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Force and Motion

Force:

Force is defined as “pull “and “push “is called “force “.

OR

“An agent which produces motion or-tends to produce motion, which stops motion or tends to stop the motion of a body is called force.”

OR

“An agent which changes the state or tends to change the state of body is called force.”

Newton’s first law of motion:

Introduction:

Newton’s law of motion explains the motion of body. Newton’s first law deals the state of body.

Statement:

Newton’s first law of motion can be stated as: “In the absence of an external force, a body in a state of rest will remain at the rest and a body in a state of motion will continue its motion in a straight line with uniform velocity.”

It can also be stated as:

“Everybody contains its state of rest, or of uniform motion in a straight line, unless it is acted upon by an unbalanced force.”

Explanation:

The law consists of two parts. The first part states that a body does not change its state of rest in the absence of external force. According to second part, a body continues its motion with its velocity and direction until and unless external force acts on it. Simply we can say that force is required to change the state of body or to produce acceleration.

Newton’s Second Law of Motion:

Introduction:

Newton’s laws discuss the motion of body. Newton’s second law of motion explains the Acceleration of motion.

Statement:

Newton’s second law of motion can be stated as, “When an external force acts on an object, it produces acceleration in it. The magnitude of acceleration is directly proportional to the magnitude of unbalanced force and its direction is exactly same as that of unbalanced force.”

It can also be stated as,

"When a force acts on an object, it produces acceleration in its own direction which is directly proportional to the magnitude of force and inversely proportional to the mass."

Mathematical Interpretation:

The relationship between the force applied and the acceleration produced in an object can be mathematically expressed as

$$\mathbf{a \propto F \text{ (For a constant mass)} \_\_\_\_\_ 1}$$

This acceleration is in the direction of applied force.

The relationship between the mass of an object and the acceleration produced in it can be mathematically expressed as

$$\mathbf{a \propto 1/m \text{ (For a constant Force)} \_\_\_\_\_ 2}$$

Combination of both above relationship gives new mathematical form

$$\mathbf{a \propto F/m}$$

Removing the proportionality constant

$$\mathbf{a = K.\ F/m}$$

Where K is a proportionality constant.

If K has value of 1

$$\mathbf{a = 1.\ F/m}$$

$$\mathbf{ma = F \text{ or,}}$$

$$\mathbf{F = ma}$$

The above is the mathematical form of Newton's 2nd law of motion.

Unit of Force:

M.K.S. System:

Newton symbol N

$$\mathbf{F = ma}$$

$$\mathbf{1\ N = 1\ kg.\ 1m / s^2}$$

If body of mass 1 kg moves with an acceleration of $1m/s^2$, than it is said that Force of 1N is acting on it.

C.G.S. System:

Dyne

$$\mathbf{F = ma}$$

$$\mathbf{1\ dyne = 1\ gm.\ 1\ cm/sec^2}$$

If 1gm mass of a body moves with an acceleration of $1cm / sec^2$, than it is said that Force of 1 dyne is acting on it.

F.P.S. System:

Pound symbol Ib

If a body of mass 1 Kg moves with an acceleration of $1\frac{ft}{s^2}$, than it is said that Force of 1 Ib is acting on it.

The SI (System International) unit of Force is Newton.

Newton's Third Law of Motion:

Introduction:

Newton's Laws of motion describes the motion of a body. Newton's 3rd law of motion explains the concept of action and reaction of a force.

Statement:

Newton's 3rd law of motion can be stated,

"To every action there is an equal and opposite reaction." FAB = - FBA It can also be stated as; "Action and reaction are just equal in magnitude but exactly opposite in direction."

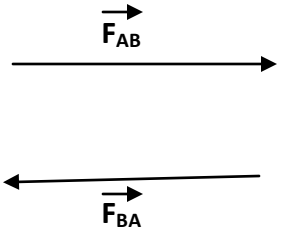
Explanation with the Help Of Illustration:

During walking, a man pushes the earth backward (action), as; a result earth exerts force on the foot of man and pushes forward (reaction).

During swimming, a swimming pushes the water from hand backward as a result water pushes the swimmer forward.

During jumping, a jumper pushes the earth back ward as a result earth throws jumper.

Analytical Interpretation:



Consider the interaction between two bodies A and B as shown in figure. The force exerted by A on B is FAB and the force exerted by B on A is FBA. Then according to the law.

$$F_{AB} = -F_{BA}$$

Equating sign shows that both forces (action – reaction) are of same magnitudes while Negative between them shows that both act in the opposite direction.

