Inertia means resistance to change

CHAPTER - 4

LAWS OF MOTION

FORCE :

It may be defined as an agency which changes or tends to change the state of rest or of uniform motion, or direction of ~~a body~~ motion

EFFECTS PRODUCED BY A FORCE :

1. Force can change speed of an object
2. Force can change the direction of an object
3. Force can change shape of an object

INERTIA :

The inherent property of a body by virtue of it cannot change by itself its state of rest or of uniform motion in a straight line is called Interia

TYPES OF INERTIA :

1. Inertia of Rest
2. Inertia of Motion
3. Inertia of direction

INERTIA OF REST :

The tendency of a body to remain in its position of rest is called Inertia of Rest

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Eg: A person standing in a bus falls backward when the bus suddenly starts. when the bus ~~st~~ moves, the lower part of the body begins to move along the bus while the upper part of the body ~~cont~~ remain at rest due to interia of rest that's why person falls backward when the bus starts

Inertia of Motion:
The tendency of a body to remain in its state of uniform motion in a straight line is called Inertia of Motion
E.g. When a moving bus suddenly stops a person sitting in it falls forward
As the bus stops, the lower part of its body comes to rest along with the bus. while the upper part of the body remains in motion due Inertia of motion, falls forward

Inertia of Direction:
The inability of a body to change by itself its direction of motion, is called inertia of direction
E.g. When a bus takes a sharp turn a person sitting in a bus experiences ~~the~~ ~~to~~ force acting away from the centre of the curve path due to his tendency to move in original direction. He has to hold on a support to prevent himself from swaying away in turning bus

Weight is a Vector quantity

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NOTE: Mass is the measure of Inertia

MOMENTUM : (P) = mass x velocity
It is equal to the product of mass and velocity of the body

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

Unit of $\vec{P}$ = $Kg\ ms^{-1}$
It is a vector quantity
Momentum = $[MLT^{-1}]$

NEWTON'S LAW OF MOTION

1st law of Motion :
Everybody continous in its state of rest or of uniform motion in a straight line unless it is compelled by some external force to ~~state~~ change that state

2nd law of Motion :
The rate of change of linear momentum of a body is directly proportion to the applied force and the change takes place in the direction of applied force

3rd law of Motion :
To every action, there is always an equal & opp. direction

NOTE: Newton's 1st law define force

MEASUREMENT OF FORCE FROM NEWTON'S 2nd law OF MOTION

If a body of mass (m) is moving with velocity (V) then its linear momentum is

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

Differentiating b/s w.r.t time

$$\frac{dp}{dt} = \frac{d(mV)}{dt}$$

$$\frac{dp}{dt} = m\frac{dv}{dt}$$

$$\frac{dp}{dt} = ma$$

Acc^n to Newton's 2nd law

$$F \propto \frac{dp}{dt}$$

$$F \propto ma$$

$$F = Kma$$

If $K = 1$

$$\boxed{F = ma}$$

IMPULSIVE FORCE :-

A large force acting for a short time to produce a finite change in momentum is called impulsive force

E.g.

Force exerted by a bat while hitting a ball

IMPULSE OF A FORCE :-

Impulse is defined as the product of force and time for which it acts. And is equal to total change in momentum

Impulse = Force × time = Total change in momentum

DERIVATION :-

Suppose a force $(\vec{F})$ acts for a small time (dt) then impulse is

$$d\vec{J} = \vec{F}dt$$

If we consider a finite interval of time from t_1 to t_2

$$d\vec{J} = \vec{F}dt$$

$$\int d\vec{J} = \int_{t_1}^{t_2} \vec{F}dt$$

If $\vec{F}_{av}$ is the average force

$$\vec{J} = \vec{F}_{av} (t)_{t_1}^{t_2}$$

$$\vec{J} = \vec{F}_{av} (t_2 - t_1)$$

$$\boxed{\vec{J} = \vec{F}_{av} \, \Delta t}$$

Impulse-Momentum Theorem

According to Newton's 2nd law of Motion

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

$$Fdt = dp$$

Integrating b/s within proper limits

$$\int_{0}^{t} F dt = \int_{p_1}^{p_2} dp$$

$$J = [p]_{p_1}^{p_2}$$

$$J = p_2 - p_1$$

Impulse = Change in Momentum

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FOR NUMERICALS

Area under force - time graph gives impulse

[Application of Impulse]

Impulse = $F \times t$ = Change in momentum

For two different forces producing the same impulse

$$J = F_1 t_1 = F_2$$

Applications of the Concept of Impulse

(i) A cricket player lower his hands while catching a ball ; When the ball is caught, the impulse recieved by the hands is equal to the product of the force exerted by the ball & the time taken to complete the catch. By moving the hands backwards, the cricketer increases the time of catch. The force exerted on his hands becomes much smaller and it does not hurt him.

(ii) A person falling from a certain height receives more injuries when he falls on a cemented ~~fall~~ floor than when he falls on a heap of Sand : In both cases, the impulse or the total change in momentum is same. On, the cemented floor, the person is stopped abruptly. So the cemented floor exerts a large force of reaction causing him severe injuries. When the person falls on a heap of sand the sand yields under his weight. The person takes longer time to stop

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(iii) Automobiles (car, buses etc) are provided with shocker: When a vehicle moves on an uneven road, it receives a jerk. The shocker increases the time of Jerk & hence reduces the force. This makes journey comfortable and saves the automobile from damage due to dumps

iv) Buffers are provided b/w the bogies of a train: Buffers increase the time of Jerk during Shunting. This decreases the force of impact b/w the bogies. The bogies are thus prevented from receiving severe jerks

v) ~~Cha~~ Chinawares are packed in Straw paper before packing: The straw paper b/w the chinawares increases the time of experiences the jerks during transportation there they strike against eachother with a lesser force and are less likely to be damaged

Newton's 3rd Law of Motion

To every action there is always equal and opposite reaction.

