Unit - 3

(Laws of Motion and Friction)

Chapter - 1

Laws of Motion

*** Force ÷**

It is a push or pull which either change or tends to change state of a body. There are generally two type of forces.

1) Balanced force.
2) Unbalanced force.

Unbalanced force is responsible for motion of a body.

*** Inertia ÷**

The inability of a body to change its state of rest or uniform motion is called inertia.

 # Newton's law of motion ÷ Acc. to this law an obj (law of inertia) be in state of rest or uniform motion until an external force acting on it. It is also called law of inerti'

Application ÷

1) When a bus starts running suddenly, the passanger standing inside will fall backward due to inertia of rest.
2) When a running bus stops suddenly then due to inertia of motion, the passanger will fall forward.

3) Mudguard protect a vechile from mud.

*** Linear momentum ÷**

It is quantity of motion of a body in rectilinear motion. It is measured as product of mass and velocity of a body. It is denoted by 'p'. It is a vector quantity.

$$\vec{p} = m\vec{v}$$

It's direction is similar to velocity vector.

S.I unit is $kg\,ms^{-1}$

Dimension formula $= [M^1L^1T^{-1}]$

*** Newton's second law of motion ÷**

Acc. to this law applied external field is directly prop. to rate of change of linear momentum i.e

$$\vec{f_{ex}} \propto \frac{d\vec{p}}{dt}$$

$$\vec{f_{ex}} = k\frac{d\vec{p}}{dt}$$

when 'k' is called proportionally constant.

If $k = 1$, then

$$\vec{f_{ex}} = \frac{d\vec{p}}{dt}$$

Another form of 2^{nd} law ÷

as $\vec{p} = m\vec{v}$

then, $\vec{f_{ex}} = \frac{d(m\vec{v})}{dt}$

Date.
Page.

$$\vec{F_{ex}} = m\frac{d\vec{v}}{dt} + \vec{v}\cdot\frac{dm}{dt}$$

as, $\frac{dm}{dt} = 0$ (m = constant)

then,

$$\vec{F_{ex}} = m\cdot\frac{d\vec{v}}{dt}$$

$$\vec{F_{ex}} = m\cdot\vec{a}$$

where $\vec{a}$ is called acceleration.

Dimension formula = $\vec{F} = m\cdot\vec{a} \Rightarrow MLT^{-2}$

$\vec{F} = [M^1L^1T^{-2}]$

Units of force ÷ There are two types of units of force.

1) Absolute units 2) Gravitational units.

→ i) Absolute units ÷

a) S.I unit (Newton) =

$$F = m\cdot a$$
$$N = kg.ms^{-2}$$

then,

$$1N = 1kg \cdot 1ms^{-2}$$

Hence force is said to be 1N if 1kg mass of an object produce an acceleration of $1ms^{-2}$.

b) C.G.S units =

$$F = m\cdot a$$
$$dyne = g \times cms^{-2}$$

When 1gm mass of an obj. produce an acc. of

Teacher's Signature.........

Date.
Page.

$1cms^{-2}$ then force is 1 dyne.

Relation b/w Newton and Dyne =

$$1N = 1kg \times 1ms^{-2}$$
$$1N = 10^3 g \times 10^2 cms^{-2}$$
$$= 10^5 gcms^{-2}$$

$1N = 10^5$ dyne [dyne = $gcms^{-2}$]

2) Gravitational units ÷

(a) S.I units ÷ $F = m\cdot g$

$$1\,kg\,f = kg \times 9.8ms^{-2}$$
$$= 9.8\,kgms^{-2}$$
$$1\,kgF = 9.8N.$$

When 1 kg mass of an obj. produce an acc. of $9.8ms^{-2}$ then force will be 1kgF.

(b) C.G.S units ÷ $F = mg$

$$1gF = 1g \times 980cms^{-2}$$
$$1gF = 980\,gcms^{-2}$$
$$1gF = 980 \text{ dyne}.$$

When 1g mass of a body produce an acc. of $980cms^{-2}$ then force will be 1gF.

* Impulse = It is defined as the product of force and the time during which force act on the obj. It is denoted by 'I'.

$$I = \vec{F}_{av.} \times t \qquad \text{Unit} \rightarrow N\cdot S$$

from Newton's 2nd law

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

Teacher's Signature.........

Date.
Page.

as $\vec{F}.\Delta t = I$

now, $I = d\vec{p}$ (Change in momentum)

$$I = \vec{p_2} - \vec{p_1}$$

Units of impulse is newton's second (ns) and $kg\,ms^{-1}$

Dimensional formula of $I = M^1L^1T^{-2} \times T^1$

$$= [M^1L^1T^{-1}]$$

* Appleation of Impulse ÷ i) A cricket player lower his hands while catching a ball. By doing this, the time intervals increase and the force decreasing. So, he will get less hurt/harm.

2) Automobiles are provided with soccer becaus shocker provided in vechile have rubber, spring because this rubber increases the time and force will decrease. So, the person will get less jerk.

3) chinawares are rapped in straw paper before packing because straw paper increase time of contact of collision b/w two chinawares. So, force will decrease and there will be less damage.

* Newton's 3rd law of motion ÷

Acc. to this law for any action, there is equal and opposite reaction.

$$\vec{F_{12}} = -\vec{F_{21}}$$

$$\vec{F_{12}} + \vec{F_{21}} = 0$$

Teacher's Signature........

Date.
Page.

Application ÷

1) Book kept on a table
2) Walking of a man.
3) Swimming.

* Newton 2nd law is real law of motion ÷

i) Newton 1st law from 2nd law ÷

Acc. to Newton 2nd law,

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

if $\vec{F} = 0$, $m\vec{a} = 0$

$m \neq 0$, $\vec{a} = 0$

as we know,

$$\vec{v} = \vec{u} + \vec{a}t$$

$$\vec{v} = \vec{u} + 0t$$

$$\vec{v} = \vec{u}$$

final velocity = initial velocity

Thus no change in velocity means no change in state of body. This is newton's 1st law.

