Unit 3

Dynamics

Teaching Periods 9 *Weightage %* 6

Pride of Pakistan, Arshad Nadeem, the first South asian to cross the 90 meter barrier in Birmingham as he clinched the gold medal, breaking the commonwealth games record in Javelin throw

In this unit student should be able to:

- Apply Newton's laws to explain motion of objects
- Define inertia (as the property of a body which resists change in motion).
- Describe and use of the concept of weight as the effect of a gravitational field on a mass.
- Apply Newton's laws of motion
- Describe the Collision, Momentum and Impulse
- Relation between Newton's 2nd law and Linear Momentum
- Explain law of conservation of Momentum
- Describe elastic and inelastic collision with examples
- Solve different problems of elastic and inelastic collisions between two bodies in one dimension by using law of conservation of momentum.
- Describe that momentum is conserved in all situations. (Rocket Situation)

Dynamics is the also the branch of mechanics in which we study about the motion with reference of force. In this chapter students will able to learn the behavior of force, how it plays its role to change the state (rest or motion) of body.

Newton's Laws of Motion

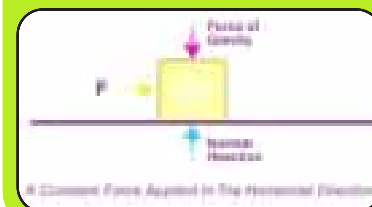
Sir Isaac Newton's laws of motion explain the relationship between a physical object and the forces acting upon it. Understanding this information provides us with the basis of modern physics.

Newton's first law: Inertia

Newton's first law states that every object will remain at rest or in uniform motion in a straight line unless compelled to change its state by the action of an external force. This tendency to resist changes in a state of motion is inertia. There is no net force acting on an object (if all the external forces cancel each other out). Then the object will maintain a constant velocity. If that velocity is zero, then the object remains at rest. If an external force acts on an object, the velocity will change because of the force. The first law of motion is also known as the law of inertia.

DO YOU KNOW?

External Force?
An external force is defined as the change in the mechanical energy that is either the kinetic energy or the potential energy in an object. These forces are caused by external agents. Examples of external forces are friction, normal force and air resistance.



Inertia

The property by virtue of which a body opposes any change in its state of rest or of uniform motion is known as inertia. Greater the mass of the body greater is the inertia. That is mass is the measure of the inertia of the body.

Numerical Application If, $F = 0$; $a = 0$; $v =$ constant (In the absence of external applied force velocity of body remains unchanged.)

Physical Application of inertia or newton's first law

1. When a moving car suddenly stops, passenger's head gets pulled in the forward direction to prevent this action diver fasten seat belts.
2. When we hitting used mattress by a stick, dust particles come out of it.
3. In order to catch a moving bus safely we must run forward in the direction of motion of bus.
4. Whenever it is required to jump off a moving bus, we must always run for a short distance after jumping on road to prevent us from falling in the forward direction.

DO YOU KNOW?

Acceleration: a measurement of how quickly an object is changing speed.

Net force (F_{net}): The sum total and direction of all forces acting on the object.

Newton's Second Law: Force

Forces can be balanced or unbalanced. An ***unbalanced force*** causes something to accelerate. It depends on the **net force** acting on the object that **always causes acceleration.**

The acceleration of an object depends on the mass of the object and the amount of force applied.

Acceleration of an object is directly proportional to the applied force

a α F (1)

Acceleration of an object is inversely proportional to the mass of an object

a α 1/m (2)

By combining both equations (1) & (2)

$$a \,\alpha\, k\frac{F}{m} \qquad \therefore\ k = 1$$

a = F/m

F = ma ……(3.1)

DO YOU KNOW?

If you *double* the mass, you *double* the force. If you *double* the acceleration, you *double* the force.
What if you double the mass *and* the acceleration?
(2m)(2a) = 4F
Doubling the mass *and* the acceleration *quadruples* the force.

Worked Example 3.1

A 50 N force applied on a box of mass 8.16 kg to move on the right across a horizontal surface. What is the acceleration of produced in the box.

Solution:

Step 1: Write the known quantities and point out quantities to be found.

$\vec{F}$ = 50 N

$m = 8.16\ kg$

$a = ?$

Step 2: Write the formula and rearrange if necessary

$$\vec{F} = ma \ \ or\ a = \frac{\vec{F}}{m}$$

Step 3: Put the value in formula and calculate

$$a = \frac{\vec{F}}{m}$$

$$a = \frac{50}{8.16}$$

$a = 6.13$ ms^{-2}

The acceleration of the box is found to be 6.13ms^{-2}.

