Chapter 5: Force and Motion-I

- ✓ **Force**
- ✓ **Basic Laws of Motion (Newton's Laws)**
- ✓ **Applying Newton's Laws**

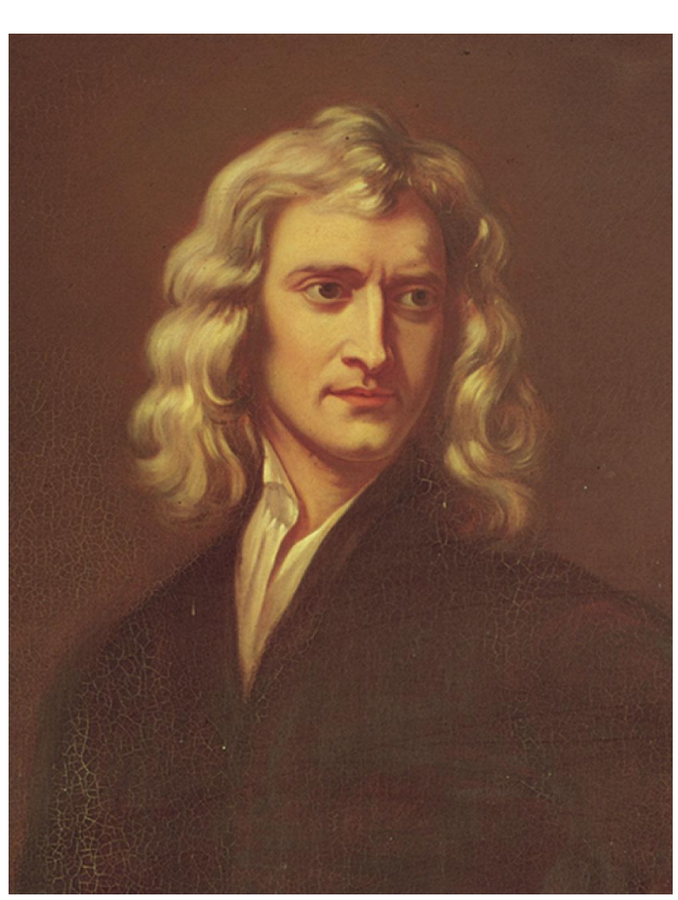
Chapter 5: Force and Motion-I

Session 9:

- ✓ **Force**
- ✓ **Basic Laws of Motion (Newton's Laws)**

Introduction

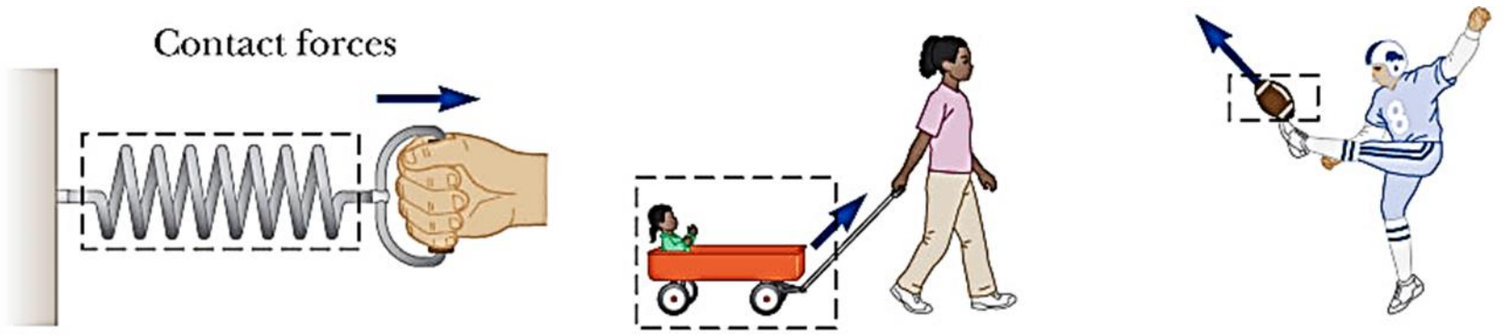
- **Chapters 2, 4: The description of an object in motion included its position, velocity, and acceleration.**
- **There was no consideration of what might influence that motion.**
- **Two main factors:**
  - **Forces acting on the object**
  - **Mass of the object**
- **Dynamics studies the causes of motion.**
- **Basic laws of motion formulated by Sir Isaac Newton.**

