering the **forces** causing the motion.
- Motion involves concepts like **position**, **velocity**, and **acceleration**.
- **Coordinates + Time → Kinematics** **Chapter 2 (Particles)** **Chapter 5 (Rigid Bodies)**

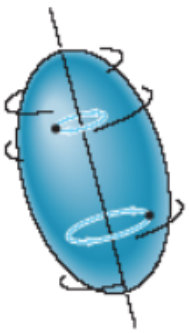
Kinetics

- Kinetics is the branch of mechanics that deals with the **motion** of objects considering the **forces** causing the motion.
- Kinetics is the study of the **causes of motion**, particularly the **forces and torques** acting on objects.
- **Motion + Forces → Kinetics** **Chapter 3 (Particles)** **Chapter 6 (Rigid Bodies)**

1.2.2 Particle and Rigid Body

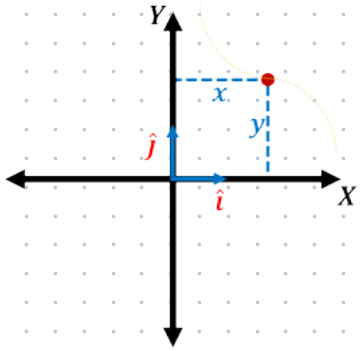
In mechanics, Objects are often categorized as:

- Particles (**having negligible size and shape**).
- Rigid bodies (**having definite shape and size**).



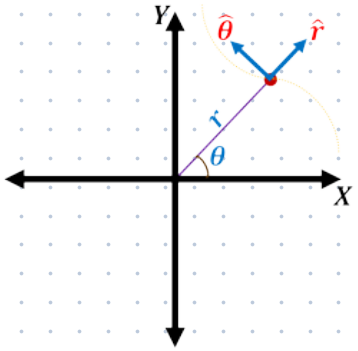
1.2.3 Coordinates (2D Plane)

Rectangular Coordinates
Fixed or Moving



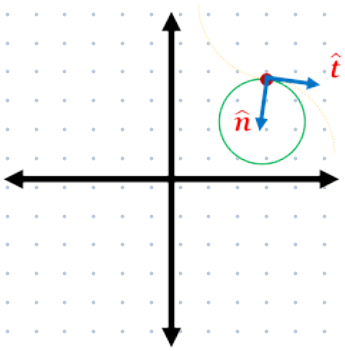
$$\vec{r} = x\hat{i} + y\hat{j}$$
$$\vec{v} = \dot{x}\hat{i} + \dot{y}\hat{j}$$
$$\vec{a} = \ddot{x}\hat{i} + \ddot{y}\hat{j}$$

Polar Coordinates
(cylindrical coordinate)



$$\vec{r} = r\hat{e}_r$$
$$\vec{v} = \dot{r}\hat{e}_r + r\dot{\theta}\hat{e}_\theta$$
$$\vec{a} = \left(\ddot{r} - r\dot{\theta}^2\right)\hat{e}_r + \left(r\ddot{\theta} + 2\dot{r}\dot{\theta}\right)\hat{e}_\theta$$

Path Coordinates
(normal-tangential coordinate)



$$\vec{r} = -r\hat{e}_n$$
$$\vec{v} = r\dot{\theta}\hat{e}_t$$
$$\vec{a} = \ddot{v}\hat{e}_t + \frac{v^2}{r}\hat{e}_n$$

1.2.4 Time

- Time is a fundamental quantity that measures the progression of events.
- It is usually denoted by (t).
- It is measured by (sec).

1.2.5 Mass

- Mass is a measure of the amount of matter in an object.
- It is usually denoted by (m).
- It is measured by (kg).

1.2.6 Force

- Force is any interaction that causes a change in the motion of an object.
- It is usually denoted by (F).
- It is measured by (N).

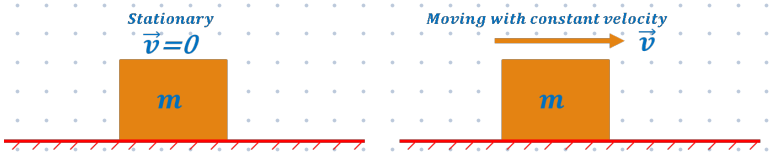
1.2.7 Vector and Scalar

- Vectors are quantities that have both **magnitude and direction**, such as **force and velocity**.
- Scalars are quantities that only have **magnitude**, such as **mass and time**.

1.3 Newton's Laws

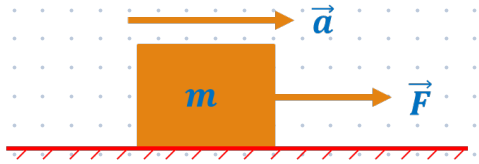
- Newton's laws of motion **describe the relationship between the motion of an object and the forces acting on it**.
- They are fundamental principles in classical mechanics.

First Law



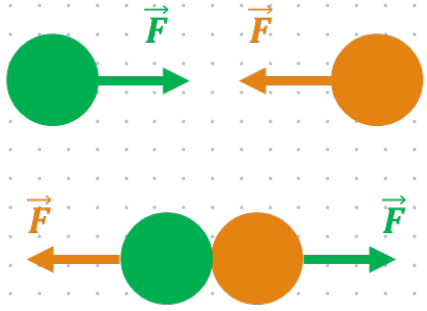
$$\Sigma\vec{F} = 0$$

Second Law



$$\Sigma\vec{F} = m \times \vec{a}$$

Third Law



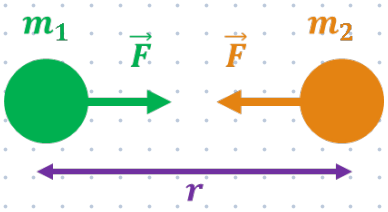
$$\vec{F} = -\vec{F}$$

1.4 Units

Units are standardized quantities used for measurement. Common units include **meters (m) for length**, **seconds (s) for time**, **kilograms (kg) for mass**, and **newtons (N) for force**.