If $\vec{F}_{BA}$ is the force exerted by a body A on B and $\vec{F}_{AB}$ force exerted by a body B on A

According to Newton's 3rd law:

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

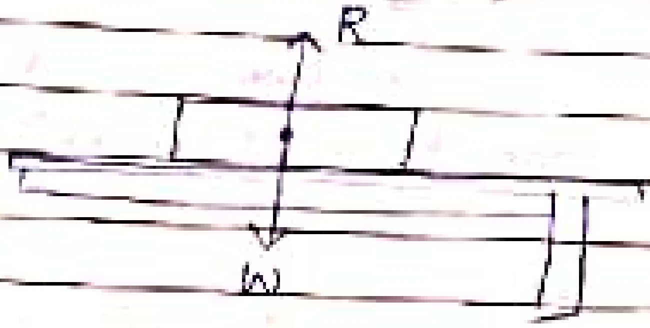
Some Important points about Newtons Third law of Motion

1. Action & Reaction always act on different bodies
2. It is applicable irrespective of the nature of the forces
3. No action can occur in absence of Reaction
4. forces of action & reaction cannot cancel eachother this is because action & reaction though equal & opp. always act on diff. bodies so cannot balance eachother

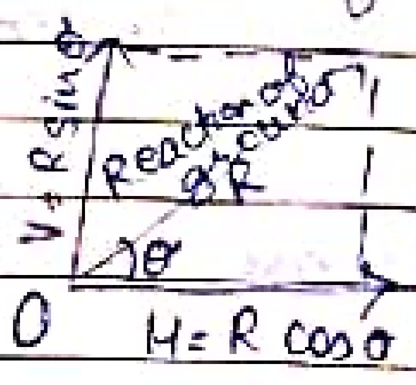
(1.) Book kept on a table: Consider a book of weight W resting on a table top. The book exerts a downward force (action) on the table equal to its own weight W. According to Newton's third law, the table also exert an equal and upward force R (reaction) on the book such that

$$\vec{R} = -\vec{W}$$

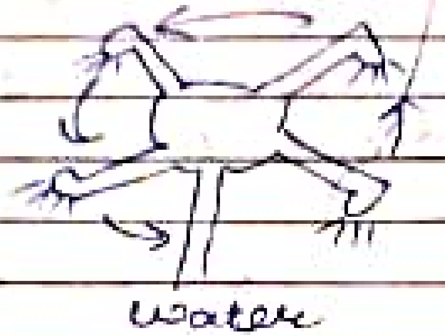
As the book is under the action of two equal and opposite forces, it remains in equilibrium.



(2) While walking we press the ground (action) with our feet slightly slanted in the backward direction. The ground exerts an equal and opp force on us. The vertical component of the force of reaction balances our weight and the horizontal component enables us to move forward, as shown



(3.) <u>Rotatory lawn sprinkler</u>: The action of a rotatory lawn sprinkler is based on third law of motion. As water issues out of the Nozzle, it exerts an equal and opp. force in the backward direction, causing the sprinkler to rotate in the opp. direction. Thus water is scattered in all direction



Pg 5.16 from Book (other Ex.)

Law of Conservation of Linear Momentum

It states that when No external force acts on a system of several interacting particles, the total linear momentum of the system is conserved

Derivation of Law of Conservation of Linear Momentum from Newtons 2nd law of Motion

Consider an isolated system of 'n' particles. Suppose the 'n' particles have masses M_1, M_2, M_3 .... M_n and velocity V_1, V_2, ... V_n resp.

Then The total time linear momentum

$$\vec{P} = \vec{P_1} + \vec{P_2} + \vec{P_3} \ldots \vec{P_n}$$

$$P = m_1v_1 + m_2v_2 + m_3v_3 \ldots \ldots + m_nv_n$$

If F is the external force acting on the system then. According to Newton's 2nd law of Motion

$$\vec{F} = \frac{d\vec{p}}{dt}$$

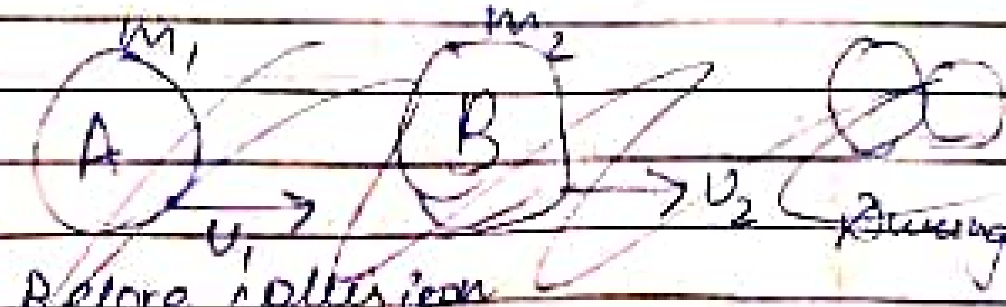
$$0 = \frac{d\vec{p}}{dt}$$

$$p = \text{constant}$$

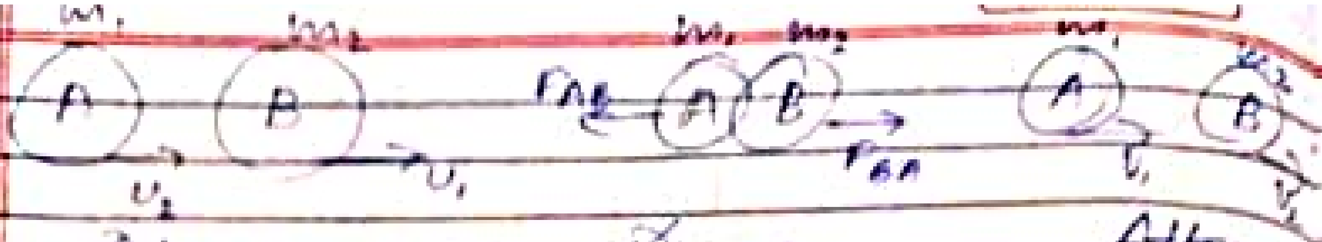
$$\vec{P_1} + \vec{P_2} + \ldots\ldots + \vec{P_n} = \text{constant}$$

Derivation of Law of Conservation of Linear momentum from Newtons 3rd Law

Consider two bodies A and B of masses 'm_1' and 'm_2' moving in the same direction along a straight line with velocities u_1 and u_2 resp ($u_1 > u_2$)
They collide for time Δt
& let velocity = v_1 & v_2



Before collision



Before collision
collision

During
collision

After
collis.

