Unit - 3

DYNAMICS

Dynamics is the study of cause of motion. In common force is cause of motion. Several other factors like mass of the object and frictional force also affect the motion of an object. These factors are also studied under dynamics. Newton's laws of motion has good deal with such factors, hence these laws govern the factors affecting the motion of body and help understanding the dynamics.

Students Learning Outcomes (SLOs)

After learning this unit students should be able to:

- Define momentum with SI unit.
- Calculate momentum using equation $p = mv$
- Define law of conservation of momentum.
- Use the principle of conservation of momentum in the case of collision of two objects.
- Solve problem using the equation Force = change in momentum / change in time.
- Identify the safety devices (such as packaging of fragile objects, the action of crumple zones and seatbelts) utilized to reduce the effects of changing momentum.
- State Newton's laws of motion.
- Distinguish between mass and weight
- Solve problem using $F = ma$, and $w = mg$
- Explain the forces acting on a body moving on a curved path.
- Calculate the centripetal force on a body moving along a circular path using mv^2/r .
- Define friction.
- Explain the effect of friction on the motion of a vehicle in the context of tyre surface, road conditions including skidding, braking force.
- Identify the relationship between load and friction by sliding a trolley carrying different load with the help of a spring balance on different surfaces.
- Demonstrate that rolling friction is much lesser than sliding friction.

What causes a body to change its speed? What causes the cricket ball to change its direction from wicket to boundary line? When you stop paddling your bicycle it does not stop at once. Why? After learning this unit you will be able to answer these and some other similar questions.

Do You Know!

- Force is required to change the position, state or shape of an object.
- Force can act as pull or push agent.
- Force produces acceleration.
- It can produce distortion.
- Force is a vector.

Force

Force is the agent that changes the state of rest or uniform motion of a body.

Its SI unit is Newton (N)

One Newton (1 N) is the amount of force that can produce 1 ms^{-2} acceleration in 1 kg mass.

An object (Fig 3.1)at rest needs a force to get moving; a moving object needs a force to come in rest or change its velocity or direction. The magnitude of a force can be measured using a spring balance.

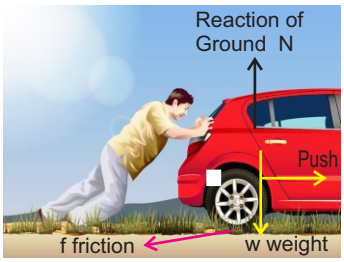


Fig 3.1
Force moves or tends to move a body from state of rest.

Activity

Take a cardboard box (Fig 3.2). Connect it to a spring balance through a string. Pull the string and note down the reading of the spring balance. How much force is required to make it moving? Put a few book on the box. Now pull the string until the box starts moving. Note down the reading on spring balance.

Again put many books on the box and pull it. Fill your observations in the table 3.1 below and discuss with your colleagues.

Fig. 3.2

Table 3.1

Case	Force required	Discussion
Empty box		
Few books on box		
Many books on box		

3.1 MOMENTUM

If a cricket ball(Fig3.3) and a car are moving with same speed, which one is easier to stop it with hands? Why it is not possible for a person to stop even a slow moving truck(Fig 3.4) by pulling from backside?

The momentum depends upon the quantity of mass and velocity of the object. Greater the mass greater will be momentum. Similarly faster the speed greater will be momentum.

In terms of an equation,

The momentum of an object is equal to the mass multiplied by the velocity of the object.

Momentum = mass x velocity

Symbolically, the momentum is represented by **p**. Thus, the above equation can be written as

$$\mathbf{p = mv} \quad \text{---------- (3.1)}$$

where m is the mass and v is the velocity. The momentum is vector quantity.

Fig. 3.3

Fig 3.4
A man trying to stop a truck by pulling it from back

SI Unit of Momentum

A mass unit is multiplied by a velocity unit to provide a momentum unit. This is consistent with the equation for momentum. The SI unit of momentum is describe below,

Momentum = mass × velocity

= $kgms^{-1}$

= $kgms^{-2} \times s$

or = Ns (Newton second)

Do You Know!

The pull of gravity on:
a fly = 0.001N
an apple = 1N
The frictional force slowing a rolling football =2N
The force required to squash an egg =50N
The tension in a rope towing a car = 1000N (1kN)
The fractional force exerted by the brakes of a car = 5000N (5kN)
The push from the engines of a space rocket =1000000N (1MN)

Do You Know!

Momentum is defined as quantity of motion contained in a body. Momentum is product of mass and velocity of a moving object. Hence it is mass times the velocity (**p = mv**).

Worked Example 1

A car of mass 800 kg is moving with velocity of 2 ms^{-1}. Its momentum can be calculated as;

Solution

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

m = 800 kg
v = 2ms^{-1}
p = ?

Step 2: Write the formula and rearrange if necessary.

p = mv

Step 3: Put the values in formula and calculate.

p = 800kg × 2ms^{-1}
p = 1600 $kgms^{-1}$

Thus, momentum of the car is 1600$kgms^{-1}$.

Worked Example 2

A 60kg object is moving at a velocity of 5 meters per second. What is its momentum?

Solution

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

Mass of object m = 60 kg
Velocity of object v = 5 ms^{-1}
Momentum p = ?

