Lesson 2:-Newton’s Laws of motion

Key Terms and Concepts

- **Dynamics:** The subdivision of mechanics that deals with the motion of objects in relation to the physical factor that causes the motion, the force.
- **Force:** An external agent of a body that changes state of rest or state of motion of that body.
- **Inertia:** The tendency of a body to oppose any change in its state of rest or its state of uniform motion
- **Net force:** The sum of two or more forces (Resultant force)
- **Acceleration:** The time rate of change of velocity. It could happen when a body changes its speed or direction of motion or both.
- **System:** A collection of objects, elements or components that are organized for a common purpose. Anything outside the system is the surrounding.
- **Action and reaction:** During an interaction between two objects the force one exertion the other is Action and the force it is acted upon by the other is Reaction
- **Weight:** The gravitational pull on an object
- **Normal forces:** A force with which to objects push one another and acting perpendicularly at the surface of contact

Laws of Motion

Newton’s First Law of Motion

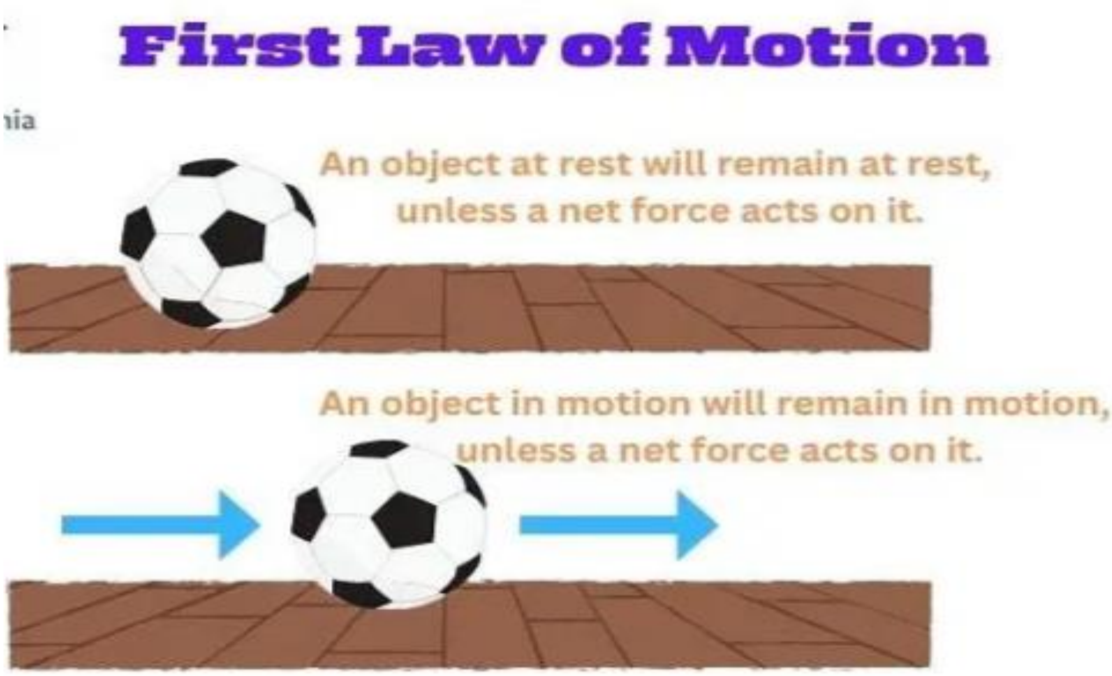
- **Newton’s First Law of Motion** is stated as follow **< < an object at rest remains in a state of rest and an object in motion continues in motion along a straight line with constant speed unless an external force acts upon it>>**
- Newton’s first law of motion is also called the law of inertia.
- The property of a body to remain at rest or to remain in motion with constant velocity is called inertia

According to the **Law of Inertia, “Inertia is an inherent property of a body which has the inability to change its state of rest or uniform motion or direction of motion by itself.”**

- Mass is the measure of inertia.
- More is mass more is inertia.