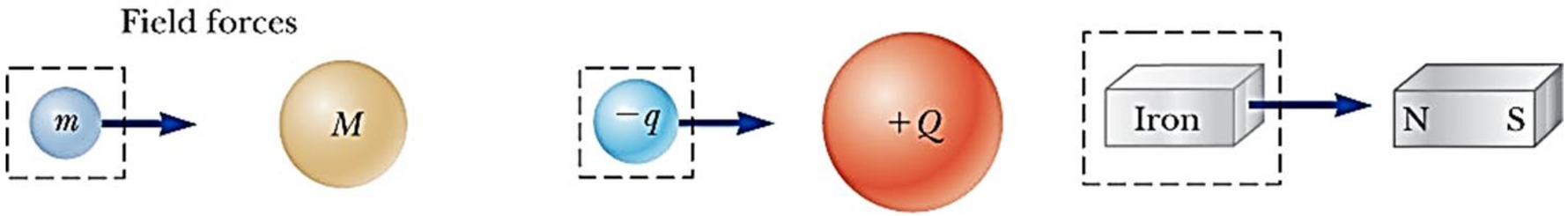


Force

❖ **Force** is what **cause any change in the velocity** of an object.

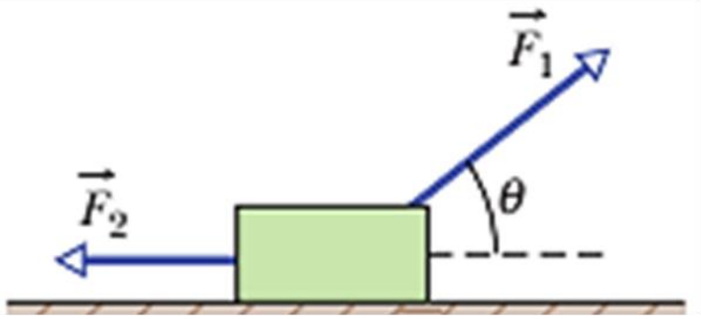
❖ **Newton's definition**: force is that which **causes an acceleration.**