2) Newton's 3rd law from 2nd law ÷

Consider two bodies A and B let f_{ab} and f_{ba} be the force exert on A and B respectively. p_A and p_B be the linear momentum respectively. then,

$$\vec{f_{AB}} = \frac{dp_A}{dt} \quad \text{— i)}$$

$$\vec{f_{BA}} = \frac{dp_B}{dt} \quad \text{— ii)}$$

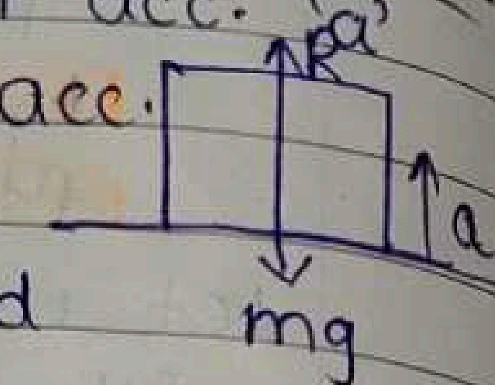
Add eq^n (i) and (ii)

Teacher's Signature........

Apparent weight of a Man in a lift|elevator

1) when lift moves upward with an acc. 'a'

let the lift is moving with an acc. 'a' in upward direction. 'R' be the normal reaction acting in upward direction.

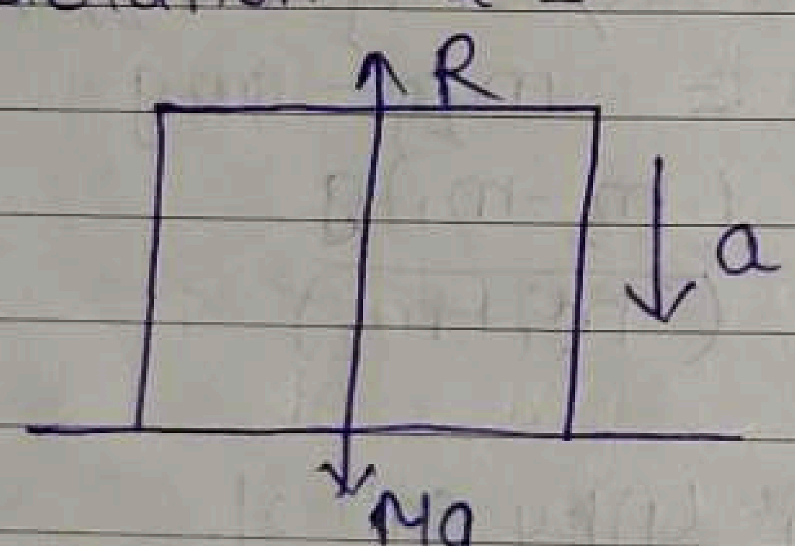


Weight mg will act in downward
The net force will be = R − mg

$$Ma = R - Mg$$
$$R = ma + mg$$
$$R = m(a+g)$$

Thus, $R > mg$ is apparent weight of man increas when lifted man move in upward direction.

2) when lift move in downward direction with an acceleration 'a' =



The acc. 'a' is acting in downward direction
Then net force will be = Mg − R

$$Ma = Mg - R$$
$$R = Mg - Ma$$
$$R = m(g-a)$$

hence, $R < Mg$ apparent weight < true weigh
Thus apparent weight will decrease when lift move in downward direction.

3) when lift move up|down with a uniform velocity = as velocity is uniform

$$a = 0$$

* for upward motion direction ÷

$$R = m(g+a)$$
$$R = m(g+0)$$
$$R = mg$$

Apparent weight = true weight

* For downward motion

$$R = m(g-a)$$
$$R = m(g-0)$$
$$R = mg$$

Apparent weight = True weight.

iv) When lift is at rest ÷
If lift is at rest then acc. (a) will be zero so, no change in weight
Thus, $R = mg$
Apparent weight = True weight

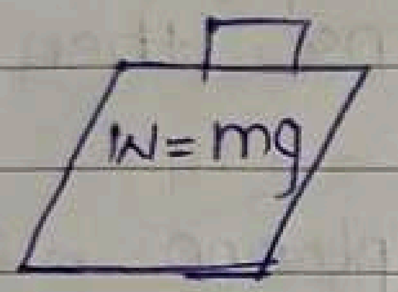
Q=1) A body of mass 60kg is placed in a lift the lift starts accelerating downward with uniform acc. of $2ms^{-2}$

1) What is actual weight.
2) What is value of effective acc. due to gravity
3) Normal reaction offered by lift on body.
4) Reading of weighting machine.
5) Apparent weight.

Chapter = 2

Connected motion

* **Weight** ÷ Weight is the force by which earth attracts a body towards its centre. It is also known as gravity. The direction of weight will be vertically downward.