According to Newton's 3^{rd} law :

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

where F_{BA} ~~is the force~~ Body 'A' exert force on body B

~~Impulse of F_{BA}~~

Impulse of $\vec{F}_{AB}$ = $\vec{F}_{AB} \times \Delta t$ = Change in momentum of A
$= m_1 v_1 - m_1 u_1$

Impulse of $\vec{F}_{BA}$ = $\vec{F}_{BA} \Delta t$ = Change in momentum of B
$= m_2 v_2 - m_2 u_2$

Now,

$$F_{AB} \Delta t = -F_{BA} \Delta t$$

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

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

$$\boxed{m_1 v_1 + m_2 V_2 = m_1 u_1 + m_2 u_2}$$

Total linear momentum after collision = Total L.M before collision

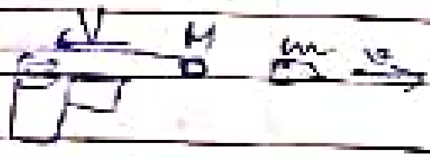
Examples :

(1) Recalling of a gun; Let 'M' be the mass of the mass of the gun and 'm' be the mass of the bullet. Before firing, both the gun & bullet are at rest. After firing, both the gun & the bullet are at rest. After firing, the bullet moves with velocity $\vec{v}$ and the gun moves with velocity $\vec{V}$. As no external force acts on the system, so according to the principle of conservation of momentum, total momentum before firing

= Total momentum after firing

$$0 = m\vec{v} + M\vec{V}$$

$$M\vec{V} = -m\vec{v}$$



$$\vec{V} = -\frac{m}{M}\vec{v}$$

The negative sign shows that $\vec{V}$ & $\vec{v}$ are in opp. direction i.e the gun gives a kick in the backward direction or the gun recoils velo. ~~or gun~~ with velo $\vec{V}$. Further as $M >> m$ so $V << v$ i.e the recoil velo. of the gun is much smaller than the forward velo. of the bullet.

(ii) While firing a Bullet, the gun should be held tight to the shoulder ? The recoiling gun can hurt the shoulder. If the gun is held tightly against the shoulder, then the body and the gun together will constitute one system. Total mass become large and recoil the velo. becomes small

(iii) When a man jumps out of a boat of to the shore, the boat slightly moves away from the shore. ? Initially the total momentum of the boat & the man is zero. As the man jumps from the boat to the shore, he gains a momentum in forward dir. To conserve mom., the boat also gains an equal momentum in the opp. direction. So the boat slightly moves back

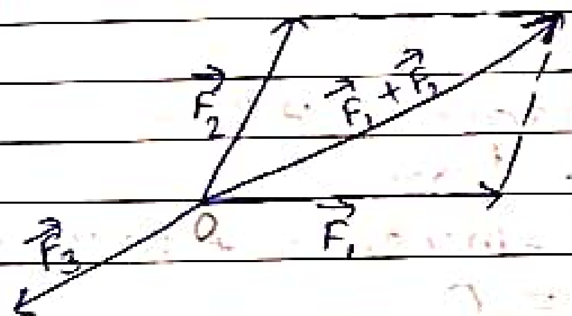
(iv) An astronaut in open space, who wants to return in the spaceship throws some object in a direction opp. to the direction of motion of the spaceship. By doing so, he gains a momentum equal & opp. to that of the thrown object & so he ~~mov~~ moves toward the spaceship

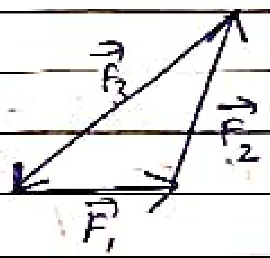
Equilibrium of Concurrent Forces

Force acting at the same point on a body are called concurrent forces. When a number of forces act on a body at a same time point and the net unbalance force is zero, the body will continue in its state of rest or of uniform motion along a straight line and are said to be Equilibrium

Expression

Consider three concurrent forces $\vec{F_1}$, $\vec{F_2}$, $\vec{F_3}$ acting at a same point at O as shown in fig





Resultant of $\vec{F_1}$ and $\vec{F_2} = \vec{F_1} + \vec{F_2}$

If the third force $\vec{F_3}$ acts on the body such that $\vec{F_3} = -(\vec{F_1} + \vec{F_2})$

then, the body will be in Equilibrium

$$\vec{F_3} = -(\vec{F_1} + \vec{F_2})$$

$$\vec{F_1} + \vec{F_2} + \vec{F_3} = 0$$

For, no. of forces acting at same point then

$$\vec{F_1} + \vec{F_2} + \dots + \vec{F_n} = 0$$

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2^{nd} Law is the Real law of motion

because we can derive 1^{st} & 3^{rd} law from 2^{nd} law of motion

1^{st} law is contained in 2^{nd} law :

According to Newtons 2^{nd} law of Motion

$$F = ma$$

In the absence of Force

$$F = 0$$

$$ma = 0$$

$$m \neq 0 \qquad a = 0$$

$$\frac{v-u}{t} = 0$$

$$v - u = 0$$

$$\boxed{v = u}$$

3^{rd} law is contained in 2^{nd} law :

Consider an isolated system of 2 bodies A & B. Suppose two bodies interect mutually with one another. According to Newton 2^{nd} law of motion