There are three **types of Inertia**

- **The inertia of Rest:** It states that if a body is at rest, it will remain at rest.
- **The inertia of Motion:** It states that if a body is moving with constant velocity, it will keep moving with that velocity.
- **The inertia of Direction:** It states that if a body moves in a particular direction, will keep moving in that direction and can't change its direction by itself
- The important aspect to remember is that if there is **no net force exerted on an item due to imbalanced forces**, the object will retain its velocity.
- If the velocity is zero, **the item is said to be at rest**.
- If an external force is applied, the **velocity will change as a result of the force**.
- **The first law of motion is also known as the Law of Inertia**.



Some examples of Applications of Newton's first law

APPLICATIONS OF FIRST LAW OR LAW OF INERTIA

- One's body movement to the side when a car makes a sharp turn.
- Tightening of seat belts in a car when it stops quickly.
- A ball rolling down a hill will continue to roll unless friction or another force stops it.
- If pulled quickly, a tablecloth can be removed from underneath of dishes. The dishes have the tendency to remain still as long as the friction from the movement of the tablecloth is not too great.
- Shaking a bottle of ketchup. When bringing the bottom down, the suddenly stopping it, inertia is what causes the ketchup to come out of the bottle.
- If one drove a car directly into a brick wall, the car would stop because of the force exerted upon it by the wall. However, the driver requires a force to stop his body from moving, such as a seatbelt, otherwise inertia will cause his body to continue moving at the original speed until his body is acted upon by some force.
- Hovercraft are vehicles that can be a challenge to manipulate because, unlike cars, they do not have the same level of friction, so inertia causes the Hovercraft to want to continue in its same direction without stopping or turning.

- Abruptly stopping a cart with an object on top causes the object on top to fall off. Inertia causes this by making the object want to continue moving in the direction that it was.
- If a stopped car is hit by a moving car from behind, the passengers inside may experience whiplash as a result of the body moving forward but the head lagging behind. The head is experiencing inertia.
- When a car is abruptly accelerated, drivers and passengers may feel as though their bodies are moving backward. In reality, inertia is making the body want to stay in place as the car moves forward.
- If an index card is placed on top of a glass with a penny on top of it, the index card can be quickly removed while the penny falls straight into the glass, as the penny is demonstrating inertia.
- If you jump from a car of bus that is moving, your body is still moving in the direction of the vehicle. When your feet hit the ground, the grounds act on your feet and they stop moving. You will fall because the upper part of your body didn't stop and you will fall in the direction you were moving.
- When you stir coffee or tea and stop, the swirling motion continues due to inertia.

Newton's Second Law of motion

"When an unbalanced force acts on an object of mass m, the object accelerates in the direction of the applied force with the magnitude of acceleration directly proportional to the net applied force and inversely proportional to the mass of the object."

Newton's second law of motion deals with the relationship between force and acceleration.
According to the second law of motion,
The rate of change of linear momentum is directly proportional to the applied force and it takes place in the direction in which the force acts.
Assume a body of mass m is traveling in a straight line with an initial velocity of u. It is uniformly accelerated to velocity, v, in time, t, by applying a constant force, F, over the entire duration, t.
Initial momentum, $\mathbf{p_1 = mu}$

Final momentum, $\mathbf{p_2 = mv}$
Now, a change in momentum can be expressed by Newton's second law of motion as:
$F \propto dP/dt$
$\Rightarrow F \propto (mv - mu)/t$
$\Rightarrow F \propto \{m(v-u)\}/t$