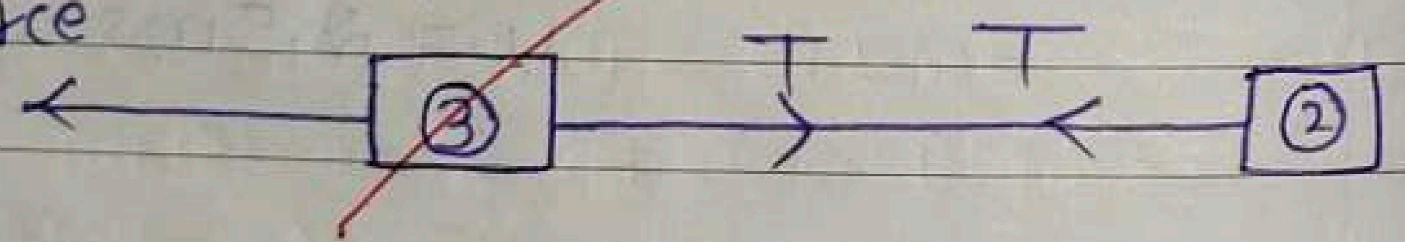


Weight(w) = mg

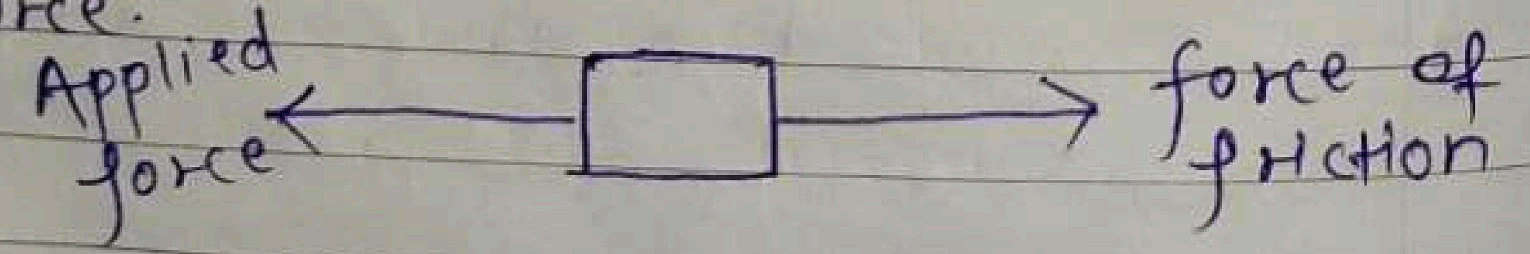
M = Mass of body , g = acc. due to gravi

* **Normal reaction** ÷ It will act perp. to the surface. It dosen't act in air. It needs a surface. It is denoted by 'R'.

* **Tension**: It is a kind of force which develops in rods, strings due to extension or compression. Tension b/w two bodies will always be equal and opposite each rope has diff tension.



* **Friction** ÷ Friction is a force which opposes motion or applied force. It will act opposite to the direction of motion or applied force.



Connected motion (Atwood's machine)

$F = ma$

$M_1 a = T - m_1 g$

$M_2 a = M_2 g - T$

let us consider two masses m_1 and m_2 connected with a string having Tension 'T' over a pulley let $m_2 > m_1$ then acceleration of mass M_1 a is in upward direction while acc. of m_2 is in downward direction.

As string is same so, Tension 'T' act same on both masses then force on block m_1

$m_1 a = T - m_1 g$ —(i)

force on block m_2

$m_2 a = M_2 g - T$ –ii)

Adding eq^n i) and ii)

$M_1 a + m_2 a = \cancel{T} - M_1 g + M_2 g - \cancel{T}$

$(m_1 + m_2) a = m_2 g - m_1 g$

$a = \frac{(m_2 - m_1) g}{(m_1 + m_2)}$

Divide eq^n (i) by eq^n 2)

$\frac{m_1 a}{m_2 a} = \frac{T - m_1 g}{M_2 g - T}$

$m_1 a (M_2 g - T) = M_2 a (T - m_1 g)$

$M_1 m_2 ag - M_1 aT = M_2 aT - M_1 M_2 ag$

$M_1 M_2 ag + M_1 M_2 ag = M_2 aT + M_1 aT$

$2 M_1 M_2 ag = aT (M_1 + M_2)$

$T = \frac{2 M_1 M_2 g}{M_1 + M_2}$

Date.
Page.

Sol^n I = change in momentum
final − initial
$= Mv - Mu$
here final momentum = 0
$m = 200gm = \frac{2}{10}$ kg
$u = 20ms^{-1}$

$I = -mu$
$= \frac{-2 \times 20}{10}$
$= -4 kgms^{-1}$

2) $I = \vec{f} \times \Delta t$
$\vec{f_{av}} = I/t$, $t = 5sec$
$= \frac{-4}{5}$
$= -0.8N.$

Q=3) A force of 12N starts acting on a body kept at rest
1) find mom. of body at $t = 2$ sec.
2) Impulse.

Sol^n 1) $F = \frac{dp}{dt}$

$f = \frac{p_2 - p_1}{t}$

here, $u = 0$, $mu = 0$
$f = \frac{p_2}{t}$, $p_2 = f \times t$
$= 12 \times 2$
$= 24 kgms^{-1}$

Teacher's Signature.........

Date.
Page.

2) I = change in momentum
$= F_{final}\ I_{initial}$ $(I = 0)$
final momentum
$= 24 kgms^{-1}$

Q=4) A bomb of mass 50g explode into 2 pieces if one peice is of mass 10kg more with a Speed of $10ms^{-1}$ then what will be velocity of other peice.

Sol^n Mom. before explosion = 0
Mass of 1st peice = 10g (m)
$= 0.01$ kg
velocity = $10ms^{-1}$
Mass of 2nd peice = 40g
$= 0.04$

velocity = n(u)
$0 = mu + Mv$
$0 = 0.04 \times u + 0.01 \times 10$
$0 = 0.04u + 0.1$
$\frac{-1.0}{0.04} = u$
$u = 2.5ms^{-1}.$

Teacher's Signature.........

Date. | Page. |

$$\vec{F}_{AB} + \vec{F}_{BA} = \frac{dp_A}{dt} + \frac{dp_B}{dt} \quad \text{— iii)}$$

For an isolated system not external force exert will be zero

$$\frac{d\vec{p}}{dt} = \frac{dp_A}{dt} + \frac{dp_B}{dt} \quad \left[0 = \frac{d\vec{p}}{dt}\right] \quad \frac{dp_A}{dt} + \frac{dp_B}{dt} = 0$$

from eqⁿ iii)

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

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

Law of conservation of linear momentum :-

Acc. to this law if external force acting on a body is zero then its linear momentum will be conserve.

from Newton's 2^{nd} law

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

but if $\vec{F}_{ex} = 0$

then, $\frac{d\vec{p}}{dt} = 0 \quad [\vec{p} = \text{constant}]$

Application :-

i) Recoil of a gun :-

When a bullet is fired from a gun then bullet moves in foreward

Date. | Page. |

direction. This is called recoil of a gun. Let M and m be the mass of gun and bullet resp. $\vec{u}$ and $\vec{v}$ be the velocity of gun and bullet respec.