Momentum:

Momentum is defined as "quality of motion is called momentum." It can also define as: "The product of mass and velocity is called momentum." Momentum describes the character sticks of motion of a body which are as follows: Under the same momentum:

1. Heavy body moves slow
2. Light body moves fast

Mathematically momentum can be interpreted as:

Momentum = mass x velocity

$$P = m\vec{V}$$

Where P: momentum, m: mass, v: velocity, Momentum is a vector quantity, The unit of momentum is N.S. or Kg. m/s.

Unit: By definition

$$P = m\vec{V}$$

In M.K.S. system P = kg m/s, multiplying and dividing by s.

$$P = \frac{Kgm}{s}.\frac{s}{s}$$

$$P = \frac{kg\ ms}{s^2}$$

But F = ma (Newton 2nd law), and in M.K.S, system the unit of Newton is $N = \frac{Kgm}{s^2}$

Unit of momentum becomes

$$P = Ns$$

Vector form of momentum can written as

$$P = m\vec{V}$$

Where mass "m "is a scalar quality.

Law Of Conservation Of Momentum:

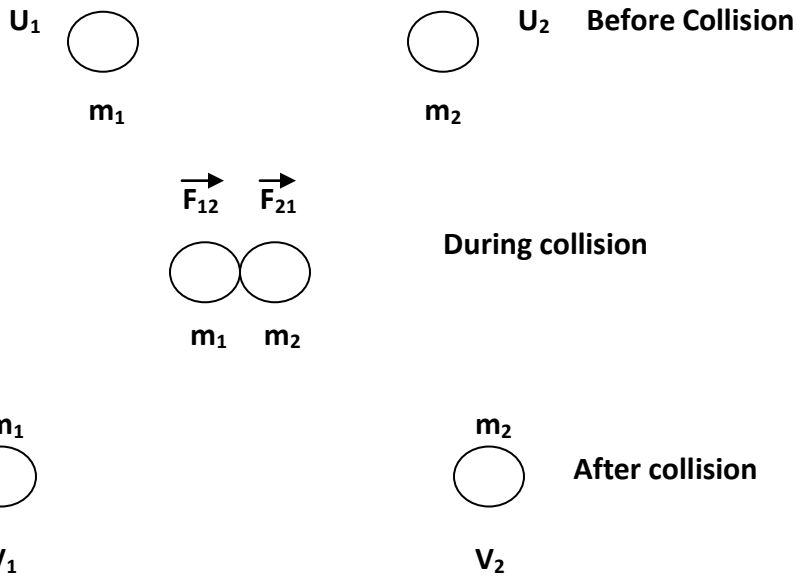
Statement:

Law of conservation of momentum can be stated as: "The total momentum before and after collision for an isolated system always remain same."

It can also be written as:

"If there is no external force acts on a system the total linear momentum of that system always remain in time."

Mathematical Interpretation:



Let mass of body 1 = m_1

Initial velocity of body 1 = u_1

Initial momentum of body 1 = m_1u_1

Mass of body 2 = m_2

Initial velocity of body 2 = u_2

Initial momentum of body 2 = m_2u_2

Total momentum before collision (initial) = $m_1u_1 + m_2u_2$ _____ (1)

Mass of body 1 = m_1

Final velocity of body 1 = v_1

Final momentum of body 1 = m_1v_1

Mass of body 2 = m_2

Final velocity of body 2 = v_2

Final momentum of body = m_2v_2

Total momentum after collision (final) = = $m_1u_1 + m_2u_2$ _____ (2)

According to law of conservation of momentum

Total momentum before collision = total momentum after collision

$$m_1u_1 + m_2u_2 = m_1u_1 + m_2u_2$$

The above equation is the mathematical interpretation of law of conservation of energy.