Newton's Third Law: Action & Reaction

Whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first. His third law states that for every **action** (force) there is an equal and opposite **reaction**. If object A exerts a force on object B, object B also exerts an equal and opposite force on object A as shown in fig: 3.1.

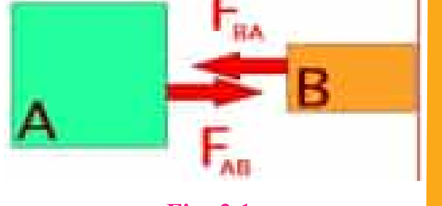


Fig: 3.1

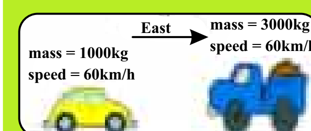
In other words, forces result from interactions.
For every force acting on an object, there is equal force acting in the opposite direction. Right now, gravity is pulling you *down* in your seat, but Newton's Third Law says your seat is pushing *up* against you with *equal force*. This is why you are not moving. There is balanced *force* acting on you– gravity pulling down, your seat pushing up.

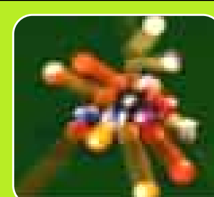
Examples

i. The motion of lift from an airfoil, the air is deflected downward by the airfoil's action, and in reaction, the wing is pushed upward.
ii. The motion of a spinning ball, the air is deflected to one side, and the ball reacts by moving in the opposite
iii. The motion of a **jet engine** produces thrust and hot exhaust gases flow out the back of the engine, and a thrusting force is produced in the opposite direction.

DO YOU KNOW?

Newton's 3rd: describes the relationship between two forces in an interaction.
One force is called the **action force.**
The other force is called the **reaction force.**
Neither force exists without the other.
They are equal in strength and opposite in direction.
They occur at the same time (simultaneously).





Self-Assessment Questions:
1. Suppose that the acceleration of an object is zero. Does this mean that there are no forces acting on it?
2. Can objects with different masses experience the same magnitude of force when they interact? Why or why not?

3.2 Momentum and impulse

3.2.1 Momentum, Impulse, and Collisions

Consider A moving van collides head-on with a compact car. What determined which way the wreckage moves after the collision?
How do you decide how to knock the billiard balls?
We cannot use Newton's second law to solve such problems because we know very little about the complicated forces involved.
To solve such problems: We introduce **momentum** and **impulse**, and the **conservation of momentum**.

Momentum and Impulse

Physical quantity that describes the quantity of motion in a body is called momentum.
The momentum of a moving body is defined as
"the product of mass and velocity of a moving body is called linear momentum"

$$\vec{P} = m\vec{V} \qquad \ldots\ldots(3.2)$$

Momentum is a vector quantity and its direction is the same as that of velocity.as shown in figure 3.2

Momentum *p* is a vector quantity
Fig: 3.2

Explanation

Momentum is that property of a moving body which determines how much effort is required to accelerate or stop a body. Hence, it may also be termed as quantity of motion of a body. From various observations it is concluded that greater effort is required to stop a body if it possesses either greater mass or greater velocity or both.

Units Of Momentum

In S.I. system: Ns [1 Ns = 1 kg m/s]
In C.G.S. system: dyne.S
In F.P.S. system: lb.s
Dimensions of Momentum
The dimension of momentum is **$[MLT^{-1}]$.**

Newton 2nd Law and Linear Momentum

Newton's Second Law can be used to relate the momentum of an object to the resultant force acting on it

$$\sum \vec{F} = m\vec{a} = m\frac{d\vec{v}}{dt} \text{ OR}$$

Newton's second law can be written in terms of momentum as
Keeping mass as constant

$$\sum \vec{F} = \frac{d\vec{p}}{dt} \quad \ldots\ldots(3.3)$$

The change in an object's momentum divided by the elapsed time equals the constant net force acting on the object

$$\frac{\Delta \vec{p}}{\Delta t} = \frac{\text{change in momentum}}{\text{time interval}} = \vec{F}_{net}$$

Impulse

Consider A tennis ball is in contact with the rickets which exerts the force of magnitude $\vec{F}$ on tennis ball for very short time Δt as shown in the fig: 3.3.