❖ **Forces** are **vectors.**

$$\vec{F} = \vec{F}_1 + \vec{F}_2$$

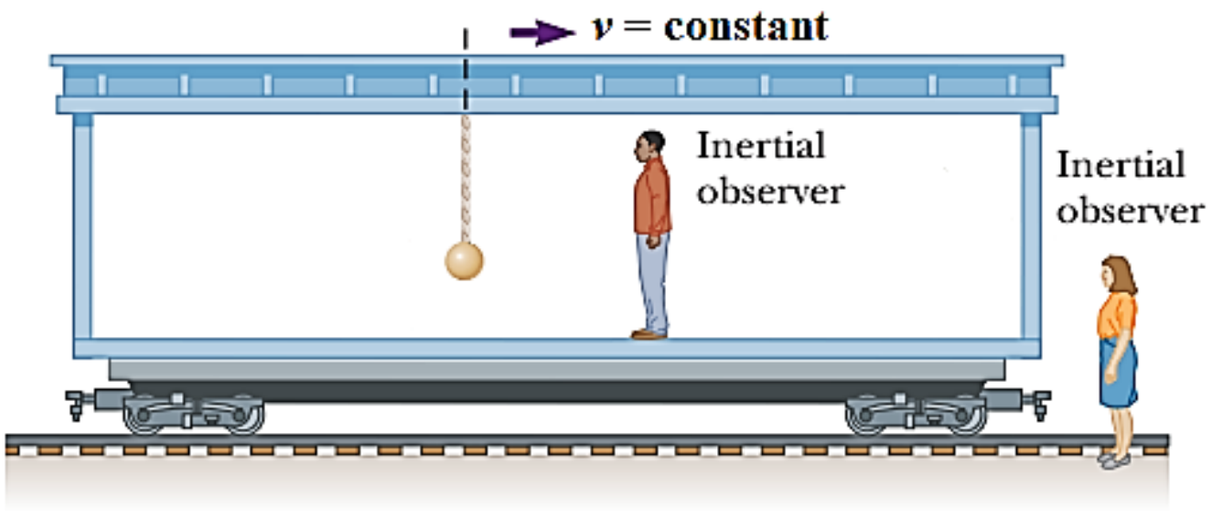


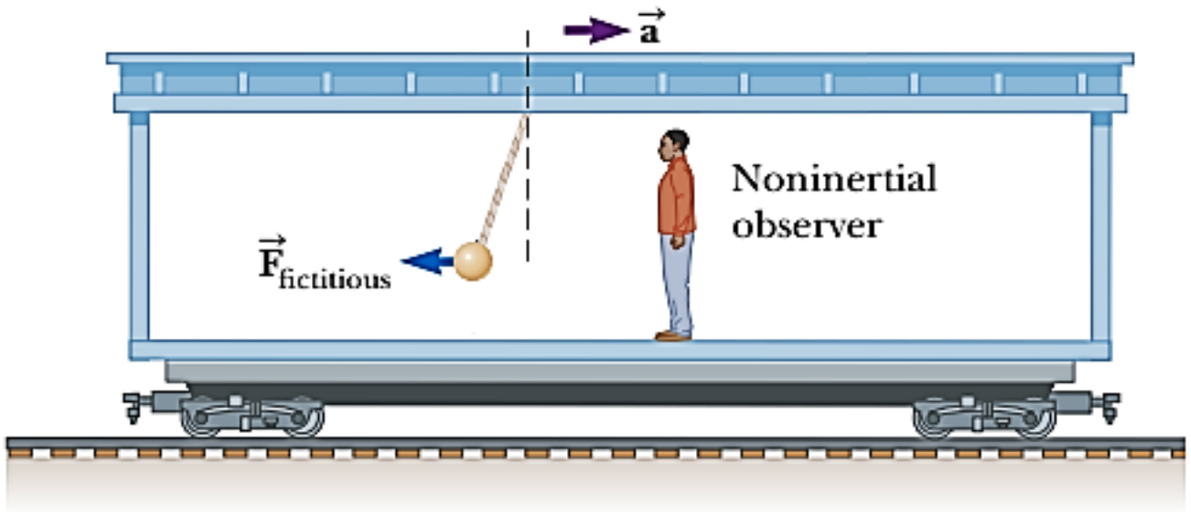
Basic Laws of Motion

1) Newton's First Law (Law of Inertia):

- In the **absence of external forces (F_{net}=0)**, when viewed from **an inertial reference frame**, an **object at rest remains at rest** and an **object in motion continues in motion with a constant velocity** (**a=0**).

- An **inertial reference frame** is one in which **Newton's laws hold**.