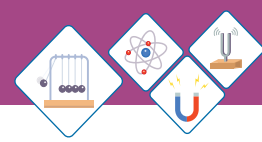
Step 2: Write the formula and rearrange if necessary.

p = mv

Step 3: Put the values in formula and calculate.

p = (60 kg) × 5ms^{-1}
p = 300 $kgms^{-1}$

Thus, the momentum of object is 300$kgms^{-1}$.



Momentum in terms of force:

We can also say that the change in momentum is equal to the force multiplied by the time interval for which it was applied. Consider a body of mass **m**, moving with initial velocity v_i. A force **F** acts on the body to produce acceleration **a**, therefore the final velocity after time **t** will become v_f. Note that if **p = mv** and **m** is constant, then the change in velocity changes the momentum of body.

$$p_i = mv_i$$

$$p_f = mv_f$$

and $p_f - p_i = (mv_f - mv_i)$ change in momentum

$p_f - p_i = m(v_f - v_i)$ divide both sides by t

$$\frac{p_f - p_i}{t} = m\,\frac{v_f - v_i}{t}$$

Since rate of change of velocity is acceleration

$$\frac{v_f - v_i}{t} = a \quad \text{Therefore} \quad \frac{p_f - p_i}{t} = ma$$

according to Newton's second law of motion F=ma
therefore,

$$\frac{p_f - p_i}{t} = F$$

$$\Delta \mathbf{p} = \mathbf{Ft} \quad \text{.....(3.2)}$$

Safety devices:

The equation (3.2) is important when it comes to consider a number of safety features in our lives. If you are moving, you have momentum. To stop moving, a force must be applied. According to the equation (3.2) if you take longer time to stop, smaller force will be used to slow down you.

Observe a car to identify the safety measures taken to reduce the risk of injuries in case of road accident. The car bumpers and grills are designed to provide extra time to reduce speed before any collision.

Fig 3.5 Styrofoam

You can find some crumple zones or bumpers on front and backside. Seat belts are provided to hold the passengers from moving suddenly. There are extra cushions and air bags as well. These measures provide extra time to change momentum of the passenger inside it. This means that force acting on the passenger is less to prevents from risk of fatal injuries.

Fragile objects, glassware and sensitive electronic components are packed in safety bags and Styrofoam(Fig 3.5) packing to reduce the effect of sudden shock.

The helmets protect from direct strike on head and provide extra time to reduce speed before something strikes to it.

Different safety helmets are used by workers, riders and sportsmen (Fig 3.6).

Worker Helmet

Motorbike Helmet

Sports Helmet

Fig 3.6 Different safety helmets

Worked Example 3

Find the force that can stop a body to rest in 4 seconds from its initial velocity of 16 ms^{-1}. The mass of body is 3kg.

Solution

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

$m = 3\,kg$

$v_f = 0\,ms^{-1}$

$v_i = 16\,ms^{-1}$

$t = 4\,second$

$F = ?$

Step 2: Write the formula and rearrange if necessary.

$p_i = mv_i$

$p_f = mv_f$

$F = \frac{p_f - p_i}{t}$

Step 3: Put the values in formula and calculate

Now $p_i = 3kg \times 16\,ms^{-1}$

$= 48\,Ns$

$p_f = 5kg \times 0ms^{-1}$

$= 0\,Ns$

Since $F = \frac{p_i - p_f}{t}$

$F = \frac{0Ns - 48Ns}{4s}$

$F = -12\,N$

Thus, 12 N force is required in opposite direction to stop the body.

Law of Conservation of Momentum:

The concept of momentum is important particularly in situations when two or more bodies are interacting with each other. It is very useful quantity when it comes to calculate what happens in collision or explosion. It is always conserved when the colliding bodies are in an **isolated system**. This means that when bodies collide no external forces act on the bodies.

Thus law of conservation of momentum states that

"The total momentum of an isolated system always remains constant"

For simplicity consider a system of two billiard balls of mass m_1 and m_2 moving in straight line with velocities u_1 and u_2 respectively where u_1 is greater than u_2 (Fig 3.7).

Total momentum of the system before collision = $m_1u_1+m_2u_2$

After collision the velocities become v_1 and v_2 respectively, therefore

Total momentum after collision = $m_1 v_1 + m_2 v_2$

According to law of conservation of momentum:

[Total momentum of the system before collision] = [Total momentum of the system after collision]

thus, $\mathbf{m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2}$ ------ (3.3)

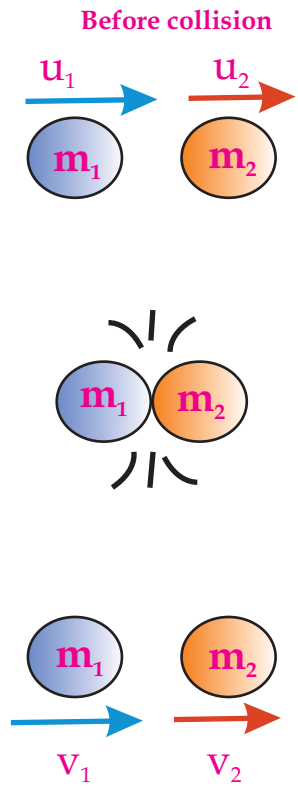


Fig 3.7

Worked Example 4

A gun of mass 8 kg fires a bullet of mass 40 gram with a velocity of 100 ms^{-1}. Calculate the recoil velocity of gun.