$\Rightarrow F \propto ma$

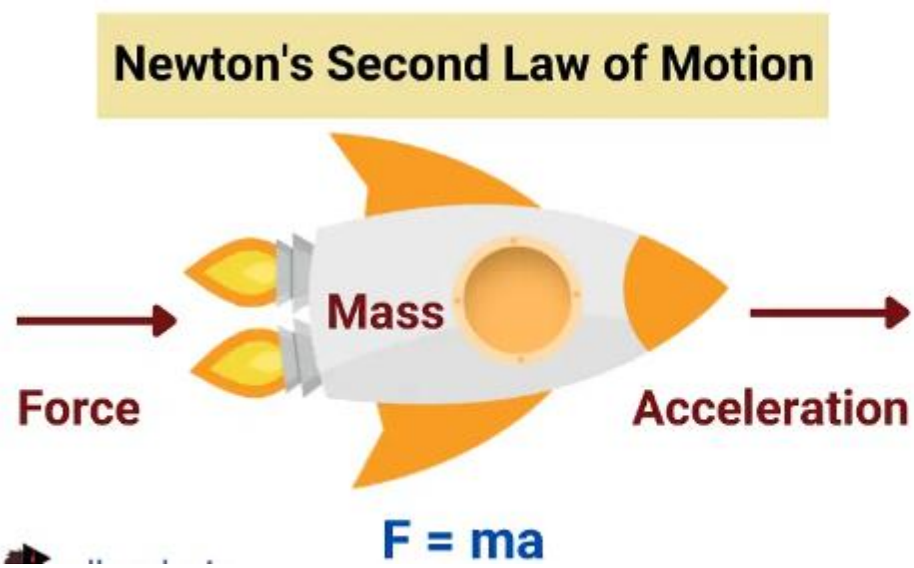
$\Rightarrow F = k\,ma$

Substituting **k = 1**, we get the formula of **Newton's second law of motion**

$$\mathbf{F = ma}$$

Where

- m is the mass of the body
- a is the acceleration of the body
- Acceleration is directly proportional to the unbalanced force and inversely proportional to the mass of the object.
- If the force acting upon an object is increased, the acceleration of the object will also be increased.
- If the mass of an object is increased, the acceleration of the object will be decreased.



Examples on Newton’s Second Law of Motion

Example 1: What will be the net force required in order to accelerate a 1000 kg car at 4 m/s^2?

Solution: Given that

- Mass of Car (m) = 1000 kg
- Acceleration of Car (a) = 4 m/s^2

Using Newton’s Second Law of Motion,

$F = m \times a$

1000 kg × 4 m/s^2 = 4000 N

Thus, the horizontal net force which is required to accelerate 1000 kg is 4000 N.

Example 2: What will be the acceleration if the net force of 12 N is applied to a 1 kg object?

Solution: It is given that,

- Force applied on Object (F) = 12 N.
- Mass of Object (m) = 1 kg

Using Newton’s Second Law of Motion,

$F = m \times a$

- a = F / m
- a = 12 N / 1 kg
- a = 12 m/s^2

Thus, the acceleration of the object will be 12 m/s^2

Newton’s Third Law of Motion

Newton’s Third Law of Motion which is also known as the law of action and reaction states that **every action has an equal and opposite reaction**. One of the bodies of the two decides the magnitude and the direction of the body. In other words, every action has an equal and opposite reaction.

- Every interaction involves two forces operating on the two interacting objects.