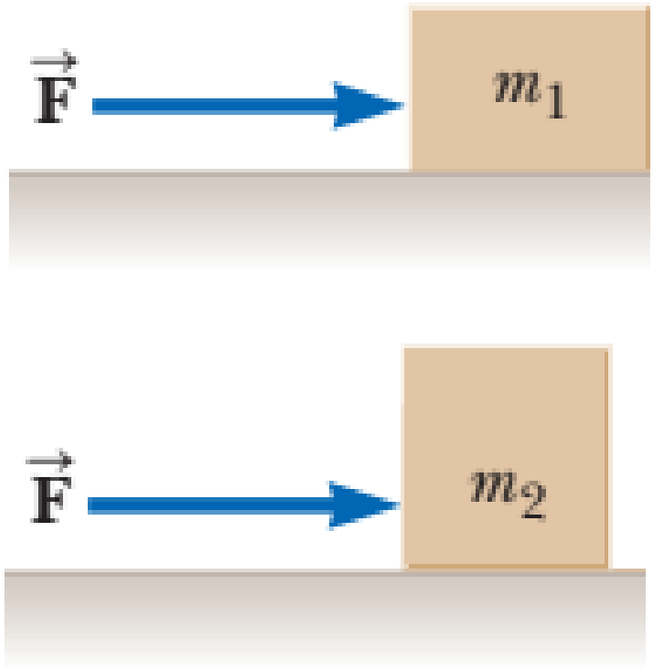


- **Inertia** is the tendency of an object to resist any attempt to change its velocity.

- We can consider the **Earth to be such an inertial frame**, although it has a small centripetal acceleration associated with its motion.

Basic Laws of Motion

- **Inertia** is the **tendency** of an object to resist any attempt to change its velocity.
- **Mass** is that **property of an object** that specifies **how much resistance** an object exhibits to changes in its velocity.



$$a_1 \neq a_2$$

$$\frac{a_1}{a_2} = \frac{m_2}{m_1}$$

$$a \propto \frac{1}{m}$$

- Mass is an **inherent property of an object**.
- Mass is **independent of the object's surroundings** and the **method used to measure** it.
- Mass is a **scalar quantity**. (SI unit is **kg**)
- **Mass** and **weight** are two **different quantities**.

m_{Earth} = 3 kg; m_{Moon} = 3 kg

w_{Earth} ~ 30 N; w_{Moon} ~ 5 N

Basic Laws of Motion

2) Newton's Second Law:

- **Force** is the **cause of changes in motion**, as measured by the **acceleration**.

$$\vec{a} \propto \frac{\sum \vec{F}}{m} \quad \Rightarrow \quad \boxed{\vec{F}_{net} = m\vec{a}} \quad \Rightarrow \quad \begin{cases} F_{net,x} = ma_x \\ F_{net,y} = ma_y \\ F_{net,z} = ma_z \end{cases}$$

$$\sum \vec{F} = \vec{F}_{net}$$

- The **SI unit** of force is the **newton** (**N**). **1 N = 1 kg·m / s²**

System	Force	Mass	Acceleration
SI	newton (N)	kilogram (kg)	m/s^2
CGS[a]	dyne	gram (g)	cm/s^2
British[b]	pound (lb)	slug	ft/s^2

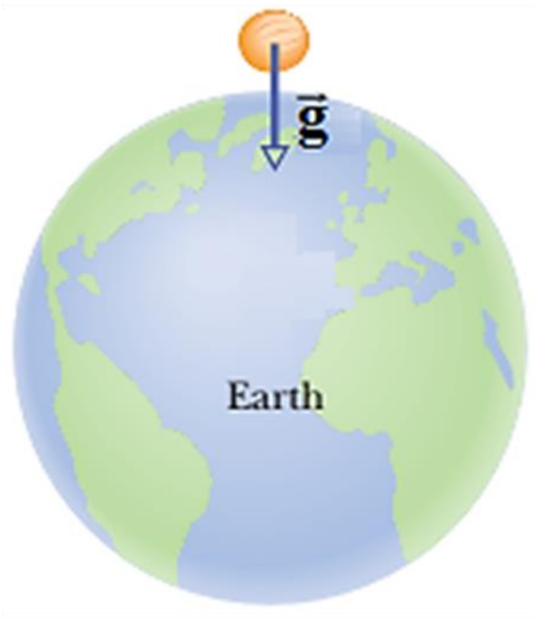
[a] 1 dyne = 1 g·cm/s².
[b] 1 lb = 1 slug·ft/s².