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

Mass of gun $m_1 = 8\,kg$

Mass of bullet $m_2 = 40\,gram = 40/1000 = 0.04\,kg$

Before collision

Velocity of bullet $u_2 = 0\,ms^{-1}$

Velocity of gun $u_1 = 0\,ms^{-1}$

After Collision

Velocity of bullet $v_2 = 100\,ms^{-1}$

Velocity of gun $v_1 = ?$

Step 2: Write the formula and rearrange if necessary.

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

or $$m_1 u_1 + m_2 u_2 - m_2 v_2 = m_1 v_1$$

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

Step 3: Put the values in formula and calculate

$$v_1 = \frac{(8kg \times 0ms^{-1} + 0.04kg \times 0ms^{-1}) - (0.04kg \times 100ms^{-1})}{8kg}$$

$$v_1 = -0.5\,ms^{-1}$$

The gun will recoil with velocity of 0.5 ms^{-1} Here -ve sign show the recoil in opposite direction.

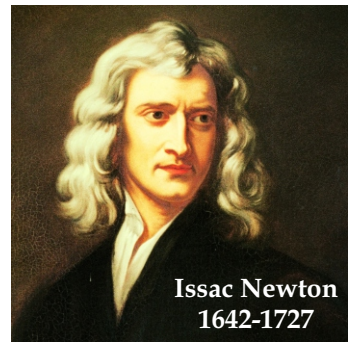
Fig 3.8 (a) A table in the state of rest

Self Assessment Questions:

Q1: Why momentum is considered equal to zero when a body comes to rest?

Q2: Why do you pull your hands while catching a fast moving ball?

3.2 NEWTON'S LAW OF MOTION


Issac Newton
1642-1727

First Law of Motion

You have often observed the table placed in your classroom . It always remains at the same place until you apply some force to move it. Like a book placed on the table remains at its place unless someone picks it back. Similarly, a satellite in the space continuously moves with constant speed because there is no air or force of friction in the space.

Contrary to above examples, a ball rolling on the ground however stops after some time because friction of ground and air resistance exert force on it and change its state of motion or direction of motion. We can define **Newton's first law of motion** as

A body continues its state of rest or of uniform motion in a straight line unless an external force acts on it.

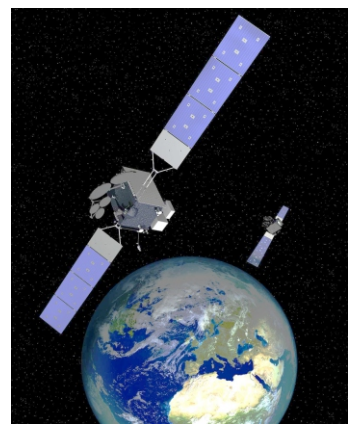


Fig 3.8 (b) A satellite in state of continuous motion around the earth.

The Newton's first law is also called law of inertia. You may have sometimes observed that you put your bag on the seat next to you. Whenever the bus stops suddenly, the bag slides forward off the seat. Why does it happen?

The bag was initially moving forward because it was on a moving bus. When the bus stopped, the bag continued moving forward, which was its initial state of motion, and therefore it slid forward off the seat.

Inertia:

Inertia is the property of an object due to which it tends to continue its state of rest or motion. Inertia is resistance to change the state.

When a bus starts moving the passengers feel a backward jerk, because their lower part of body moves

along the motion of bus but the upper part of the body tends to stay at its initial position of rest.

On the other hand when you stop paddling your bicycle it does not stop at once. The bicycle continues moving. However the road's friction and air resistance act against its motion and bring it to rest after some time.

Fig 3.9(a)

Fig 3.9(b)

Activity

Coin and card activity is very common to observe the property of inertia of a body.
You need a glass, a card and a coin.
Place the card on the glass.
Place the coin at center of card (Fig 3.9a)
Now flick the card with a jerk of finger
What did you observe?
The card moves away from the glass(Fig 3.9b).
Did the coin move away?
Why did the coin fell in the glass?
The coin tends to stay at rest.
The coin resisted to change in its state of rest.

Do You Know!

Newton's Laws of motion were published in Latin language in 1687. The first law of motion was written as "Lex I: Corpus omne perseverare in statu suo quiescendi vel movendi uniformiter in directum, nisi quatenus a viribus impressis cogitur statum illum mutare"

Self Assessment Questions:

Q3: What is reason that you experience a jerk whenever the school bus stops all of sudden?

Q4: Why it is dangerous to jump from a moving bus?

Second Law of Motion

Find few marbles of different size. Select one marble of very small size and another one larger about double the mass of first marble. Predict that by hitting with same force which marble will be accelerated more.

Now try hitting the marbles one by one with third marble with same force. You may observe that the smaller marble catches almost double the acceleration as compared to bigger marble. Can you explain this phenomena?

Newton's second law of motion describes the relation between force and acceleration. Newton's second law of motion states that;

"when a net force acts on a body it produces acceleration in the direction of force. The acceleration is directly proportional to force and inversely proportional to mass of body".

Therefore,

$$a \propto F$$

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

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

putting the proportionality constant k,

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

$$Fk = ma$$

taking value of constant k =1,

$$\mathbf{F = ma} \quad \text{.....3.4}$$

Worked Example 5

Find the force that can accelerate a body of 50 kg mass up to 5 ms^{-2}.