Then acc. to conservation of linear mom.

Momentum before firing = Momentum after firing

Before firing both gun and bullet are at rest so momentum will be zero.

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

The –ve sign indicate that velocity of gun is opp. to velocity of bullet

2) When a man jumps out of a boat to the shore, the boat slightly moves away from the shore.

3) Rocket and jet planes also work on the principal of conservation of linear momentum.

4) Explosion of bombs in parts.

Q=1) The linear momentum of a body changes from $5\,kgms^{-1}$ to $17\,kgms^{-1}$ find the impulse

Solⁿ- I = final mom. – initial mom.

$I = 17 - 5$

$I = 12\,kgms^{-1}$.

Q=2) A cricket player catch a ball of 200gm moving with velocity of $20ms^{-1}$ by lowering his hands in 5 sec.

i) find impulse 2) force exerted by ball.

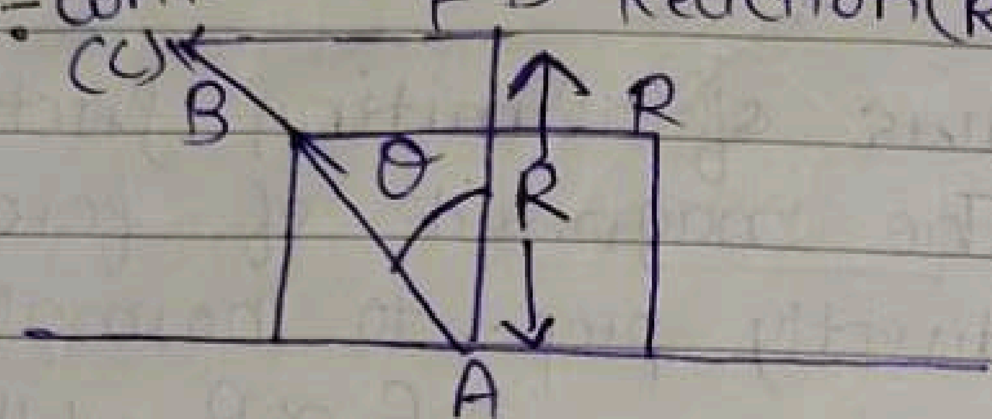
Date. | Page. |

Then, $R = \sqrt{A^2+B^2+2AB\cos\theta}$

$C = \sqrt{F^2+R^2+2FR\cos 90^\circ}$

$C = \sqrt{F^2+R^2}$

Angle of friction ÷ Contact force (C)   Reaction(R)



The angle b/w contact force (C) and normal reaction is called Angle of friction.
OR The angle of resultant of normal reaction and friction with normal reaction called angle of friction.

In ΔABD

$BD = F$

$AD = R$

$\tan\theta = \frac{BD}{AD}$

$\tan\theta = \frac{F}{R}$ — i)

But coffi. of friction $(\mu) = \frac{F}{R}$ — ii)

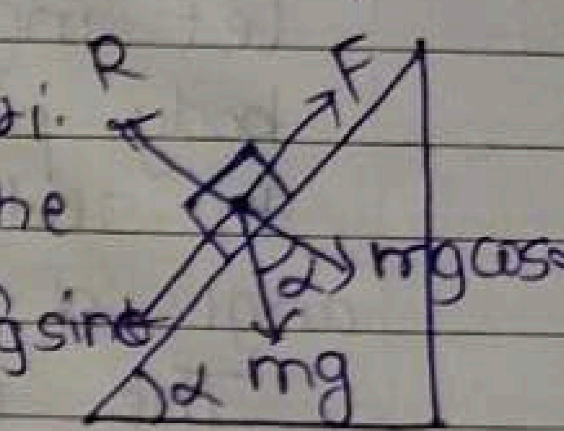
from eq^n i) and ii)

$$\boxed{\mu = \tan\theta = \frac{F}{R}}$$

Date. | Page. |

Angle of repose Or sliding ÷

It is the minimum angle of inclination of a plane with the horizental such that a body placed on the hori. Such that a body placed on the plane Just begin to slide down. It is represented by α.



let mg be the weight of body placed on inclined plane to slide down. α be the angle of repose.
The weight 'mg' spilt into two component $mg\cos\alpha$, $mg\sin\alpha$

$mg\cos\alpha$ — verticle angle

$mg\sin\alpha$ — along horizontal.

'F' and 'R' be the force of friction and normal reaction respec.

Then, $F = mg\sin\alpha$ — i)

$R = mg\cos\alpha$ — ii)

Divide eq^n i) and ii)

$$\frac{F}{R} = \frac{\cancel{mg}\sin\alpha}{\cancel{mg}\cos\alpha}$$

$\frac{F}{R} = \tan\alpha$ or $\frac{F}{R} = \tan\theta$

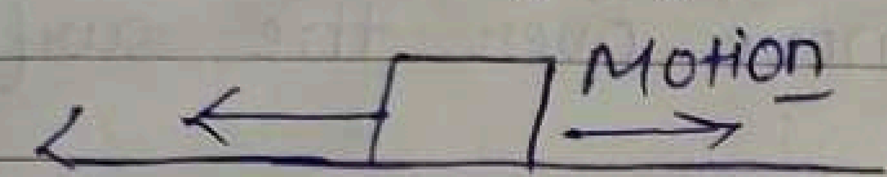
then, $\tan\alpha = \tan\theta$

or $\alpha = \theta$

Thus angle of repose is numerically equal to angle of friction.

* **Types of external friction**: There are two type of external friction.

1) **Sliding friction**: When one body slide over the surface of other body then the friction is called sliding friction.