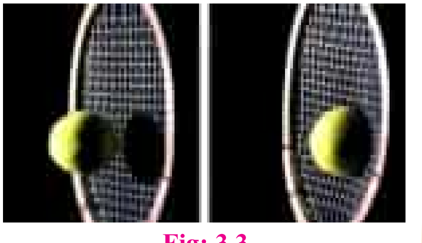


Fig: 3.3

Definition: The impulse of a force $\vec{J}$ is the product of the force and the time interval Δt during which it acts.

$$\vec{J} = \sum \vec{F}.\Delta t \ \ldots\ldots (3.4)$$

$$\vec{J} = \vec{F}.\Delta t = \Delta \vec{P}$$

$$\vec{J} = \Delta \vec{P} \ \ldots\ldots(3.5)$$

Self-Assessment Questions:

1. How is impulse related to the change in momentum of an object?
2. An object with an initial momentum of 50 kg m/s experiences an impulse of 100 Ns. Calculate its final momentum.
3. A golf club exerts an average force of 800 N on a golf ball for 0.02 seconds. If the initial velocity of the ball is 40 m/s and its final velocity is 60 m/s, what is the impulse experienced by the ball?

Worked Example 3.2

A hockey puck with a mass of 0.2 kg is sliding on the ice at a velocity of 10 m/s. It collides with a wall and bounces back with a velocity of -8 m/s. The collision lasts for 0.1 seconds. Calculate the impulse experienced by the hockey puck and the change in its momentum.

Solution:

Step 1: Calculate the initial momentum (p_initial) of the hockey puck before the collision:
p_initial = mass × initial velocity
p_initial = 0.2 kg × 10 m/s = 2 kg·m/s

Step 2: Calculate the final momentum (p_final) of the hockey puck after the collision:
p_final = mass × final velocity
p_final = 0.2 kg × (-8 m/s) = -1.6 kg·m/s

Step 3: Calculate the change in momentum (Δp):
Δp = p_final - p_initial
Δp = (-1.6 kg·m/s) - (2 kg·m/s) = -3.6 kg·m/s

Step 4: Calculate the impulse (J) experienced by the hockey puck during the collision:
J = Δp
J = -3.6 kg·m/s

The impulse experienced by the hockey puck during the collision is -3.6 kg·m/s, and the change in its momentum is also 3.6 kg.m/s.

DO YOU KNOW?

Compare momentum and kinetic energy

Changes in momentum depend on the time over which the net force acts, and it is vector quantity Changes in kinetic energy depend on the distance over which the net force acts, and it is scalar quantity.

(Note: If the derivative of any quantity is zero, it must be a constant quantity.)

Law of Conservation of Linear Momentum

The **law of conservation of linear momentum** states that if no external forces act on the system of two colliding objects, then the vector sum of the linear momentum of each body remains constant and is not affected by their mutual interaction.

Alternatively, it states that if net external force acting on a system is zero, the total momentum of the system remains constant.

Proof:

Let us consider a particle of mass ‘m’ and acceleration ‘a’. Then, from 2nd law of motion,

$$F = \frac{dP}{dt}$$

If no external force acts on the body then, F=0,

$F = \frac{dP}{dt} = 0 \ldots\ldots(3.6)$

In result ***P*** remains constant or conserved.

Law of Conservation of linear momentum for two colliding bodies

Let us consider two objects of masses m_1 and m_2 moving in straight line with initial velocities u_1 and u_2 as shown in figure 3.4(a). When two objects collide, they experience equal and opposite forces on each other for short time Δt as shown in figure 3.4(b). These forces cause a change in the momentum of the objects. After collision, objects moves in the same direction but with different velocities v_1 and v_2 respectively as shown in fig: 3.4(c).

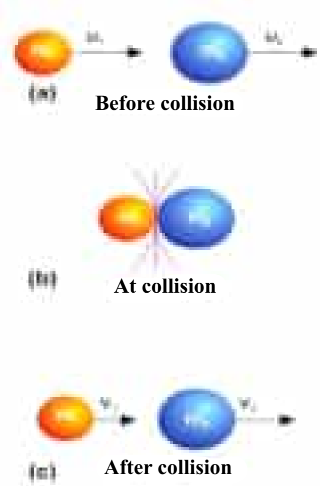


Fig: 3.4

At the time of collision m_1 exerts force on m_2 is F_{12}

$$F_{12} = (m_2v_2 - m_2u_2)/\Delta t$$

in reaction m_2 exerts force on m_1 which is F_{21}

$$F_{21} = (m_1v_1 - m_1u_1)/\Delta t$$

As per statement of Newton's 3rd law

$$F_{12} = -F_{21} \;......(3.7)$$

$$(m_2v_2 - m_2u_2)/\Delta t = -(m_1v_1 - m_1u_1)/\Delta t$$

$$m_1v_1 + m_2v_2 = m_1u_1 + m_2u_2 \;......(3.8)$$

Above equation shows that in the absence of an external force the total momentum before collision is equals to total momentum after collision or in other words total momentum remains conserved during the collision.

Elastic and Inelastic Collision

Elastic Collision

An elastic collision is that in which the momentum of the system as well as kinetic energy of the system before and after collision is conserved.