Solution

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

$m = 50\,kg$

$a = 5\,ms^{-2}$

$F = ?$

Weblinks

Teacher should encourage learners to visit following website to observe supportive information

- http://www.quia.com/jq/19675.html
- http://csep10.phys.utk.edu/astr161/lect/history/newton3laws.html
- http://www.istp.gsfc.nasa.gov/stargaze/Snewton.htm
- http://www.walter.fendt.de/ph11e/n2law.htm

Step 2: Write the formula and rearrange if necessary.

$$F = ma$$

Step 3: Put the values in formula and calculate

$$F = 50kg \times 5ms^{-2}$$

$$F = 250\ N$$

Thus the force is 250N.

Worked Example 6

Find the force that stops a car of 1000 kg mass from its velocity of 72 km/h over a distance of 40 meters.

Solution

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

$m = 1000\,kg$

$v_i = 72\,km/h = 72 \times 1000/3600 = 20\,ms^{-1}$

$v_f = 0ms^{-1}$ as the car comes to rest

$S = 40\,m$

$a = ?$

$F = ?$

Step 2: Write the formula and rearrange if necessary.

$$2aS = v_f^2 - v_i^2$$

$$a = \frac{v_f^2 - v_i^2}{2S}$$

and $F = ma$

Step 3: Put the values in formula and calculate

$$a = \frac{(0ms^{-1})^2 - (2ms^{-1})^2}{2 \times 40m}$$

$$a = -5\,ms^{-2}$$

Now

$$F = m\,a$$

$$F = 1000\,kg \times -5ms^{-2}$$

$$F = -5000\,N$$

Thus an opposing force of 5000N acts on the car.

Mass and Weight

Mass is the actual amount of material contained in a body and is measured in kg. Whereas weight is the force exerted by the gravity on that object (w= mg). Mass is independent of everything but weight is different on the earth, moon, and other places due to difference of gravitational pull.

Mass is the amount of matter present in a body while weight is a measure of how strongly gravity pulls on that matter. Mass is an intrinsic property of the body and remains the same wherever the body might be.

Weight is a force, (Force = mass x acceleration). The weight of an object is the mass times the acceleration due to gravity.

The weight of the body differs from place to place. For example, objects weigh lesser on the moon where gravity is lower as compared to that on the Earth.

Comparison Chart	Mass	Weight
Definition	Mass is the quantity of matter in a body regardless of its volume or of any forces acting on it.	Weight is a measurement of the gravitational force acting on an object.
Effect of gravity	Mass is always constant at any place.	The weight of an object depends on the gravity at that place.
Unit of Measurement	Mass is measured in kilogram (kg)	Weight is measured in Newton (N)

(a) Beam balance

(b) Spring balance

(c) Electronic balance

Fig 3.9

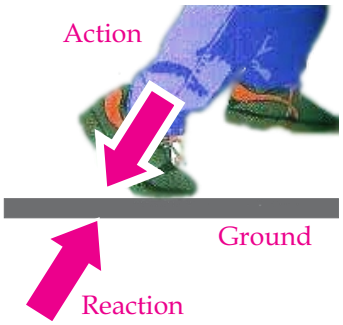


Fig 3.10 (a)

Balance used for measurement	Mass is measured using a pan balance, a triple-beam balance, lever balance or electronic balance.	Weight is measured using a spring balance.

Newton's Third Law of Motion

This law describes what happens when a body exerts a force on another body. Many times you through a ball towards wall and it bounces back. If it is thrown with greater force the ball is returned back with greater push. It is because the wall reacts against the action of ball.

While walking on ground you push the ground with feet the ground pushes you back thus you move (Fig. 3.10 a). As these forces always occur in pairs, so when one body pushes against another, the second body pushes back just as hard.

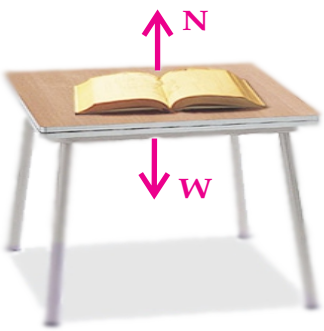


Fig 3.10 (b)

For example, when you put a book on table the book pushes the table downward, the table pushes back the book upward (Fig 3.10 b). Thus Newton's third law of motion can be defined as:

To every action, there is an equal and opposite reaction.

The action and reaction are forces that occur together as a pair. They are always equal in quantity but opposite in direction.

While standing on ground the gravity pulls you down against the ground, the ground pushes up against your feet.

When a rocket ignites its fuel behind it, the expanding exhaust gas pushes on the rocket causing it to accelerate (Fig 3.10 c).

Fig 3.10 (c)

SELF ASSESSMENT QUESTIONS:

Q5: What is role of force according to Newton's second law of motion?

Q6: What happens according to Newton's third law, while you pull a catapult?

Q7: Why mass does not differ, while weight differs from place to place?

3.3 UNIFORM CIRCULAR MOTION

Take a smaller bucket, tie a piece of string to its handle. Hold the other end of string and rotate the bucket in vertical circle (Fig 3.11). You may feel some pull on your arm. Now put few coins in the bucket, again rotate it. It is amazing the coins do not fall even the bucket goes bottom up. More interesting will be the experimenting with some water. Pour about a cup of water in the bucket. Now try rotating the bucket around and up. How interesting it is? The water stuck to the bottom of bucket. The force that keeps it stuck is known as centrifugal force and the force you apply against the pull on your arm is known as centripetal force.