Basic Laws of Motion

Some Particular Forces:

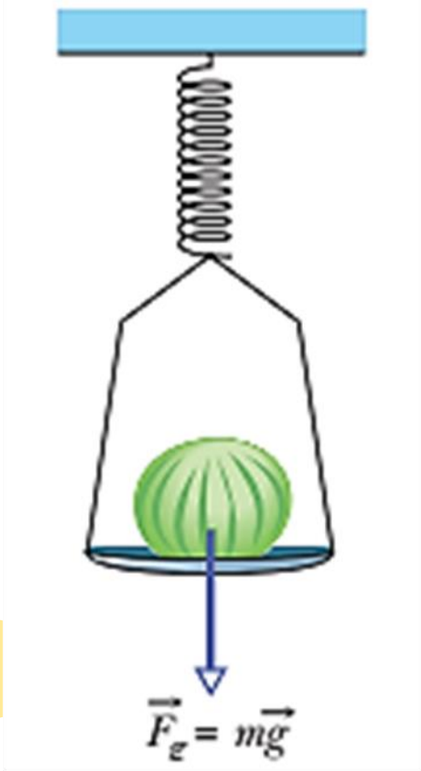
- **Gravitational Force**, $\vec{\mathbf{F}}_g$, is the force that the Earth exerts on an object.

$$\vec{\mathbf{F}}_g = m\vec{\mathbf{g}}$$



- **Weight, W,** of a body is equal to the **magnitude of the gravitational force** on the body.

$$W = \left|\vec{\mathbf{F}}_g\right| = mg$$



Gravitational mass and **inertial mass** have the same value.

Basic Laws of Motion

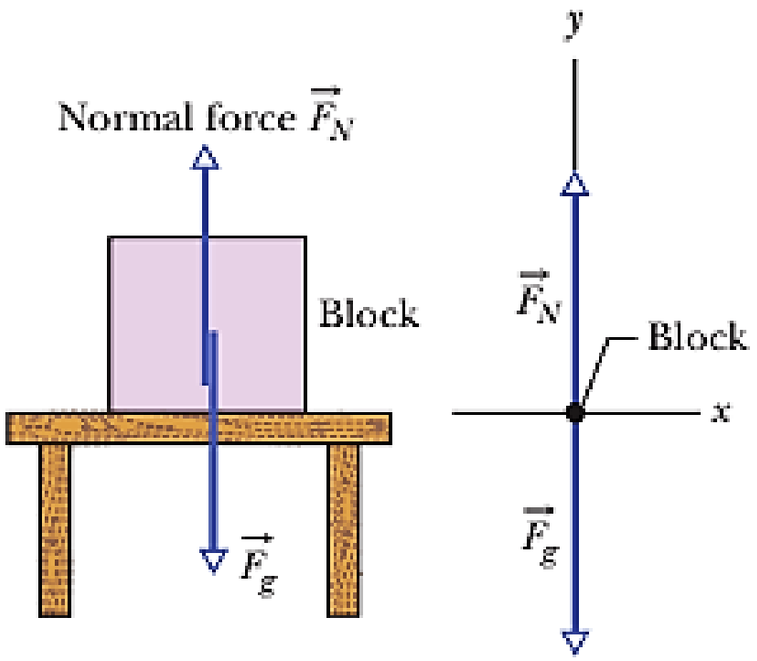
Some Particular Forces:

- **Normal Force,** $\vec{\mathbf{F}}_N$.