Force exerted by A on B

$$\vec{F}_{BA} = \frac{d\vec{P}_B}{dt}$$

Force exerted by B on A

$$\vec{F}_{AB} = \frac{d\vec{P}_A}{dt}$$

$$\vec{F}_{BA} + \vec{F}_{AB} = \frac{d}{dt}\left(\vec{P}_B + \vec{P}_A\right)$$

In the absence of any external force

$$\frac{d}{dt}\left(\vec{P}_B + \vec{P}_A\right) = 0$$

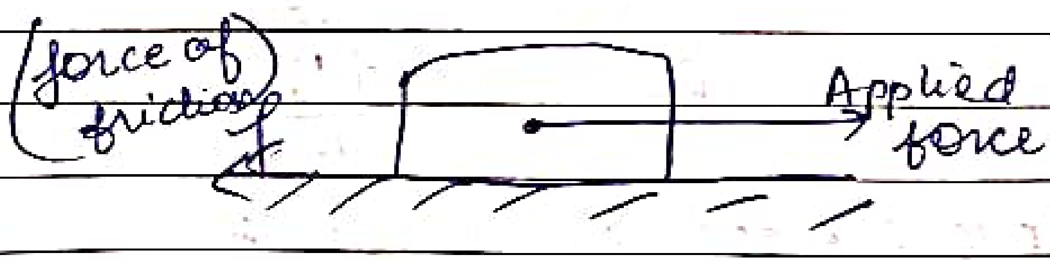
$$\vec{F}_{BA} + \vec{F}_{AB} = 0$$

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

Action = − Reaction

Friction:

When a body moves or tends to move over a surface of another body a force comes into plane which acts parallel to the surface of contact and opposes the relative motion this opposing force is called friction



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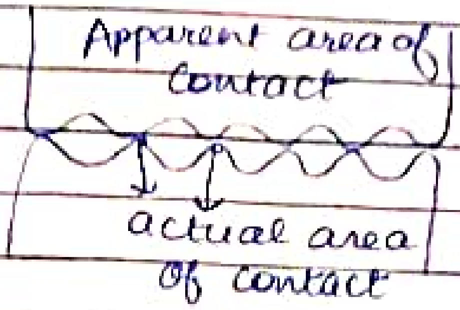
Cause of Friction :-



The force of friction is due to the atomic or molecular force of ~~fraction~~ attraction b/w the two ~~for~~ surfaces at the pt. of actual contact Due to the Surface irregularties. The actual area of contact is much smaller than the apperent area of contact. The pressure at the point of contact is very large. Molecular bonds are ~~forced~~ formed at these point. Force sliding one body over the surface of other there bond has to be broken. The force required to break such bond is called force of friction

STATIC FRICTION, LIMITING Friction, Kinetic fricti..

Consider a wooden Block placed over a horizontal table, the block is attached to a string which passes over a frictionless pulley and carries a scale pan at the free end. If we place a small weight in scale pan, a horizontal force act on the block and the block does not move. The force of friction comes into plane which balances the applied force

➢ "The force of friction which comes into plane b/w two bodies for one body actually start moving over the other is called static friction" (f_s)

As the applied force ~~as the applied force~~ on the block is increased the ~~applied~~ static friction also increases to balance the applied force and the block does not move. Once the applied force is increased beyond a certain limit, the block just begins to move. At this stage the static friction is maximum

➢ The maximum ~~force~~ of static friction which comes into plane when a body just start moving over the surface of another body is called limiting friction (f_s^{max})

Once the motion has begin the force of friction decreases the smaller force is now necessary to maintain uniform motion

» The force of friction which comes into play when a body is in the state of steady motion over the surface of another body is called Kinetic or dynamic ~~motion~~ friction (f_K)

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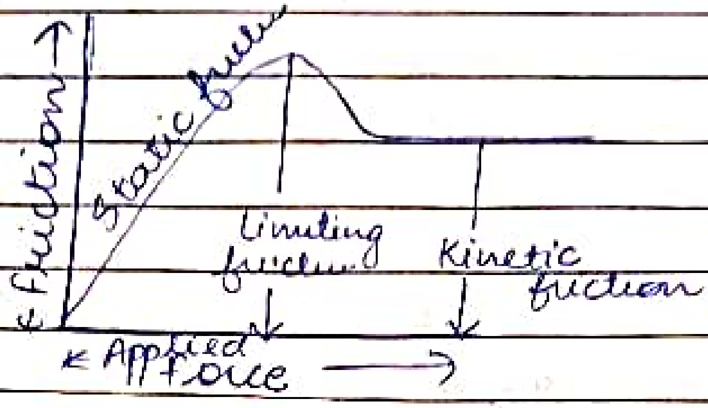


Acc^n to Graph as the applied force increases the static friction increases accordingly to balance it. This shows that static friction is a self adjusting force

$$f_K < f_s^{max.}$$

Laws of Limiting friction

(1.) The limiting friction depends on the nature of the surfaces in contact and their state of polish.

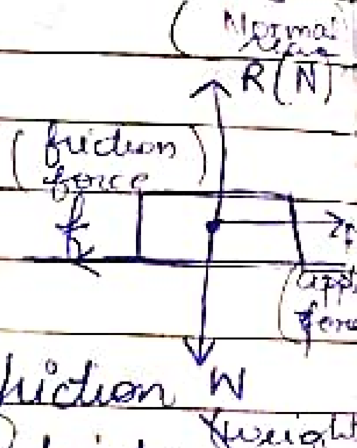
(2.) The limiting friction acts tangential to the two surfaces in contact and in a direction opp to direction of motion of the body

(3.) The value of limiting friction is independent of the area of the surface in contact so long as the normal reaction remains the same.