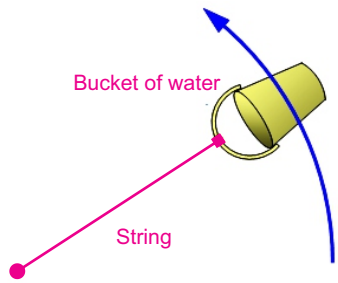


Fig 3.11

Centripetal Force

The force required to move a body along a circular path is called Centripetal force.

It is denoted by F_c. The centripetal force is always directed towards center of the circular path. It depends on three factors: (i) the velocity of the object v (ii) the object's distance from the center "r" and (iii) the mass of the object "m". It is given by relation

$$F_c = \frac{mv^2}{r} \quad \text{..... (3.5)}$$

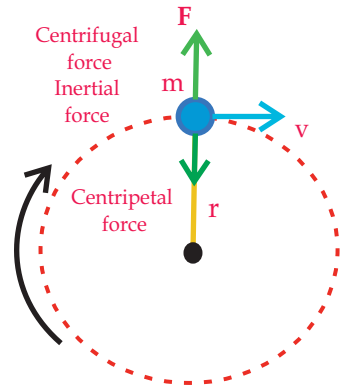


Fig3.12
Centripetal and centrifugal forces acting on an object.

Where m = mass of body moving in circle.
v = velocity of body.
r = radius of circle

The velocity of the object is constant and perpendicular to a line running from the object to the center of the circle.

Worked Example 7

A cyclist is making a turn along a circle of radius 20 m, at a speed of 5 m/s. If the combined mass of the cyclist plus the cycle is 60 kg, calculate the static friction that road exerts on the tyres?

Solution

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

$r = 20\,m$
$v = 5\,ms^{-1}$
$m = 60\,kg$
$F = ?$

Step 2: Write the formula and rearrange if necessary.

$$F_c = \frac{mv^2}{r}$$

Step 3: Put the values in formula and calculate

$F_c = 60\,(5 \times 5)/\,20$
$= 60 \times 25/20$
$= 75\,N$

Thus road must exert a force of 75N on tyres.

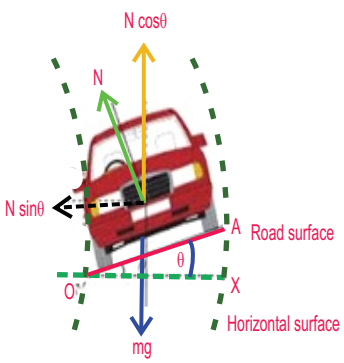


Fig 3.13

Centrifugal Force

Centrifugal force is the tendency of an object to leave the circular path and fly off in a straight line. Thus it is defined as:

A force that acts outward on a body which moves along a curved path is called centrifugal force.

- It is always directed away from center of curvature.
- The magnitude of centrifugal force is equal but opposite in direction to centripetal force.

Application of Centrifuge

Centrifuge appliances are used to separate heavier particles from lighter particles in liquids e.g. Sugar crystals are separated from molasses. Blood analysis is carried out through a centrifuge process in laboratory. Cream separator is used to separate the cream from skimmed milk. An ultracentrifuge is used for separating small particle from large molecules. Gas centrifuge is used for separation of isotopes.

Road Banking

The outer edge or bank of the road is raised to a certain height at the curved part of roads. This provides the centripetal force against the tyres of vehicle hence prevents from skidding (Fig 3.13).

Cream Separator

The milk plants in country are using high speed spinners to separate cream from milk. The skimmed milk is heavier whereas the cream is lighter. When the milk is spun at high speed the heavy particles are pushed towards the walls of the spinner. These particles push the lighter particles of cream to the center where from it is collected through a tube (Fig 3.14).

Fig 3.14
Cream separator

Dryer

Now a days built-in dryer is available in most of washing machines. It spins the wet clothes hence the

Fig 3.15, Dryer

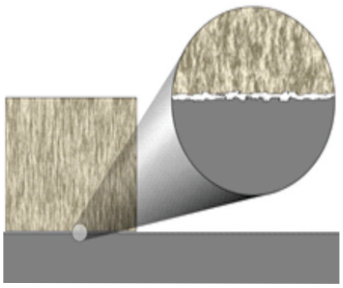


Fig. 3.16 Projection of Roughness of surfaces.A wooden block and cemented floor

Table 3.2
Value of coefficient of friction for different surfaces.

Tyre and Road	1.0
Iron and Iron	1.0
Glass and Glass	0.9
Wood and Cemented floor	0.6
Wood and Marble	0.4
Wood and Leather	0.4
Wood and Wood	0.3
Metal and Metal	0.3

water droplets are thrown away from the perforated walls of the dryer and clothes get dry instantly Fig 3.15.

Self Assessment Questions:

Q8: Why do we feel pushed outward while a car turns on a curved road?

Q9: Which force prevents a passenger from falling down a roller coaster while it turns the riders into upside-down position?