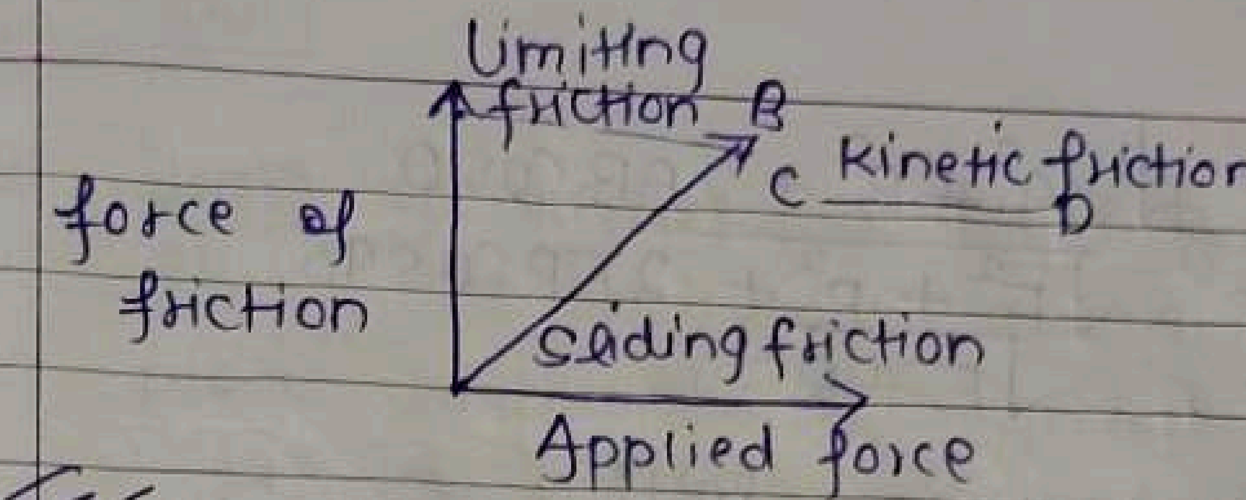
2) **Rolling friction** :- When one body rolls over the surface of another body, then the friction is called rolling friction. for ex: Motion of a wheel.

* **Types of sliding friction**: There are three types of sliding friction.

1) **Static friction**: It is the force of friction b/w two surfaces when there was a no relative motion b/w them. Such that the two surface were at rest. It is also called self adjusting force.

2) **Limiting friction**: It is the force of friction b/w two surface when the body is actually not moving but is ready to move. It is also called self adjusting the max. Static friction.

3) **Kinetic friction** :- It is the force of friction b/w two surfaces when one surface moves over the other. The value of kinetic friction will be less than limiting friction.



* **Laws of limiting friction**:

1) The magnitude of force of friction will be directly prop. to normal reaction

$f \propto R$ where f is force of friction, R is normal reaction.

2) The direction of limiting friction is always opp. to direction of motion/Applied force.

3) The value of limiting friction depend on nature of surfaces and their nature of material.

4) The value of limiting friction doesn't depend on area of contact.

* **Cofficient of friction** :- $F \propto R$

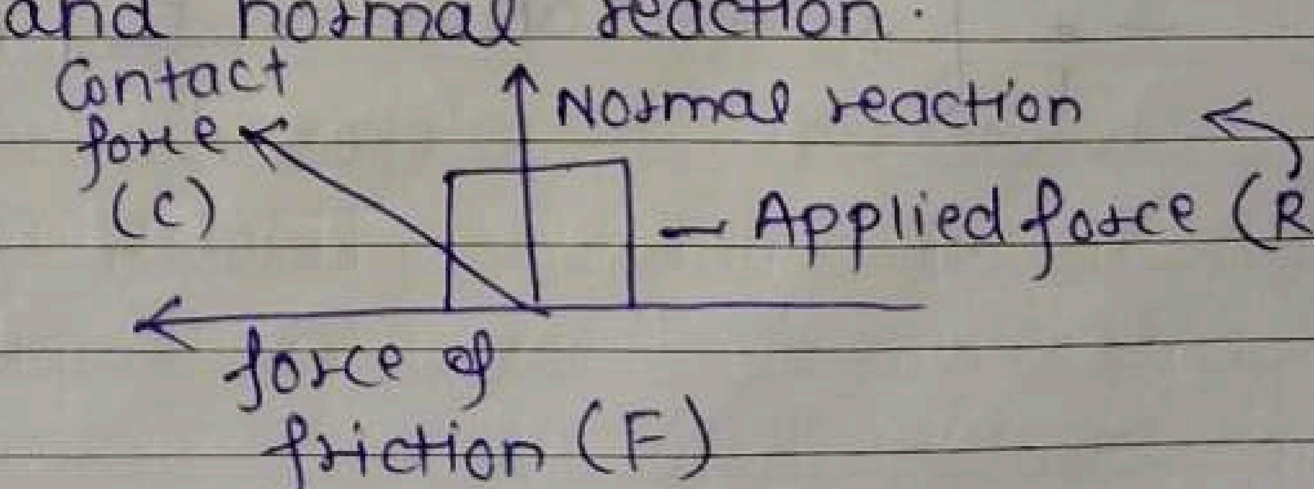
$F = \mu R$

Where 'μ' is Coffoicient of friction

So, $\mu = \frac{f}{R}$

It has no unit. It doesn't have dimensions.

* **Contact force**: It is the resultant of force of friction and normal reaction.



Date.
Page.

$$Ma = T_1 - mg$$
$$Ma = (Mg + T_2) - T_1 \quad \text{—(1)}$$
$$+\,Ma = mg - T_2 \quad \text{—(2)}$$
$$2ma = 2mg - T_1$$
$$a = \frac{2g - T_1}{2}, \quad a = g - \frac{T_1}{2}$$

$$m\left(g - \frac{T_1}{2}\right) = T_1 - mg$$

$$mg - \frac{T_1 m}{2} = T_1 - mg$$

$$2mg = T_1 + \frac{T_1 m}{2}$$

$$2mg = \frac{3T_1}{2}$$

$$\boxed{T_1 = \frac{4mg}{3}}$$

Teacher's Signature.........