(4.) The limiting friction ($f_s^{max.}$) is directly proportional to the normal reaction R between the two surfaces

i.e.

$$f_s^{max} \propto R$$



$$f_s^{max} = \mu_s R$$

where μ_s is cofficient of limiting friction (Static friction)

It is defined as the ratio of limiting friction to the Normal reaction is called coff. of limiting friction

$$\frac{f_s^{max}}{R} = \mu_s$$

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Friction is necessary evil
or Advantages & disadvantages of friction

A. Advantage

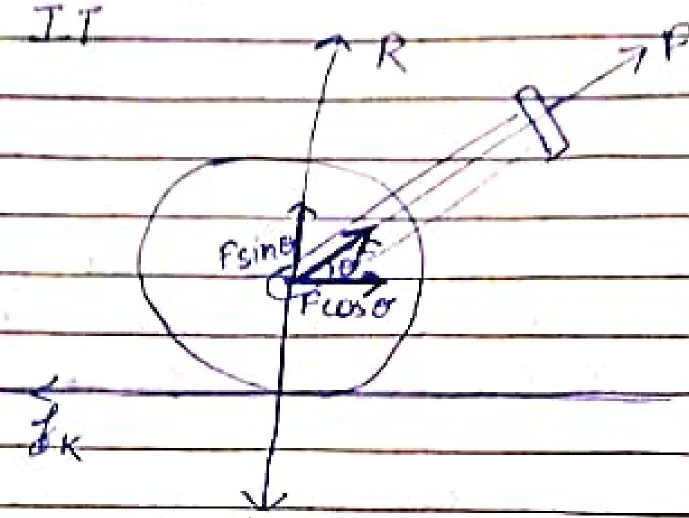
1. It is due to friction b/w ground and feet that we are able to ~~move~~ walk
2. It is due to friction we can write
3. The brakes of vehicle cannot work without friction
4. Various part of machine are able to rotate because of belt and pulley
5. The tyre of vehicle are ~~to~~ made rough to increase friction

B. Disadvantage

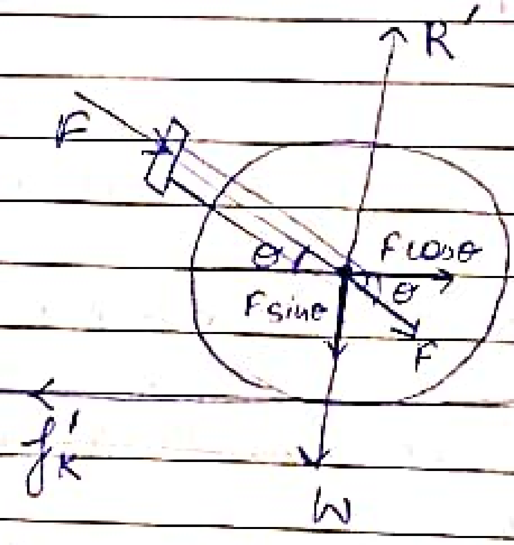
1. Wear & Tear of the machinery is due to friction
2. A large amount of power is wasted in overcoming friction and the efficiency of the machine ~~of machines~~ decreases considerably
3. Excessive friction b/w rotating parts of a machine produces enough heat and causes damage to the machinery

As friction has both advantage & disadvantage we can say that friction is necessary evil

IT IS EASIER TO PULL A LAWN ROLLER THAN TO PUSH IT



(a) Pulling a roller



(b) Pushing a roller

Suppose a force (F) is applied to pull a lawn roller of weight (W).
F has two rectangular component :
1. Horizontal component (F cosθ) help to move roller forward
2. Vertical component (F sinθ) ~~help a~~ acts ~~helps~~ in upward (~~pulling~~ pulling) and downward (~~pushing~~ pushing)

In case of pulling:

$$R + F\sin\theta = W$$
$$R = W - F\sin\theta$$
$$f_K = \mu_K R = \mu_K(W - F\sin\theta) \quad \text{--- (1)}$$

In case of pushing:

$$R' = W + F\sin\theta$$
$$f_K' = \mu_K R' = \mu_K(W + F\sin\theta) \quad \text{--- (2)}$$

Comparing (1) and (2)

$$f_K < f_K'$$

So it is easier to pull a lawn roller than to push it

ROLLING FRICTION :

The force of friction that comes into plane when a body rolls over the surface of another body is called rolling friction
E.g. When a wheel rolls over a road Rolling friction comes into the plane

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ROLLING FRICTION IS SMALLER THAN SLIDING FRICTION.

When a wheel rolls without slipping over a hori. plane the surfaces at contact do not rub eachother. The relative velocity of the point of contact of the wheel with respect to the plane is zero if there is no slipping. There is no sliding or static friction in such an ideal situation we need to overcome rolling friction only which is smaller than sliding friction

LAWS OF ROLLING FRICTION :

Experiments shows that -

1. Rolling friction is directly proportional to the normal reaction

$$f_r \propto R$$

2. Rolling friction is inversely proportional to the radius of the rolling cylinder or wheel.

$$f_r \propto \frac{1}{r}$$

combining above two :-

$$f_r \propto \frac{R}{r}$$

$$f_r = \mu_r \frac{R}{r}$$

Where μ_r is cofficient of rolling friction

METHODS OF REDUCING FRICTION

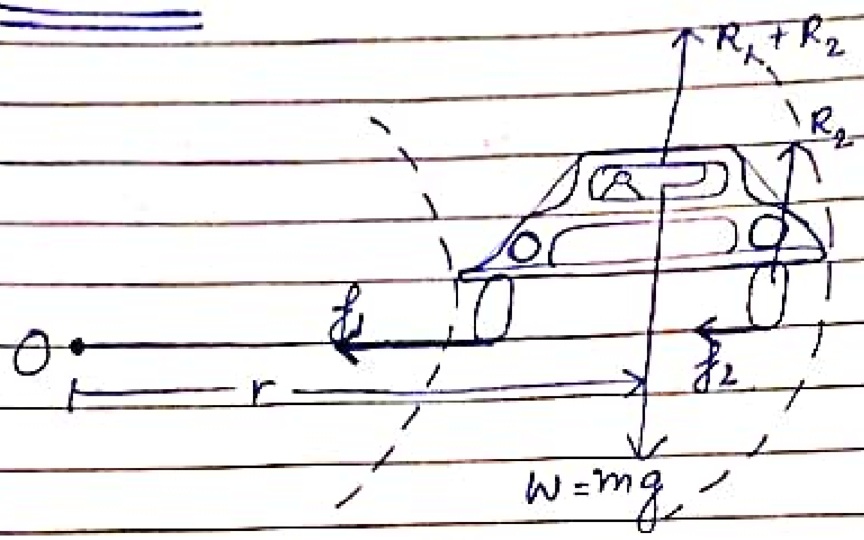
1. By polishing the bumps and depression b/w surfaces in contact get minimised
2. Lubrication - It fills up depression b/w the surfaces in contact & hence reduces friction
3. Stream lining - Friction due to air is considerably reduced by streamlining shape of the body

CENTRIPETAL FORCE :→

$$F = ma$$
$$= \frac{mv^2}{r}$$
or
$$= m\omega^2 r \qquad \left(a = \frac{v^2}{r} = \omega^2 r \right)$$

A force required to make a body move along a circular path with uniform speed is called centripetal force.
It always acts along the radius and towards the centre of the circular path

CAR ON A CIRCULAR LEVEL ROAD



$$R_1 + R_2 = mg$$

When a car negotiates a curved level road, the force of friction b/w the road & the tyre provides the necessary centripetal force required to keep the car in motion along the curve

Consider a car of weight ~~mg~~ $W = mg$ going around a circular level road of radius r with constant speed v.