3.4 FRICTION

When you through a ball why does it come to rest?When we kick a ball and a box with same force why the ball covers more distance? Well! in previous grades you came to know that friction helps us walk easily, it prevents from sliding but sometimes it has disadvantages as well.

Friction is a contact force caused by the roughness or deformation of the materials in contact. The frictional force between a wooden block and cemented floor caused by the roughness of both the surfaces is projected in Fig. 3.16. Frictional forces are always parallel to the plane of contact between two surfaces and opposite to the direction of the applied force.

The force that resists relative motion between two surfaces is called friction.

Friction is self adjusting. It can increase to a certain value known as limiting force (F_s). It is proportional to normal force R.

$$F_s \propto R$$

The ratio between limiting force and normal reaction R is constant that is represented by coefficient of friction μ

Thus, $$\mathbf{F_s = \mu R} \text{ ..... } (3.6)$$

or $$\mu = \frac{F_s}{R}$$

when a body is placed on a surface its weight w acts downward then according to Newton's third law of motion R = W, here w = mg by putting the value R = mg in eq. (3.6) we get

$$F_s = \mu mg \quad \text{..... (3.7)}$$

The coefficient of friction has different values for different surfaces as shown in the table 3.2.

Activity

Let us experience difference of friction on different surfaces.

You need a wooden block, a spring balance, connecting strings and few weight slots (Fig 3.17).

Put a 1 kg slot on the block.

Pull it across the wooden table, note down the reading from spring balance.

Now put 3 kg weight on the block, again pull it and note the reading. Similarly put the 5 kg weight on block and note down the reading in the observation table.

Now repeat the experiment with different surfaces.

Note down the reading for glass surface, cemented floor and carpeted floor. Now put few piece of pipes under the wooden block and repeat the activity. Observe how rolling friction is lesser than sliding friction.

Fill the table3.3 below with observations then discuss the difference of force of friction in each case.

Also discuss the use of ball bearings in vehicles.

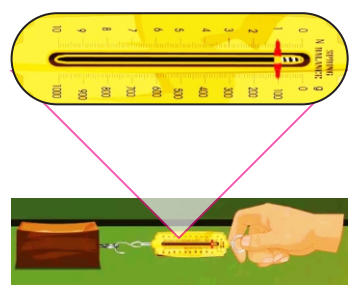


Fig 3.17

Table 3.3

Surface	Reading for Load on Wooden Block		
	1kg	3kg	5kg
Cemented floor			
Carpeted floor			
Glass surface			
Wooden Table			
Rolling on pieces of pipes			

Types of Friction

Static friction

It is force acting on an object at rest that resists its ability to start moving. The maximum static friction is known as "limiting friction"

Kinetic friction

It is the force that resists the motion of a moving object. It is interesting to know that in almost all situations, static friction is greater than kinetic friction.

Sliding friction

When one body slides over the other body the friction between two surfaces is said to be sliding friction.

Rolling friction

When a body moves on wheels the friction is said to be rolling friction. Rolling friction is much lesser than the sliding friction.

Weblinks

Supportive information
Web link about friction

http://www.phy.ntnu.edu.tw/java/frictio/friction.html

Do You Know!

Safety ramps are constructed along roadside where failure of brakes is feared due to sharp inclination of road.

In case of rolling friction the contact area between two surfaces is lesser than the contact area in case of sliding bodies. Therefore ball bearings are used in vehicles that they reduce the contact area as compared to the contact area of axel and bush. A pedestal fan with ball bearing saves a lot of electricity therefore the customers always select a fan with ball bearing rather than one with bush and axel.

Advantages of Friction

Friction enables us to walk on ground. Friction protects from sliding, as sand is thrown to maintain friction on inclined railway tracks during rain. The car brakes slow down the car to stop safely. Threads and grooves are designed on tyres to increase the friction and improve grip between road and wheel (Fig 3.18 a). Now vehicles are equipped with Anti-lock Braking System (ABS). ABS is designed to maintain steering stability, improve vehicle control, avoid skidding and decreases stopping distances on dry and slippery surfaces. The ABS maintains the static friction as the wheel starts slipping it releases the brake automatically for a fraction of a second then holds wheel again to create static friction between road and tyres (Fig 3.18 b).

Fig. 3.18 (a) Tyre Grooves improve grip on road

Disadvantages of Friction

A large amount of energy is wasted in the machines due to friction.

Friction leads to wear and tear of parts hence increases the service cost.

Failure of oil pump in car engine results contact between dry metals which yields high temperature hence the car engine is seized.

Fig 3.18 (b) You might have noticed a logo on some cars

Fig 3.18 (c) Ball Bearings reduce friction

Fig 3.18 (d) Lubricating the bicycle chain

Ways to reduce Friction

Wheels, pullies, ball bearings, lubricants and graphite are used to overcome the friction; Fig 3.18 (c). Lubricating the motor axel, sewing machine and bicycle chain reduces friction and prevents wear and tear; Fig 3.18 (d). The shape of vehicle is also designed to reduce air resistance.

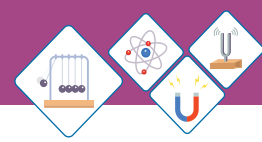
Self Assessment Questions:

Q10: Why it is easier to walk wearing flat slippers than the high heel sandals?

Q11: Why leather sheet is used in brake drums of motor bike?