Mass And Weight:

Mass	Weight
1. The quality of a matter present in a body is called mass.	**1.The force with which earth attracts everything towards its center is called**
2. It is denoted by m.	**2. It is denoted by W.**
3. It remains same at every altitude.	**3. It varies with height.**
4. It is independent of direction.	**4. It always acts downwards.**
5. It is scalar quantity.	**5. It is vector quantity.**
6. Units in different systems are as follows: **M.K.S. System: kg** **C.G.S. System: gm** **F.P.S. System : smg**	**6. Units in different systems are as follows** **M.K.S. System: N** **C.G.S. System : Dyne** **F.P.S. System : Ib**
7. Mathematically m = w / g	**7. Mathematically w = mg**

Force of Friction:

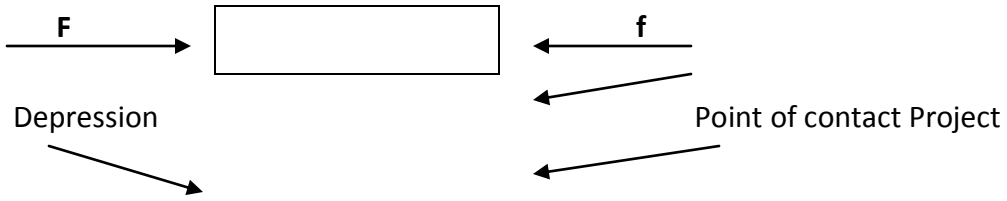
Symbol: It is denoted by " F ".

Definition:

Whenever a body slides over any surface their surface tends to resist the motion of a body. The apposite force offered by the surface to stop the motion of a body is called force of friction**.**

Reason:

Due to roughness of surface. Whenever an object slides over any surface then blockage of protection and depression between object and the surface causes force of frication.



Direction:

The direction of force of friction is always opposite to the direction of motion.

Position:

The frictional force develops at the point of contact between the object and surface.

Factors Affecting the Force of Friction:

Following are factor affecting the force of friction.

i. Weight of body:

Force of friction increases as the weight of the body increases.

ii. Normal of Reaction of Surface:

Force of friction increases as the normal reaction of the surface increases, because normal reaction depends on the weight and it increases as weight Increase.

iii. Roughness of surface (nature of surface):

If the surfaces rough then it has more force of friction, if the surface is smooth then it has less friction.

Mathematical Interpretation:

Mathematically friction can be interpreted as:

$$f \propto R$$

$$f = \mu R$$

Where f = force of friction

R = normal reaction of the surface

μ = coefficient of friction.

Mathematical $\mu = \frac{f}{R}$

It is define as "the ratio of force of friction to the normal reaction of the surface is called force of friction." It depends on the nature of the surface. It has no units.

Types of frication:

Following are the types of friction.

Static friction:

The force of friction which acts on a body when it is in a state of rest, then it is said to be static friction.

Mathematically fs = μ.R

Fs = static friction

μ = coefficient of static friction

R = normal reaction

Kinetic friction:

The force of friction which acts on a body when it is in a state of motion it is called kinetic friction.

Mathematically $f_k = \mu_k R$

f_k = static friction

μ_k = coefficient of kinetic friction

R = normal reaction

Rolling friction:

If a heavy spherical body is set to be rolling it experiences and opposing force called rolling friction. **OR**

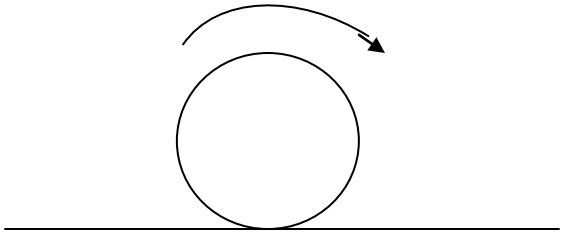
When a body rolls over a surface, the force of friction is called rolling friction.

By magnitude rolling friction is very small because in case of rolling the area of contact between body (rolling body) and the surface is very small.

For example:

Rolling friction between is 1/100 of the sliding (kinetic) friction between them.

Rolling Friction



Advantages and disadvantages:

Advantages:

Following are the advantages of friction:

1. It produces balance (help in walking).
2. It produce grip in joints.
3. It makes the object stable at its position.
4. It produces heat.

Disadvantages:

Following are the disadvantage of friction:

1 .More amount of force is required to move any object.
2 .More amount of energy required to perform work.
3 .It produces heat.
4 .Due to friction, surface destroyed.

Methods of reading friction:

Following are the methods used for minimizing friction.

1. Various parts of machines which are moving over one other are properly lubricated.
2. In machine the sliding of various is usually replaced by rolling and this is done by ball bearing.
3. Where sliding is unavoidable a thick layer of oil is used between sliding surfaces
4. The front part of fast moving object should be made oblong.