Now, $f_1 = \mu R_1$

$f_2 = \mu R_2$

$$f = f_1 + f_2$$
$$= \mu R_1 + \mu R_2$$
$$= \mu (R_1 + R_2)$$
$$f = \mu mg$$

For a car to stay on the road, the max force of friction must be equal to or greater than centripetal force

$$\mu mg \geq \frac{mv^2}{r}$$

$$\mu \geq \frac{v^2}{rg}$$

$$v^2 \leq \mu rg$$

$$v \leq \sqrt{\mu rg}$$

$$\boxed{v_{max} = \sqrt{\mu rg}}$$

NOTE: If the speed exceeds v_{max} the car will skid and go off the road in circle of radius greater than R. This is because the max available friction is insufficient to provide the necessary centripetal force hor. component = centripetal force

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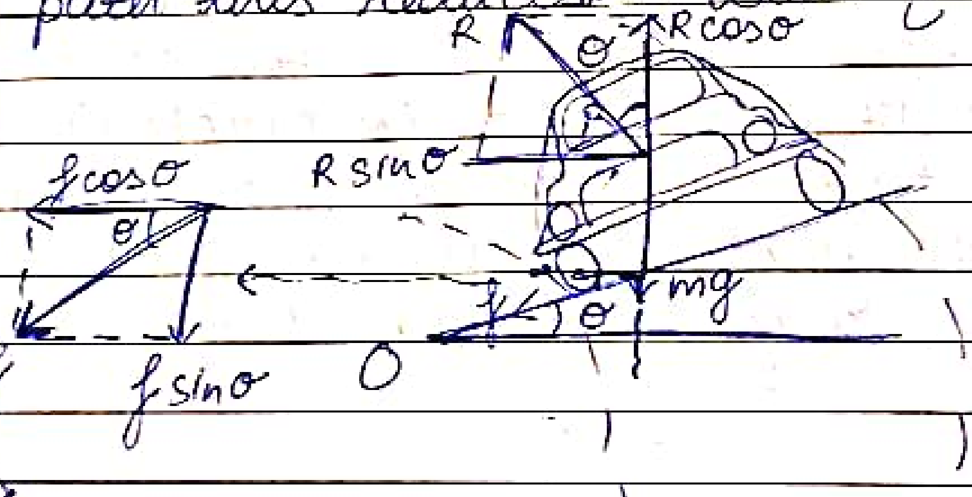
BANKING OF THE CURVED ROAD :-

The system of raising the outer edge of a curved road above its inner edge is called banking of the curved road. The angle through which the outer edge of the curved road is raised above the inner edge is called angle of banking

When the circular road is bend, the hori. component of normal reaction of the road provides the necessary centripital force for the vehicle to move it along the curved path this reduces the wear & tear of tyre.



Derivation -

Consider a car of weight mg going along a curved path of radius 'r' with speed 'v' on a road. Bend at an angle θ

- weight mg acting vert. downward
- Normal Rx = R ~~of the re~~ acting at ∠θ with vertical

$$R\sin\theta + f\cos\theta = \frac{mv^2}{r} \quad \text{--- (1)}$$

$$mg + f\sin\theta = R\cos\theta$$

$$R\cos\theta - f\sin\theta = mg \quad \text{--- (2)}$$

Dividing (1) by (2)

$$\frac{R\sin\theta + f\cos\theta}{R\cos\theta - f\sin\theta} = \frac{\cancel{m}v^2/r}{\cancel{m}g}$$

$$\frac{R\sin\theta + f\cos\theta}{R\cos\theta - f\sin\theta} = \frac{v^2}{rg}$$

Dividing Numerator & Denominator of LHS by $R\cos\theta$

$$\frac{\dfrac{R\sin\theta + f\cos\theta}{R\cos\theta}}{\dfrac{R\cos\theta - f\sin\theta}{R\cos\theta}} = \frac{v^2}{rg}$$

$$\frac{\tan\theta + \dfrac{f}{R}}{1 - \dfrac{f}{R}\tan\theta} = \frac{v^2}{rg}$$

$$\frac{\tan\theta + \mu}{1 - \mu\tan\theta} = \frac{v^2}{rg}$$

$$v^2 = rg\left(\frac{\tan\theta + \mu}{1 - \mu\tan\theta}\right)$$

$$\boxed{v = \sqrt{rg\left(\frac{\tan\theta + \mu}{1 - \mu\tan\theta}\right)}}$$

...al cases : When $\mu = 0$ (when there is no friction)