Date.
Page.

[CHAPTER = 3]

* **Force of friction** ÷ Friction is an opp. force that comes into play when one body moves or tried to move over the surface of another body.
OR It is the force that develops at the surface of contact b/w two bodies and opposes their relative motion.

* Cause of friction ÷ Friction comes due to roughness of surface, when two bodies are incontact with each other than these irregularties get interlocked. The force of friction also arises due to strong molecular forces of attraction b/w the two surfaces at the point of contact. Thus friction comes due to adhesive forces.

* Types of friction ÷ There are two types of friction.

1) **External friction** ÷ When two bodies tried to move over surface of one another then external friction arises this is also called contact friction.

2) **Internal friction** ÷ The friction b/w the diff. layers of liquid or gases is called internal friction. This is also called viscous force (viscosity)

Teacher's Signature.........

Date.
Page.

Soln i) $R = mg$
$= 60 \times 9.8$
$= 588\ kg$

ii) $R = m(g-a)$
$\cancel{M}g' = \cancel{m}(g-a)$
$g' = g - a$
$g' = 9.8 - 2$
$g' = 7.8\ ms^{-2}$

iii) $R = m(g-a)$
$= 60(9.8-2)$
$= 60 \times 7.8$
$= 468$

4) Reading = normal reaction = 468
v) Apparent weight = 468 (R)

2) A string balance is attached to the swilling of a lift A man hangs his bag on the string and spring reads 49N when lift is stationary. What will be reading of spring balance if lift moves downward with acc. of $5 ms^{-2}$.

Soln At rest, $R = 49N$ $g = 9.8$
$R = mg$
$m = \frac{R}{g} = \frac{49 \times 10}{98}$
$m = 5 kg$

in downward direction,
$R = m(g-a)$
$= 5(9.8-5)$
$= 5 \times 4.8$
$= 24.0\ N.$

3) A lift is moving upward with uniform Velocity $20 ms^{-1}$

Teacher's Signature.........

Date.
Page.

1) What will be acceleration
2) A body of mass 7 kg is placed in lift reading

Soln i) $a = 0$
ii) $R = mg$
$= 7 \times 9.8$
$= 68.6 N.$

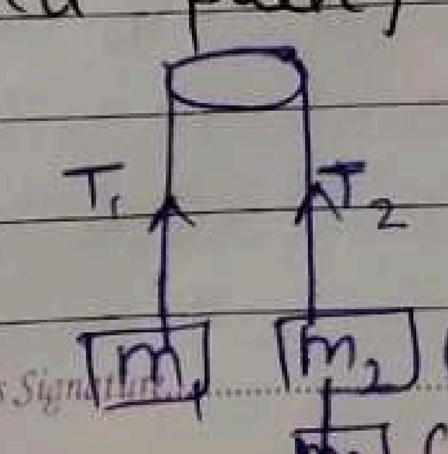
5) A light spring passes over a frictionless pulley to one of its end a mass of 6kg is attached. A mass of 10kg is attached to other end. 1) Tension in thread 2) Acceleration

Soln i) $M_1 a = T - M g$
$+ M_2 a = M g - T$

$m_1 a + m_2 a = -m_1 g + m_2 g$
$a(m_1 + m_2) = g(m_2 - m_1)$
$a(6+10) = 10(10-6)$
$a = \frac{\cancel{40}\ \cancel{20}\ 10\ 5}{\cancel{16}\ 8\ 4\ 2} = \frac{5}{2} = 2.5$

$6 \times 2.5 = T - 6 \times 10$
$15 = T - 60$
$T = 60 + 15$
$T = 75 N$

6) Three bodies A, B, C each of mass m are hanging on string over a fixed pulley
1) Tension 2) Acc. of bodies.

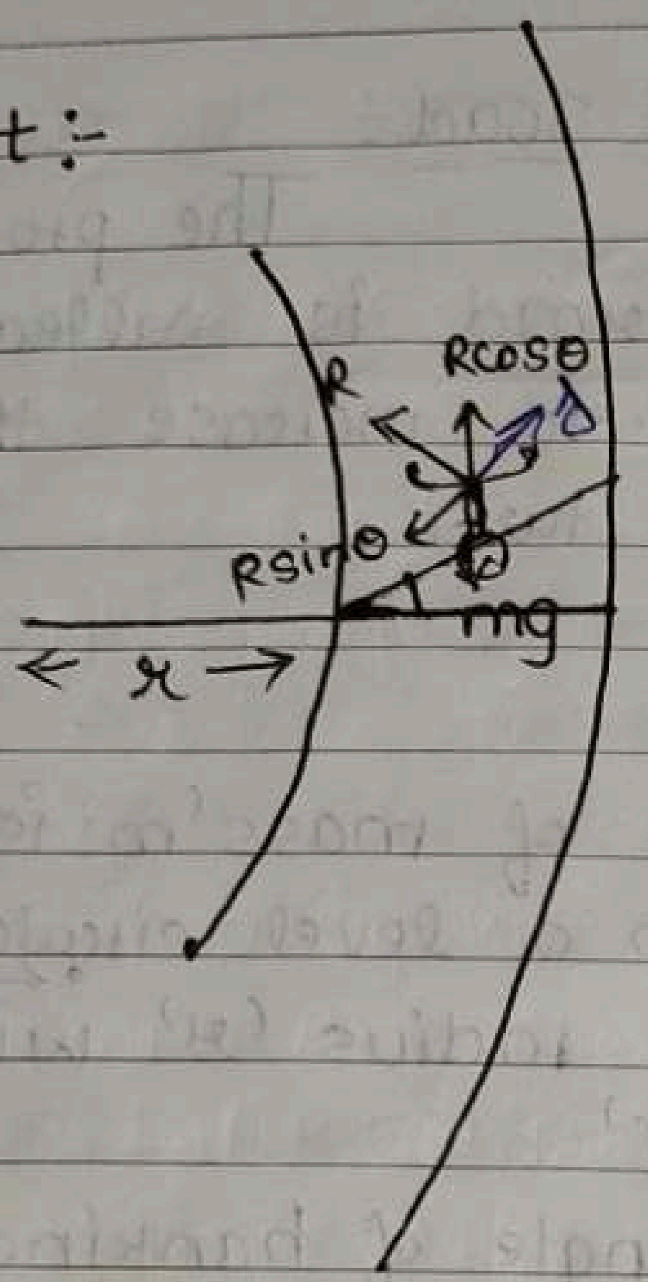


Soln $m_1 a = T_1 - m_1 g$
$m_2 b = (m_2 g + T_2) - T_1$
$m_3 a = m_3 g$

Teacher's Signature.........