Quantity	Symbol	SI units	Unit Symbols	U.S. Customary Units	Unit Symbols
Mass	**M**	**kilogram**	**kg**	Slug	-
Length	**L**	**meter**	**m**	**foot**	**ft**
Time	**T**	**second**	**s**	**second**	**s**
Force	**F**	Newton	N	**pound**	**lb**

1.5 Gravitation



$$F = G\frac{m_1 \times m_2}{r^2}$$

F the mutual force of attraction between two particles

G a universal constant called the constant of gravitation 6.673×10^{-11} $\mathrm{m}^3/(\mathrm{kg} \cdot \mathrm{s}^2)$

m_1, m_2 the masses of the two particles

r the distance between the centers of the particles

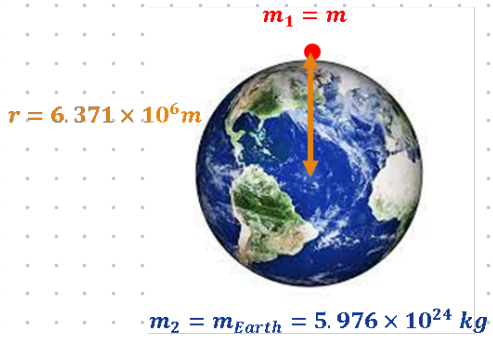
1.6 Dimensions

The principle of dimensional homogeneity can be summarized as follows:

- All physical relations must be dimensional homogeneous.
- In an equation, the dimensions of all terms must be the same.

Example 1:

Prove that the gravitational acceleration **g** is equal to 9.81 m/sec^2



Example 2:

Determine your mass in slugs. Find your weight in newtons and calculate the corresponding weight in pounds-force Ibf.

Example 3:

Determine the weight in newtons of a car which has a mass of 1500 kg. Convert the given mass of the car to slugs and calculate the corresponding weight in pounds-force.

ans. $W = 14720\ N$ and $W = 3310\ lbf$ and $m = 102.8\ slugs$

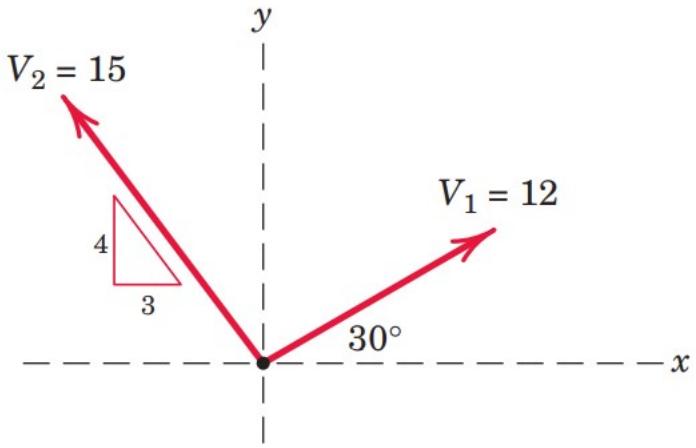
Example 4:

The weight of one dozen apples is 5 lb. Determine the average mass of one apple in both SI and U.S. units and the average weight of one apple in SI units.

ans. $m = 0.01294\ slugs$ and $m = 0.1888\ kg$ and $W = 1.853\ N$

Example 5:

For the given vectors $\vec{V_1}$ and $\vec{V_2}$, determine $V_1 + V_2$, $\vec{V_1} + \vec{V_1}$, $\vec{V_1} - \vec{V_1}$, $\vec{V_1} \times \vec{V_1}$,$\vec{V_1} \cdot \vec{V_2}$, and the angle between $\vec{V_1}$ and $\vec{V_2}$. Consider the vectors to be non-dimensional.

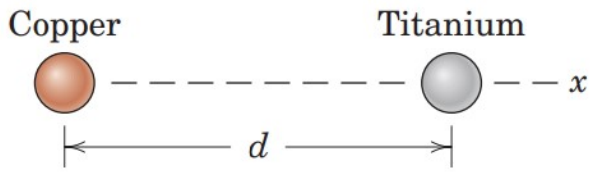


Ans.

Example 6:

The two 100-mm-diameter spheres constructed of different metals are located in deep space. Determine the gravitational force F which the copper sphere exerts on the titanium sphere if (a) $d = 2\ m$, and b) $d = 4\ m$.

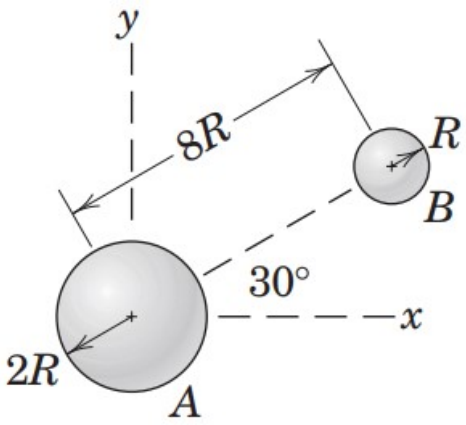
ans. $a) -1.255 \times (10^{-10})i\ N$ and $b) -3.14 \times (10^{-10})i\ N$



Example 7:

Two uniform aluminum spheres are positioned as shown. Determine the gravitational force which sphere A exerts on sphere B. The value of R is 50 mm.

ans. $F = (5.73\hat{i} + 3.31\hat{i}) \times 10^9 \ N$



End of Chapter One