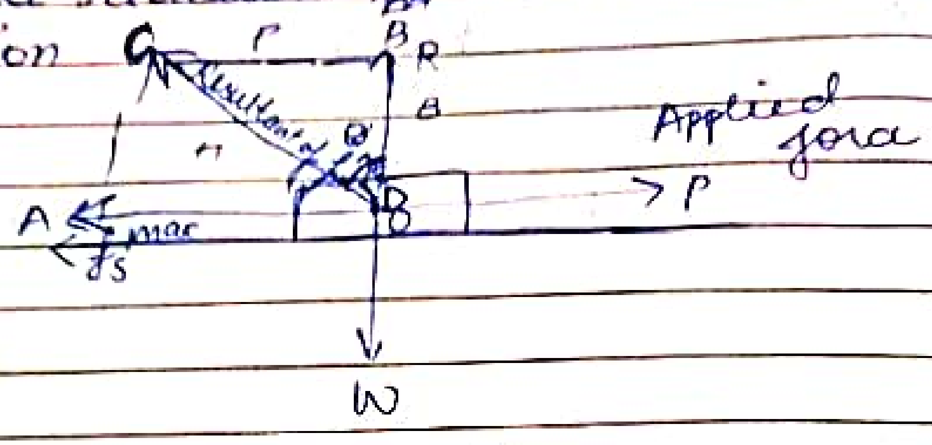
$$\boxed{v = \sqrt{rg\tan\theta}}$$

Sq. b/s $\Rightarrow$ $v^2 = rg\tan\theta$

$$\frac{v^2}{rg} = \tan\theta$$ θ is angle of banking

Angle of Friction :

It is defined as the angle which the resultant of the limiting friction and normal reaction makes with the normal reaction



$$\tan\theta = \frac{BC}{DB}$$

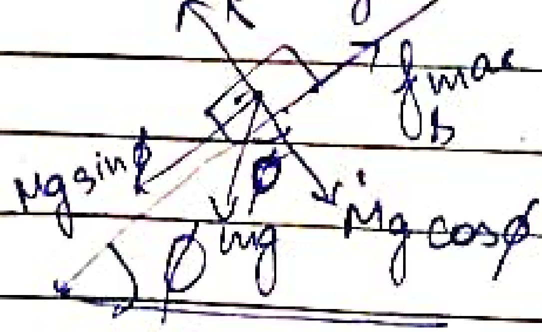
$$\tan\theta = \frac{BA}{DB}$$

$$\tan\theta = \frac{f_s^{max}}{R}$$

$$\boxed{\tan\theta = \mu_s}$$

Angle of Repose

It is the minimum angle that an inclined plane makes with the horizontal when a body placed on it just beings to slide



$$f_s = mg \sin\phi \quad \text{— (1)}$$

$$R = mg \cos\phi \quad \text{— (2)}$$

$$(1) \div (2)$$

$$\frac{f_s^{max}}{R} = \frac{mg \sin\phi}{mg \cos\phi}$$

$$\boxed{\mu_s = \tan\phi}$$

NOTE : $\mu_s = \tan\theta = \tan\phi$

$$\theta = \phi$$

LAWS OF KINETIC FRICTION :

1. Kinetic friction opposes the relative motion and has a constant value depending on the nature of two surface in contact
2. The value of the Kinetic friction is independe[nt] normal Rx remain the same
3. The f_K does not depend on velocity provide[d] the velo. is neither to large nor to small
4. f_K is directly proportional to Normal Rx b/w 2 surfaces

$$f_K \propto R$$

$$f_K = \mu_K R$$

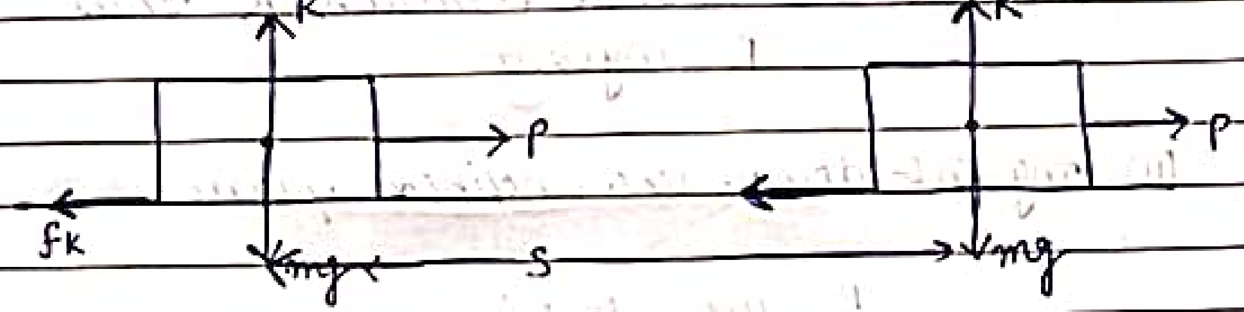
$$\boxed{\mu_K = \frac{f_K}{R}}$$

LAWS OF MOTION

Work Done against Friction:

- work done in sliding a body over a horizontal surface.

Consider a body of weight mg resting on a rough horizontal surface.



work done against friction in moving the body through distance S will be

$$W = f_K \times S$$

But $f_K = \mu_K R = \mu_K \cdot mg$

$$W = \mu_K \cdot mg S.$$

- work done in moving a body up an inclined plane

Suppose a body of weight mg is placed on an inclined plane, A force P is applied on the body so that it just begins to slide up the inclined plane.

(II) when lift moves downwards with acceleration 'a':
Net downward force on man is

$$mg - R = ma$$

Apparent weight, $\boxed{R = m(g-a)}$

$\therefore$ when lift accelerates downwards, apparent weight of man decreases.

(III) when the lift is at rest or moving with uniform velocity v downward/ upward.
The acceleration $a = 0$. Net force on the man is

$$R - mg = m \times 0 = 0$$

$$\boxed{R = mg}$$

$\therefore$ Apparent weight = Actual weight

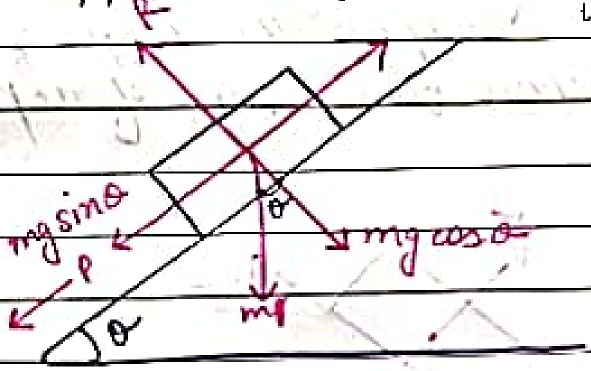
(IV) when the lift falls freely.
If the supporting cable of the lift breaks, the lift falls freely under gravity.
Then $a = g$. The net downward force on the man is

$$R = m(g-g) = 0.$$

$\therefore$ Apparent weight $= 0$.