Date. Page.

* **Bending of cyclist** :-



Consider a cyclist of weight 'mg' taking a turn on a circular track of radius 'r' 'θ' be the angle inclination.
The reaction 'R' split into two components
1) $R\cos\theta$
ii) $R\sin\theta$
Then from diagram :
$R\sin\theta = f$ -1)
$R\cos\theta = mg$ -2)
Where 'f' is centrifugal force
$R\sin\theta = \frac{mv^2}{R}$ - iii)

Divide eqn iii) by ii)
$$\frac{R\sin\theta}{R\cos\theta} = \frac{\frac{\cancel{m}v^2}{r}}{\cancel{m}g}$$

$$\tan\theta = \frac{v^2}{rg} \quad \text{or} \quad \theta = \tan^{-1}\left(\frac{v^2}{rg}\right)$$

as $\tan\theta = \mu$ is called coff. of friction

Teacher's Signature........

Date. Page.

$$\mu = \frac{v^2}{rg}$$
$$\text{or} \quad v = \sqrt{\mu r g}$$
$$v = \sqrt{rg\tan\theta}$$

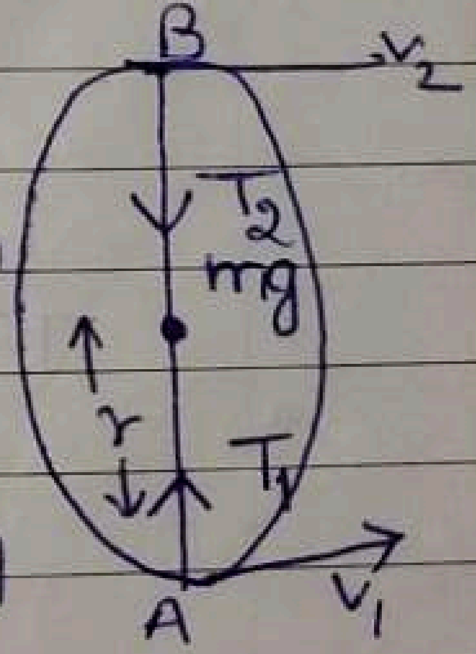
* A car takes a circular turn of radius 20m travelling with a speed of 36km/h find the coff. of friction b/w tyre and road.

Soln
$v = \sqrt{\mu r g}$ $\quad$ $v = \frac{\overset{2}{\cancel{36}} \times 5}{\cancel{18}} = 10\,m/s$
$10 = \sqrt{\mu \times 20 \times 9.8}$

Good
13/7/23

$$\frac{100}{20 \times 10} = \frac{v^2}{rg}$$
$$\rightarrow \frac{1}{2}$$

* **Non- uniform circular motion** :- consider a body of weight 'mg' moving in a vertical circle of radius 'r'. let A be the lowest and B be the test part of circle v_1 and v_2 be the velocity of body at point A and B resp.



T_1 and T_2 be the force of tension acting at a point 'A' and 'B'. for circular motion centripital force acting on every point lying on the circle.
As, point A
$$T_1 - mg = \frac{mv^2}{r} \quad \text{-i)}$$

At, point B

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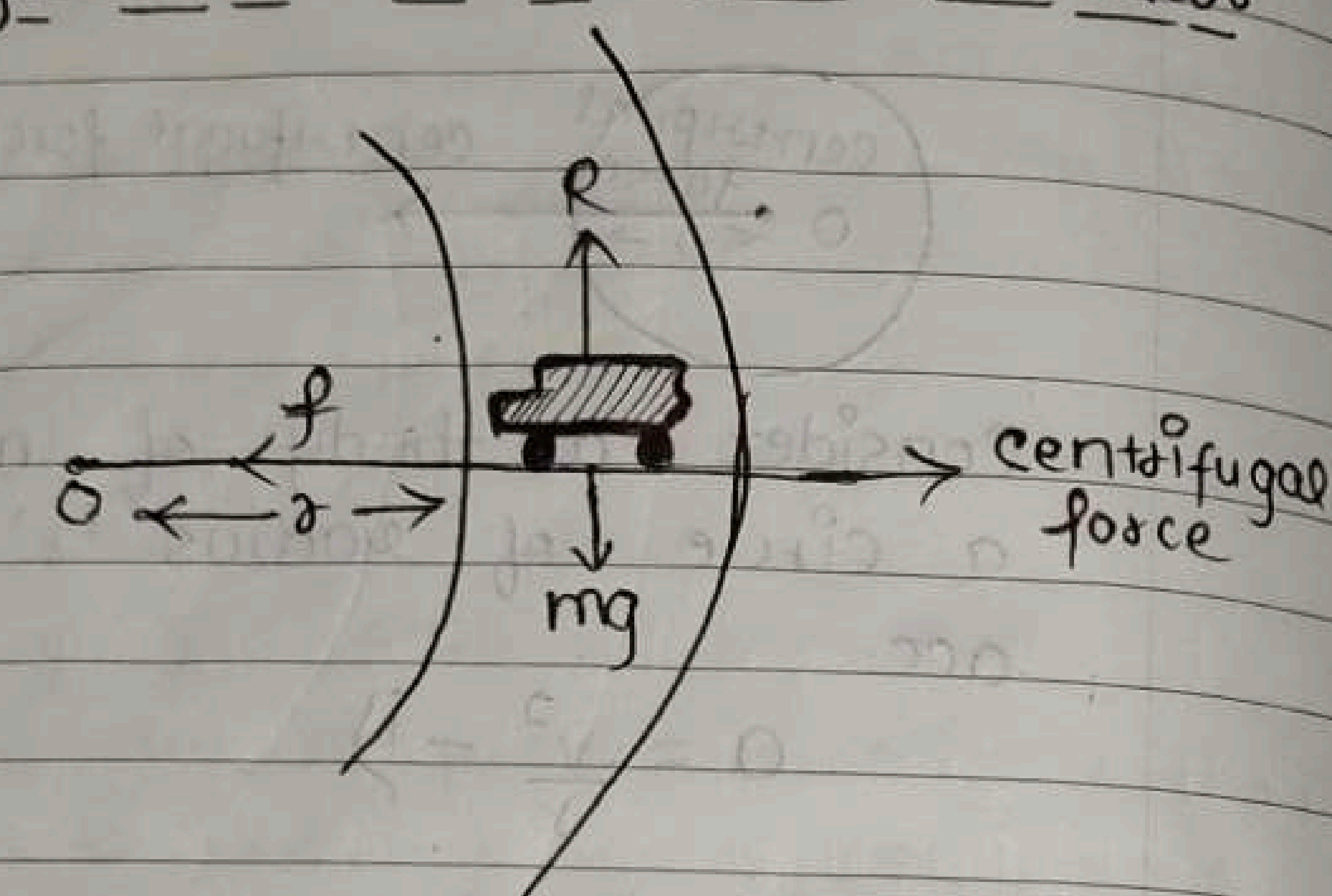
* Velocity of safe turn on a level circular road ÷