Inelastic Collision

An inelastic collision is that in which the momentum of the system before and after collision is conserved but the kinetic energy before and after collision is not conserved.

Elastic Collision in One Dimension

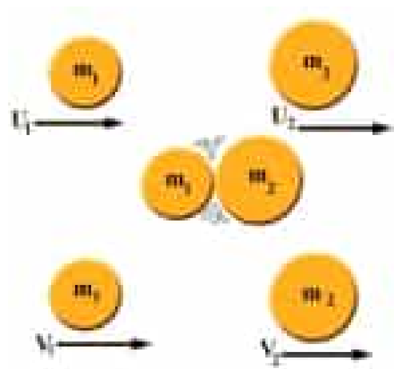


Fig: 3.5

Consider two non-rotating spheres of mass m_1 and m_2 moving initially along the line joining their centers with velocities u_1 and u_2 in the same direction. Let u_1 is greater than u_2. They collide with one another and after having an elastic collision start moving with velocities v_1 and v_2 in the same directions on the same line as shown in fig:3.5.

Momentum of the system before collision = $m_1u_1 + m_2u_2$

Momentum of the system after collision = $m_1v_1 + m_2v_2$

According to the law of conservation of momentum:

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$m_1v_1 - m_1u_1 = m_2u_2 - m_2v_2$

$m_1(v_1 - u_1) = m_2(u_2 - v_2)$ ……(3.9)

Similarly

K.E of the system before collision = $\frac{1}{2} m_1u_1^2 + \frac{1}{2} m_2u_2^2$

K.E of the system after collision = $\frac{1}{2} m_1v_1^2 + \frac{1}{2} m_2v_2^2$

Since the collision is elastic, so the K.E of the system before and after collision is conserved.

Thus

$\frac{1}{2} m_1v_1^2 + \frac{1}{2} m_2v_2^2 = \frac{1}{2} m_1u_1^2 + \frac{1}{2} m_2u_2^2$

$\frac{1}{2} (m_1v_1^2 + m_2v_2^2) = \frac{1}{2} (m_1u_1^2 + \frac{1}{2} m_2u_2^2$

$m_1v_1^2 - m_1u_1^2 = m_2u_2^2 - m_2v_2^2$

$m_1(v_1^2 - u_1^2) = m_2(u_2^2 - v_2^2)$

$m_1(v_1+u_1)(v_1-u_1) = m_2(u_2+v_2)(u_2-v_2)$ …… (3.10)

Dividing equation (3.10) by equation (3.9)

$$\frac{m_1(v_1+u_1)(v_1 \square u_1)}{m_1(v_1 \square u_1)} = \frac{m_2(u_2+v_2)(u_2 \square v_2)}{m_2(u_2 \square v_2)}$$

$v_1+u_1 = u_2+v_2$

From the above equation

$v_1 = u_2 + v_2 - u_1$__________(i)

$v_2 = v_1 + u_1 - u_2$__________(ii)

Putting the value of v_2 in equation (3.9)

$m_1 (v_1-u_1) = m_2 (u_2-v_2)$

$m_1 (v_1-u_1) = m_2\{u2-(v_1+u_1-u_2)\}$

$m_1(v_1-u_1) = m_2\{u_2-v_1-u_1+u_2\}$

$m_1(v_1-u_1) = m_2\{2u_2-v_1-u_1\}$

$m_1v_1-m_1u_1 = 2m_2u_2-m_2v_1-m_2u_1$

$m_1v_1+m_2v_1 = m_1u_1-m_2u_1+2m_2u_2$

$v_1(m_1+m_2) = (m_1-m_2)u_1-2m_2u_2$

$$V_1 = \frac{(m_1-m_2)u_1}{(m_1+m_2)} + \frac{2m_2\ u_2}{(m_1+m_2)} \quad ……(3.11)$$

In order to obtain V_2 putting the value of V_1 from equation (i) in equation (3.9)

$m_1 (v_1-u_1) = m_2(u_2-v_2)$

$m_1(u_2+v_2-u_1-u_1) = m_2(u_2-v_2)$

$m_1(u_2+v_2-2u_1) = m_2(u_2-v_2)$

$m_1u_2+m_1v_2-2m_1u_1 = m_2u_2-m_2v_2$

$m_1v_2+m_2v_2 = 2m_1u_1+m_2u_2-m_1u_2$

$v_2(m_1+m_2) = 2m_1u_1+(m_2-m_1)u_2$

$$V_2 = \frac{2m_1\ u_1}{(m_1+m_2)} + \frac{(m_2-m_1)\ u_2}{(m_1+m_2)} \quad ……(3.12)$$

Self-Assessment Questions:

1. How does kinetic energy change in an elastic collision? Why?
2. What happens to the objects involved in an inelastic collision after the collision?