Work done in moving a body down an inclined plane.

Suppose a body of weight mg on an inclined plane. A force P is applied to just slide the body down the inclined plane.



The weight mg of the body has 2 components:

(I) mg cosθ perpendicular to the inclined plane. It balances the normal reaction R. Thus

$$R = mg\cos\theta$$

(II) mg sinθ down the inclined plane.

$$P = f_k - mg\sin\theta$$

$$f_k = \mu_k R = \mu_k\, mg\cos\theta$$

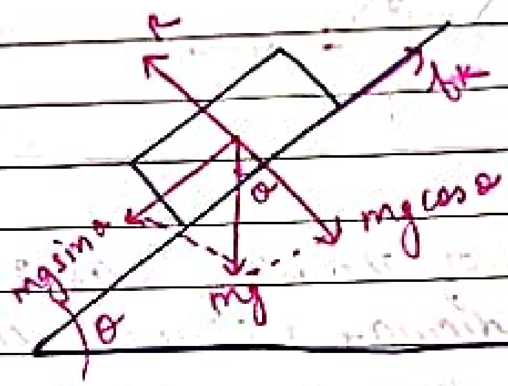
$$P = \mu_k\, mg\cos\theta - mg\sin\theta$$

$$= mg(\mu_k\cos\theta - \sin\theta)$$

$$W = P \times S = mg(\mu_k\cos\theta - \sin\theta)s.$$

7) ACCELERATION OF A BODY SLIDING DOWN A ROUGH INCLINED PLANE:

consider a body of weight mg placed on an inclined plane suppose the angle of inclination θ be greater than the angle of repose.



The weight mg has 2 rectangular components:

(i) mg cos θ perpendicular to the inclined plane. It balances the normal rxn R. Thus,

$$R = mg\cos\theta$$

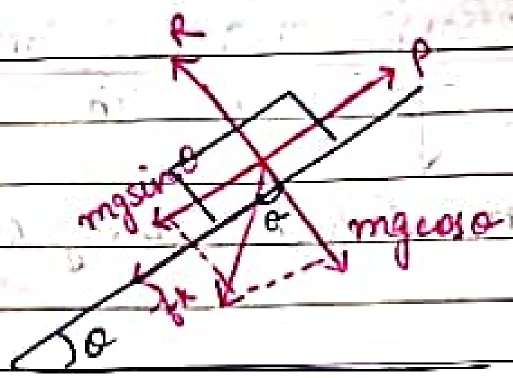
(ii) mg sin θ down the inclined plane.

$$F = mg\sin\theta - f_k$$

$$f_k = \mu_k R = \mu_k mg\cos\theta$$

$$ma = mg\sin\theta - \mu_k mg\cos\theta$$

Hence $a = g(\sin\theta - \mu_k\cos\theta)$.



The weight mg of the body has two components:
(I) mgcosθ perpendicular to the inclined plane. It balances the normal reaction R. Thus

$$R = mg\cos\theta$$

(II) mg sinθ down the inclined plane.

$$P = mg\sin\theta + f_k$$

But $f_k = \mu_k R = \mu_k mg\cos\theta$

$$P = mg\sin\theta + \mu_k mg\cos\theta$$
$$= mg(\sin\theta + \mu_k\cos\theta)$$

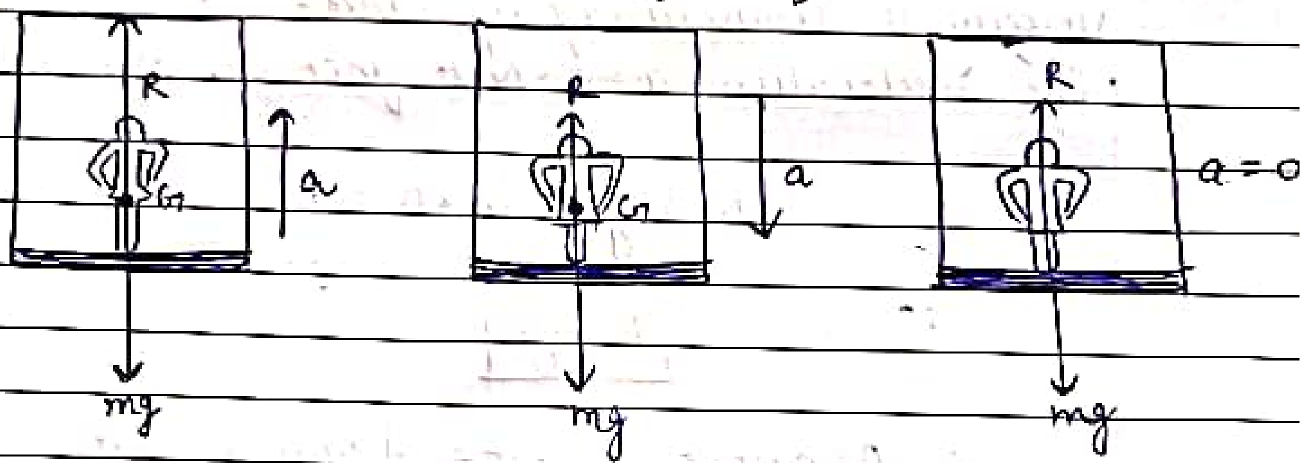
Work done in pulling the body through distance S up the inclined plane is

$$W = P \times S = mg(\sin\theta + \mu_k\cos\theta)S.$$

Apparent weight of a man in an elevator/lift:

Consider a man of mass m standing on a weighing machine placed in a lift. The actual weight of the man is mg.

The weighing machine reads the reaction R & which is the force experienced by the man. So R is the apparent weight of the man.



(a) (b) (c)

(1) when the lift moves upwards with acceleration 'a' net upward force on the man is

$$R - mg = ma$$

$\therefore$ Apparent weight, $R = m(g+a)$

$\therefore$ Apparent weight of man increases if lift accelerates upwards.