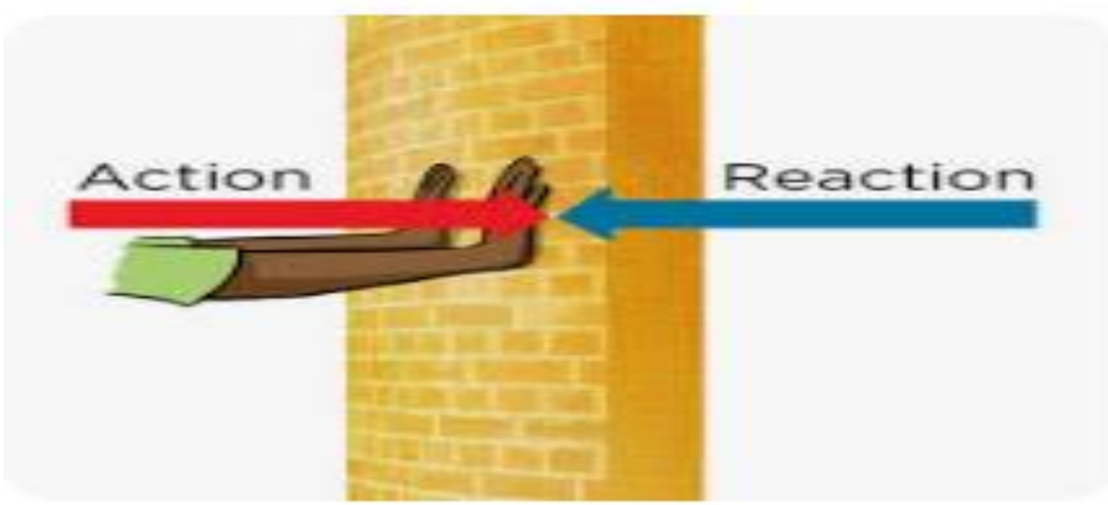
- The forces exerting **pressure** on the first object are the same as those exerting pressure on the second object.
- When compared to the force on the second object, the force on the first object acts in the opposite direction.
- Action and reaction forces are always equal and in opposition to one another.
- The push or pull that occurs when one object interacts with another is referred to as a force.
- Frictional, tensional, and applied forces are examples of contact-related forces, whereas gravitational, electrical, and **magnetic forces** are examples of distance-related forces.

If object A exerts a force (FA) on object B, then object B will exert a force (FB) of equal magnitude and opposite direction back on object A.

Action-Reaction Pair

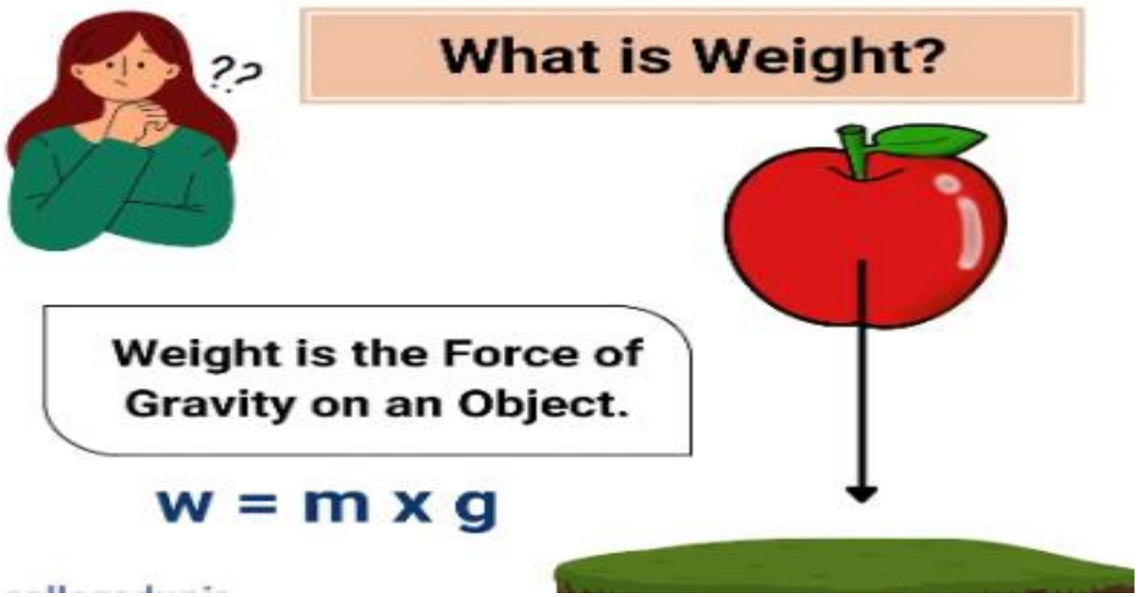
Action Force: The action force is the initial external force applied to the body.
Reaction Force: The force a body utilizes to react in the opposite direction to an action force is referred to as reaction force.
If body A is exerting force on body B, then the force acting on body B is known as action and the opposite force is called reaction.
If Fa = force exerted by Body A on body B
Fb = force exerted by body B on A
then,
Fa = Action and Fb = reaction.