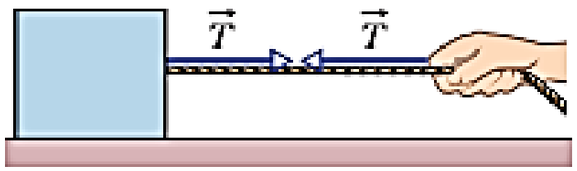
$$\vec{\mathbf{F}}_N - \vec{\mathbf{F}}_g = m\vec{a} \quad \Rightarrow \quad F_N - F_g = ma_y$$

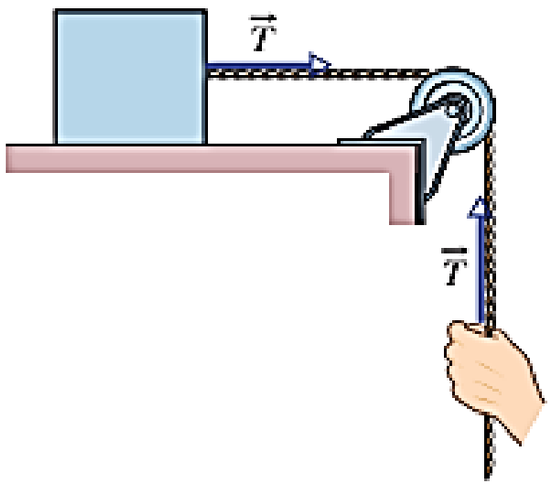
$$F_N = mg + ma_y = m(g + a_y)$$

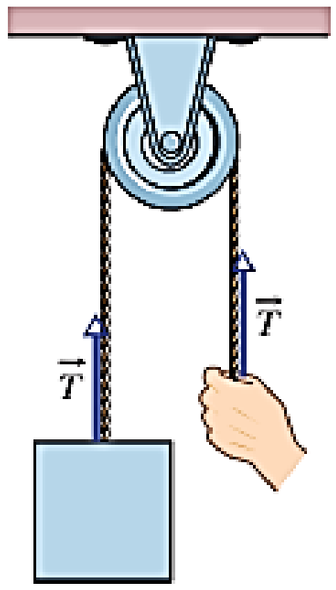
$$if\ a_y = 0 \quad \Rightarrow \quad F_N = mg$$



- **Tension, T.**







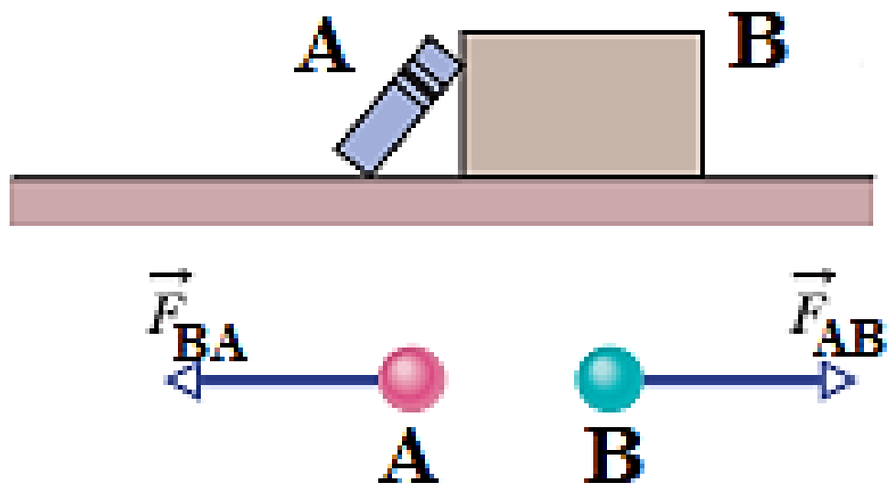
A **cord** is often said to be **massless**

Basic Laws of Motion

3) Newton's Third Law:

- When two bodies interact, the **forces on the bodies from each other** are always **equal in magnitude and opposite in direction**.

$$\vec{F}_{AB} = -\vec{F}_{BA}$$



Note on notation: $\vec{F}_{AB}$ is the force exerted *by* A *on* B.

- The **action force** is equal in magnitude to the **reaction force** and opposite in direction.