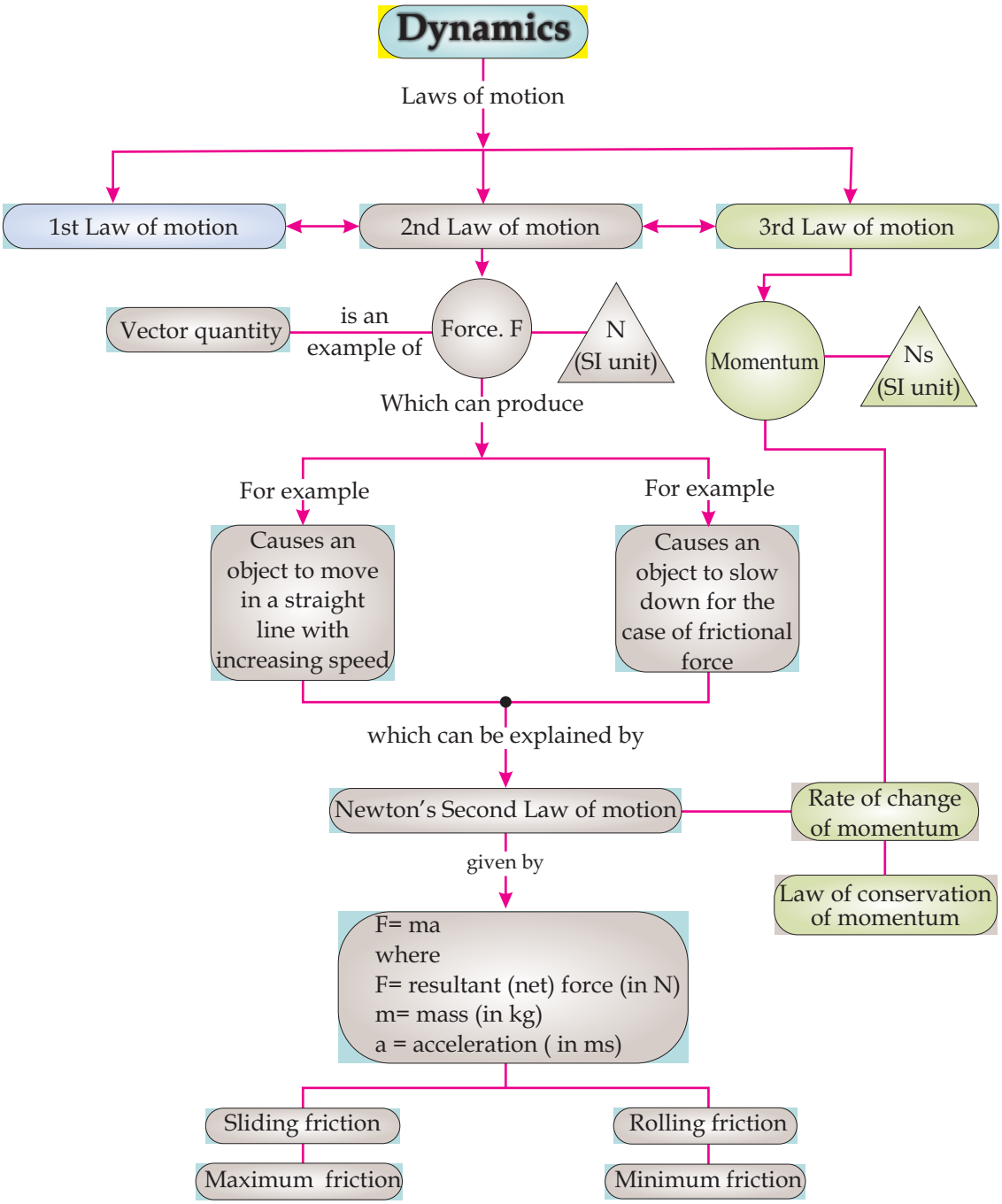
SUMMARY

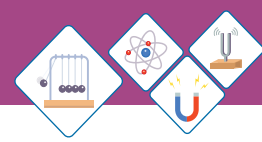
- Dynamics is the study of cause of motion. In common force, mass of the object and frictional forces affect the motion of an object.
- Force is the agent that changes the state of rest or motion of a body. It can accelerate a body.
- Momentum is defined as quantity of motion contained in a body. Momentum is product of mass and velocity of a moving object.
- Newton's first law of motion explains that the objects resist to change their state of rest or motion. It is also called law of Inertia.
- Inertia is the property of an object due to which it maintains its state of rest or motion.
- Newton's second law of motion states that a net force produces acceleration in the direction of force (F= ma).



- Newton's third law of motion states that for every action, there is an equal and opposite reaction.
- Centripetal force is required to move a body along a circular path.
- Centrifugal force is tendency of an object to move away from circular path. It is always opposite and equal to centrifugal force.
- Centrifuge equipments are helpful in many laboratory as well as daily life processes.
- The force that resists relative motion between two surfaces is called friction.
- Maximum static friction is called limiting friction. The static friction is always greater than kinetic friction.
- The Rolling friction is much lesser than the sliding friction due to smaller contact area.
- Safety devices are designed to decrease momentum of a body and provide extended time to remain safer.