Worked Example 3.3

Two objects, A and B, are initially at rest on a frictionless surface. Object A has a mass of 0.5 kg, and object B has a mass of 0.8 kg. Object A collides with object B. After the collision, object A moves to the right at a velocity of 4 m/s, and object B moves to the left at a velocity of 2 m/s.

a) Calculate the total momentum before the collision.

b) Calculate the total momentum after the collision.

c) Calculate the kinetic energy before and after the collision.

Step 1: a) Total momentum before the collision:

Step 2: Initial momentum of both objects is zero since they are at rest. Therefore, the total momentum before the collision is 0 kg·m/s.

Step 3: b) Total momentum after the collision:

Total momentum after the collision is the sum of the momenta of objects A and B:

$P_A = m_A \times v_A = 0.5\ kg \times 4\ m/s = 2\ kg \cdot m/s$ (to the right)

$P_B = m_B \times v_B = 0.8\ kg \times (-2\ m/s) = -1.6\ kg \cdot m/s$ (to the left)

Total momentum after the collision: $2\ kg \cdot m/s - 1.6\ kg \cdot m/s = 0.4\ kg \cdot m/s$ (to the right)

Step 4: c) Kinetic energy before the collision:

Both objects are initially at rest, so the initial kinetic energy is zero.

Step 5: d) Kinetic energy after the collision:

Kinetic energy after the collision for object A:

$K \cdot E_A = (1/2) \times m_A \times v_A^2 = (1/2) \times 0.5\ kg \times (4\ m/s)^2 = 4\ J$

Kinetic energy after the collision for object B:

$K \cdot E_B = (1/2) \times m_B \times v_B^2 = (1/2) \times 0.8\ kg \times (-2\ m/s)^2 = 1.6\ J$

Total kinetic energy after the collision: 4 J + 1.6 J = 5.6 J

Friction

When a solid object moves or attempts to move over the surface of another solid object as shown in fig:3.6. its motion is always opposed by a retarding force. This force is called friction. Thus, friction is the force directed opposite to the direction of motion or attempted motion. The frictional force is always parallel to the surface in contact.

The friction and normal forces are really components of a single contact force

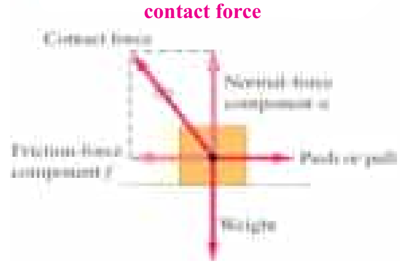


Fig: 3.6

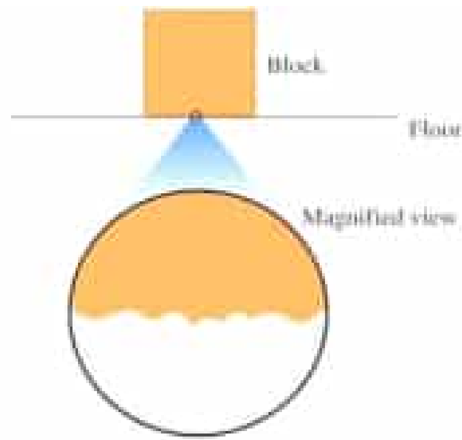
Origin of Friction

Classical view

According to Classical view, when two objects are kept in contact, there forms an interlock between the irregular surfaces and to break the interlock, we need an extra force. This force measures the force of friction.

Modern view

According to modern theory, friction is due to intermolecular force of attraction between the surfaces in contact. When two surfaces are put together, the actual area of contact is very less than the apparent area of contact. The pressures at the contact points are very high and the molecules are pushed very close so that attractive forces between them weld the surfaces together at contact points (which is called cold welding). To break this attachment we need an extra force as shown in fig:3.7.



On a microscopic level, even smooth surfaces are rough; they tend to catch and cling

Fig: 3.7

Types of Friction

Static Friction

The friction force that comes into play between the two surfaces when one body tends to move on the surface of other body is called static friction.

$$f_s \leq \mu_s n$$

The maximum value of static friction is called limiting friction.

Kinetic Friction

The frictional force that comes into play between the two surfaces when one body moves on the surface of other body is called kinetic friction.

$$f_k = \mu_k n / \ldots\ldots(3.13)$$

There are two types of kinetic friction. They are:

a) Sliding Friction

The friction that exists between two surfaces when one body is sliding on the other is called sliding friction. For example: friction between the wood block and the road when the wood block slides on the road.

b) Rolling Friction

The friction that exists between two surfaces when one surface is rolling over the other is called rolling friction. For example: friction between the tyre of moving vehicle and the road.