- Both bodies depend on each other for action and reaction.
- There is no cause-effect relationship between the bodies of action-reaction.
- Their action and reaction to different bodies cannot be canceled out.
- The action-reaction pair involves mutual forces which are opposite and equal between the bodies.



Weight and the Gravitational Force

- When an object is dropped, it accelerates toward the center of the Earth.
- According to Newton's second law, acceleration is the effect caused by a force.
- Therefore, a falling object, experiences a downward force known as weight of the object denoted by **W**
- The magnitude of the weight is the product of mass (m) and the value of acceleration due to gravity g.
- Weight is a vector whose direction is always down towards the center of the Earth
- Weight = (mass)(acceleration due to gravity)
- W=mg
- Near to the surface of the earth, the magnitude of g is $9.8.m/s^2$



Example 1: The mass of a body is 50 kg. Using the weight formula, compute the weight of the body. (Hint: g = 9.8 m/s^2).

Solution: To determine the body's weight, we are given that

- Mass of the Body (m) = 50 kg
- $g = 9.8\ m/s^2$

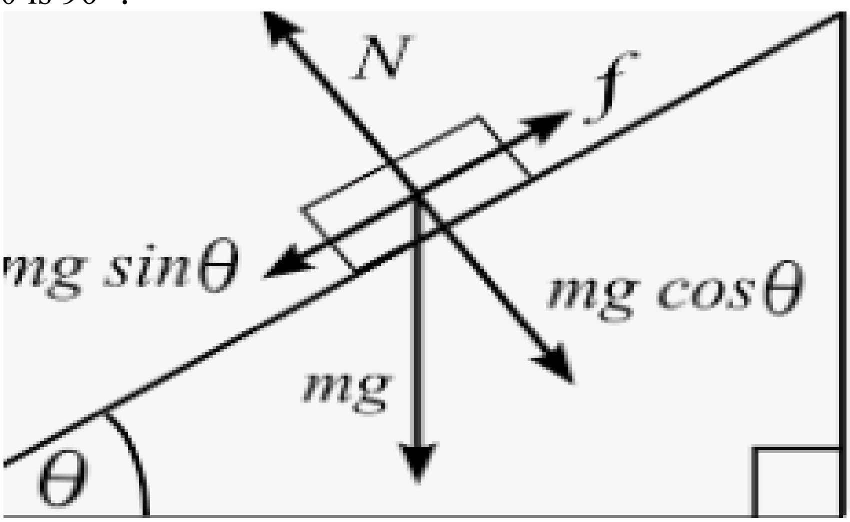
Using the Weight Formula,

W = mg

W = 50 × 9.8

W = 490 N

Normal Force

- Normal force is a type of contact force - two objects or surfaces have to touch for there to be a normal force.
- Since the book is in equilibrium, the net force acting on the book is zero. Therefore, on a level surface the normal force is equal to the weight. F_g = w =mg
- Note that as the name implies normal force is always normal (perpendicular) to the surface.
- Thus the weight and the normal force are equal only when the object is placed on a level surface. 4
- In most cases objects are placed on non-leveled surfaces such as on an inclined plane as shown in Figure
- The normal force is less than the weight by a factor of cos θ.
- As θ is increased the normal force that supports the object is decreased and it will be zero when θ is 90^0 .
- 

- When θ is 0 , the inclined plane becomes a level surface and obviously **F = W cos θ = mg cosθ**