CONCEPT MAP


Dynamics
Laws of motion
1st Law of motion
2nd Law of motion
3rd Law of motion
Vector quantity
is an example of
Force. F
N (SI unit)
Momentum
Ns (SI unit)
Which can produce
For example
For example
Causes an object to move in a straight line with increasing speed
Causes an object to slow down for the case of frictional force
which can be explained by
Newton's Second Law of motion
Rate of change of momentum
given by
Law of conservation of momentum
F= ma
where
F= resultant (net) force (in N)
m= mass (in kg)
a = acceleration (in ms)
Sliding friction
Rolling friction
Maximum friction
Minimum friction



End of Unit Questions

Section (A) Multiple Choice Questions (MCQs)

1. Newton's First law of motion is also known as law of
   a) speed b) rest
   c) inertia d) force
2. Quantity of matter contained in body is called_____.
   a) mass b) volume
   c) area d) weight
3. Quantity of motion contained in a body is called
   a) force b) inertia
   c) momentum d) gravity
4. Law of conservation of momentum defines that the total momentum of a system of two bodies before and after collision_____.
   a) remains constant
   b) retains more momentum
   c) losses some momentum
   d) None of above is true
5. Weight of a body can be measured using a spring balance, it differs from place to place because of variation in _____.
   a) acceleration b) gravitational pull
   c) velocity d) size of spring balance
6. It is easier to push an empty shopping cart than a full one, because the filled cart has more mass than the empty one. This can be expressed by
   a) $F > m$ b) $F < m$
   c) $F \alpha 1/m$ d) $F \propto m$

7. Centrifugal force is always directed
   a) towards centre
   b) away from centre
   c) along the circular path
   d) all sides

8. Friction opposes motion between two bodies in contact because of
   a) charges on bodies
   b) weight of bodies
   c) roughness of surfaces
   d) None of above

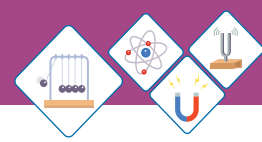
9. Which statement is true for limiting frictional force.
   a) it is greater than rolling friction
   b) it is greater that sliding friction
   c) it is greater that kinetic friction
   d) all are true

10. A man pulls a crate of mass 25 kg across leveled ground with a horizontal force of 60 N.A constant force of friction of 20 N acts on the sledge. What is the acceleration of the sledge?
   a) $0.63\ ms^{-2}$ b) $1.6\ ms^{-2}$
   c) $2.4\ ms^{-2}$ d) $3.2\ ms^{-2}$

Section (B) Structured Questions

Momentum

1. a) Define momentum with SI unit?
   b) Find the moment of body of mass 6 kg moving with a velocity of $25\ ms^{-1}$.
   c) What will be the velocity if the momentum becomes 200Ns?



2. a) When a free falling object moves towards earth due to pull of earth on it. Does earth also move towards that object due to reaction? Explain.
   b) A body of mass 10 kg is moving with velocity of 10 ms^{-1}. A force acts for 5 seconds to reduce its velocity to 2 ms^{-1} . Find the momentum of body before and after application of the force on it.
3. a) Why a wire fence is designed in the helmet of batsman?
   b) How does it prevent from injuries?

Laws of motion

4. a) State the Newton's first law of motion. Give some common examples?
   b) Enlist some common observations that are caused by the property of inertia?
5. a) Define Newton's second law of motion.
   b) A force of 3400 N is applied on a body of mass is 850 kg, find the acceleration produced by the force?
   c) How much force should be applied on a body of mass 425kg to produce acceleration same as calculated in part b.
6. a) Show the relationship between applied force and the acceleration produced in the body?
   b) Find the mass of a body which is accelerated by applying a force of 200 N, that speeds up it to 36 ms^{-1}.
   c) What should be the acceleration of the same body if the applied force changes to 280N.
7. An empty car has 1200 kg mass. Its engine can produce acceleration of 4 ms^{-2}. If 300 kg load is added to mass by passengers and luggage. What acceleration the same engine will produce?

8. a) Enumerate at least three clear differences between mass and weight?
   b) The mass of an object is 60 kg, find its weight on (i) Earth (ii) Moon (iii) Mars assume the acceleration due to gravity on Earth = 9.8 ms^{-2} on Moon=1.6 ms^{-2} and on Mars= 3.7 ms^{-2}

Circular motion

9. a) Define the forces acting on an object in circular motion?
   b) Draw a figure showing the direction of centripetal force, centrifugal force and velocity of an object along a circular path.
   c) A car is running on a circular part of highway having about 1000m radius. The mass of car is 600kg and its velocity is 72 kmh. Find
      (i) Centripetal force exerted by the car.
      (ii) Centripetal acceleration of car.
   d) List down some purposeful uses of centrifuge that human are benefitting everyday.

Friction

10. a) What is force of friction? Explain with two examples from daily life.
    b) A block is placed on a wet slippery floor. The mass of block is 15 kg. When it is pulled through a string and spring balance, it shows force equal to 3 N. Find the coefficient of friction. ($Fs = \mu mg$)
11. a) How anti-lock braking system prevents the risk of sliding?
    b) Enlist any four uses of rolling friction in everyday life?

12. Explore the following phenomenon in relation with dynamics
    a) When an air filled balloon is released.
    b) Riding a bicycle needs continuous paddling.
    d) The biker ridding in the death well.
    e) You always feel a pullback whenever you pull on your school bag or some heavier object.