Laws of Friction

a) The frictional force opposes the relative motion of two surfaces.
b) The frictional force is parallel to the surfaces in contact.
c) The frictional force is directly proportional to the normal reaction.
d) The frictional force is independent of the area of contact.
e) The frictional force depends upon the nature of the two surfaces in contact and their state of roughness.
f) The kinetic friction is independent of the relative velocities of the surfaces.

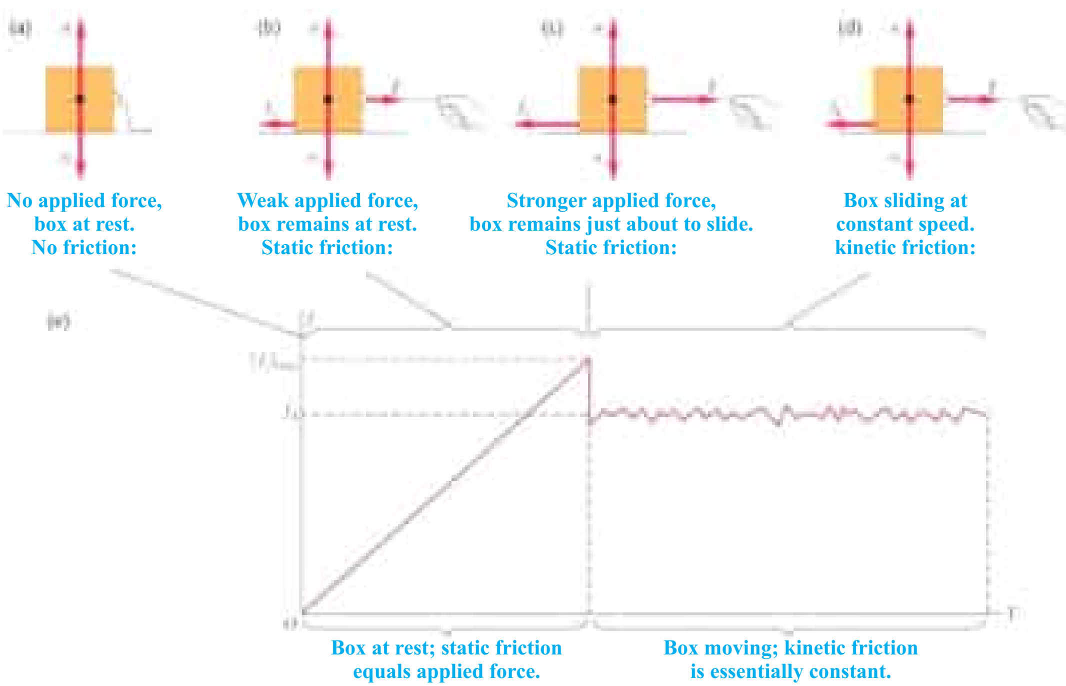


Fig: 3.8

Angle of Friction

Angle of friction is defined as the angle made by the resultant of frictional force and the normal reaction with the normal reaction as shown in fig:3.9.

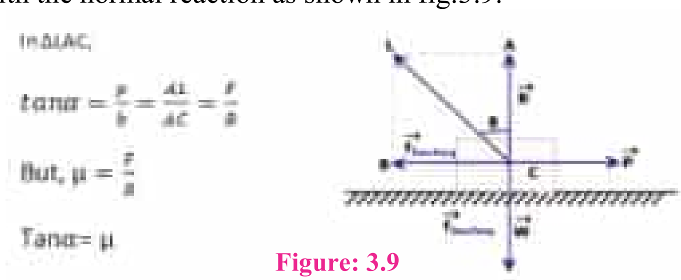


Figure: 3.9

Therefore, tangent of angle of friction is called coefficient of friction.

Relation between Angle of Friction and Angle of Repose

Angle of repose is defined as the minimum angle made by an inclined plane with the horizontal such that an object placed on the inclined surface just begins to slide.

Let us consider a body of mass 'm' resting on a plane.

Also, consider when the plane makes 'θ' angle with the horizontal, the body just begins to move.

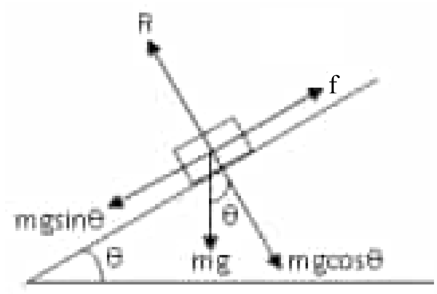


Fig: 3.10

Let 'R' be the normal reaction of the body and 'f' be the frictional force.

Here,

$mg\sin\theta = -f \longrightarrow$ (i)

$mg\cos\theta = -R \longrightarrow$ (ii)

Dividing equation (i) by (ii)

$$\frac{mg\sin\theta}{mg\cos\theta} = \frac{-f}{-R}$$

$$\tan\theta = \frac{f}{R}$$

Or, $\tan\theta = \mu$, where 'μ' is the coefficient of friction

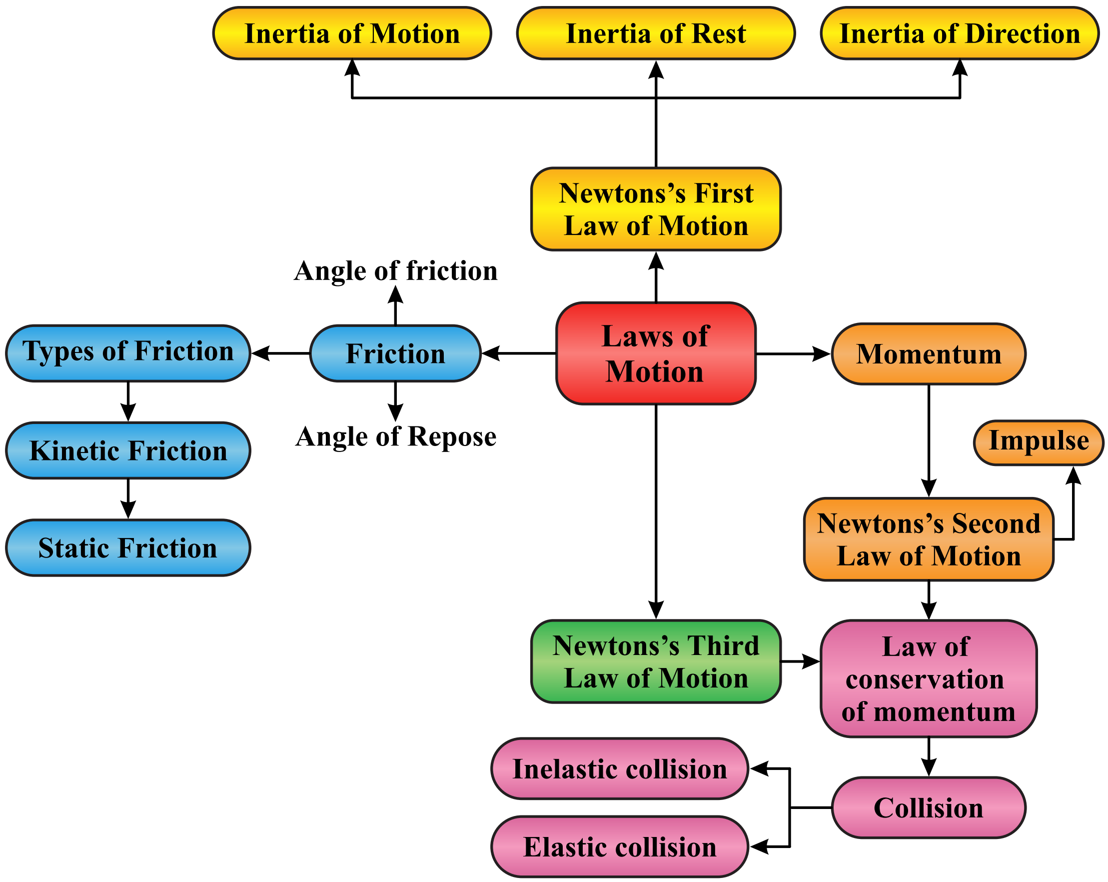
Or, $\tan\theta = \tan\alpha$ $\quad (\tan\alpha = \mu)$

where 'α' is the angle of friction

$\boldsymbol{\theta = \alpha}$

Angle of repose is equal to angle of friction.

CONCEPT MAP


Inertia of Motion
Inertia of Rest
Inertia of Direction
Newtons's First Law of Motion
Angle of friction
Types of Friction
Friction
Laws of Motion
Momentum
Angle of Repose
Kinetic Friction
Impulse
Newtons's Second Law of Motion
Static Friction
Newtons's Third Law of Motion
Law of conservation of momentum
Inelastic collision
Collision
Elastic collision

SUMMARY

- Dynamics: Study of the forces and torques that cause motion and the resulting effects.
- Force: Push or pull on an object; causes acceleration.
- Newton's Laws of Motion:
- First Law (Law of Inertia): An object at rest stays at rest, and an object in motion stays in motion unless acted upon by an external force.
- Second Law (F = ma): The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass.
- Third Law (Action-Reaction): For every action, there is an equal and opposite reaction.
- Inertia: Resistance of an object to changes its state in its motion due to its mass.
- Friction: Resistance force between two surfaces in contact; opposes relative motion.
- Normal Force: Force exerted by a surface to support the weight of an object in contact with it.
- Momentum: Product of an object's mass and velocity or quantity of motion; conserved in a closed system.
- Impulse: Change in momentum of an object due to an applied force over a time interval.
- Conservation of Momentum: In a closed system, the total momentum before a collision is equal to the total momentum after the collision.
- Elastic Collision: Collisions where both momentum and kinetic energy are conserved.
- Inelastic Collision: Collisions where momentum is conserved, but kinetic energy is not.

EXERCISE

Section (A): Multiple Choice Questions (MCQs)

1. The rate of change of linear momentum of a body is called a:
   a) Linear force b) Angular force
   c) Power d) Impulse
2. The term mass refers to the same physical concept as:
   a) weight b) inertia
   c) force d) acceleration
3. Which one of the following force is also called as self adjusting force ?
   a) frictional force b) tension
   c) Weight d) Thrust
4. The laws of motion shows the relationship between:
   a) velocity and acceleration b) mass and velocity
   c) mass and acceleration d) force and acceleration

5. The motion of rocket in the space is according to the law of conservation of:
   a) Energy b) linear momentum
   c) mass d) angular momentum
6. A bomb of mass 12 kg initially at rest explodes into two pieces of masses 4kg and 8kg . The speed of 8kg mass is 6 m/s. The kinetic energy The kinetic energy of 4 kg mass is:
   a) 32 J b) 48 J
   c) 114 J d) 288 J
7. If momentum is increased by 20% then K.E increases by:
   a) 44% b) 55%
   c) 66% d) 77%
8. The kinetic energy of body of mass 2kg and momentum of 2 Ns is:
   a) 1 J b) 2 J
   c) 3 J d) 4 J
9. For the same kinetic energy, the momentum is maximum for:
   a) an electron b) a proton
   c) a deuteron d) alpha particle
10. A 3kg bowling ball experiences a net force of 15N. What will be its acceleration.
   a) 35 m/s2 b) 7 m/s2
   c) 5 m/s2 d) 35 m/s2

Section (B): Structured Questions

CRQs:

1. State Newton's second law of motion.
2. How does mass affect an object's acceleration?
3. What are the different types of forces that can act on an object?
4. How do you calculate net force?
5. State the law of conservation of momentum.
6. What is the difference between elastic and inelastic collisions?
7. How does impulse relate to force and time?
8. How does friction influence the motion of an object?

ERQs:

1. Explain Newton's Second Law of Motion and how it relates force, mass, and acceleration. Provide an example to illustrate the concept.
2. How does the conservation of momentum apply in each type of collision? Give real-life examples of both types of collisions.
3. Explain how the concept of impulse is related to the change in momentum of an object. Provide an example of an everyday life where impulse plays a significant role.
4. State the law of conservation of momentum. Provide an example from everyday life that demonstrates the principle of momentum conservation.

Numericals:

1. A car weighing 9800 N is moving with a speed of 40 Km/h. On the Application of breaks it comes to rest after traveling a distance of 50 meters. Calculate the average retarding force? **(Ans: 1234. 57 N)**
2. A helicopter weighs 3920 N. Calculate the force on it if it is ascending up at the rate of $2m/s^2$. What will be the force on helicopter if it is moving up with a constant speed of 4 m/s? **(Ans: 4720 N, 3920 N)**
3. A 100 grams bullet s fired from a 10 kg gun with a speed of 100m/s. What is the speed of recoil of the gun? **(Ans: 10 m/s)**
4. A machine gun fires 10 bullets per second into a target. Each bullet weighs 20 gram and had a speed of 1500 m/s. Find the necessary force to hold the gun in position? **(Ans: 300 N)**
5. A 50 grams bullet is fired into a 10 kg block that is suspended by a long cord so that it can swing as a pendulum. If the block is displaced so that its center of gravity rises by 10cm, what was the speed of bullet? **(Ans: 281.4 m/s)**
6. A 70-gram ball collides with another ball of mass 140 gram. The initial velocity of the first ball is 9m/s to right while the second ball is at rest. If the collision were perfectly elastic, what would be the velocity of two balls after the collision? **(Ans: - 3m/s, 6 m/s)**
7. A truck weighing 2500 kg and moving with a velocity of 21m/s collides with a stationary car weighing 1000 kg. The truck and car move together after the impact. Calculate their common velocity? **(Ans: 15 m/s)**