let a car of mass 'm' is moving on a level circular track of radius 'r' with a velocity 'v' 'R' be the normal reaction and 'mg' be the weight acting in downward direction. 'f' is the force of friction. Centrifugal force also exerted on it.

For motion on level road –
friction ≥ centrifugal force
For uniform motion on level circular road
friction = Centrifugal force

$$f = \frac{mv^2}{R}$$

as, $f = \mu R$

$$\mu R = \frac{mv^2}{r}$$

$$\mu \cancel{m} g = \frac{\cancel{m} v^2}{r} \quad \because [R = mg]$$

$$\mu g = \frac{v^2}{r}$$

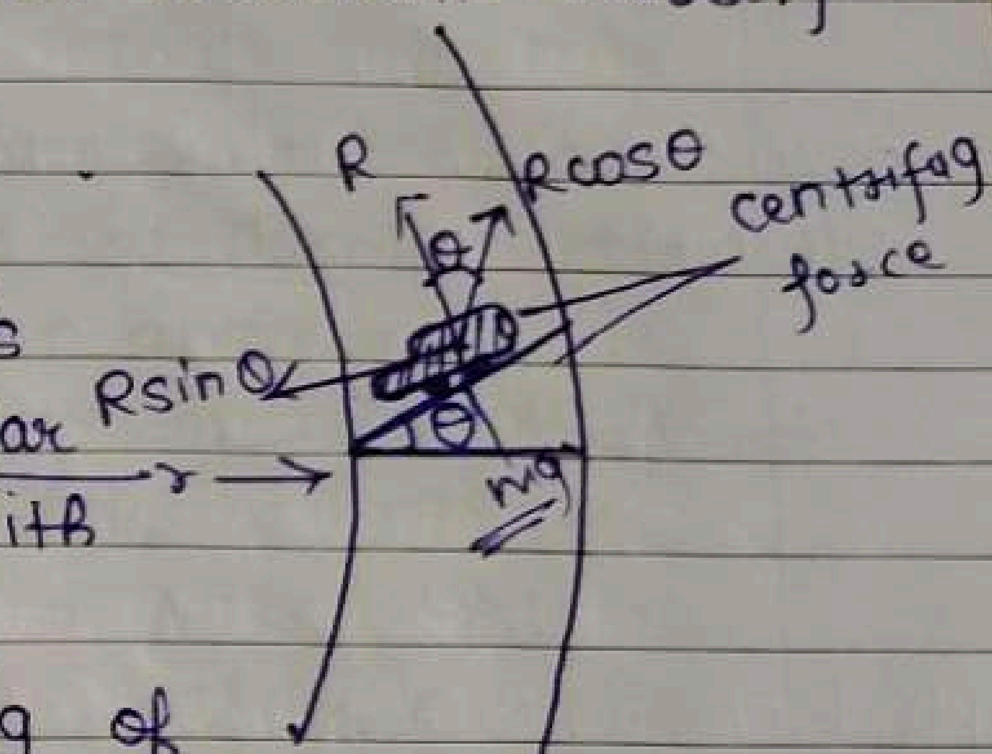
$$v^2 = \mu r g$$

$$v = \sqrt{\mu r g}$$

* where 'μ' is cofficien of friction b/w road and type of car

* Banking of road ÷

The process of raising outer and off road is called banking of road. It is done to increase the maximum velocity of safe turn.



let a case of mass 'm' is moving on a level circular track of radius 'r' with velocity 'v'
'θ' be angle of banking of road. The normal reaction 'R' spilt into two component → Rcosθ, Rsinθ
Then,

$$R \sin\theta = \frac{mv^2}{r} \quad \text{–i)}$$

$$R \cos\theta = mg \quad \text{–ii)}$$

Divide eqn i) and ii)

$$\frac{R \sin\theta}{R \cos\theta} = \frac{\frac{mv^2}{r}}{mg}$$

$$\tan\theta = \frac{v^2}{rg} \quad \text{–iii)}$$

as we know,

$$\mu = \tan\theta$$

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

$$v = \sqrt{\mu r g}$$

Angle of banking will be

$$\tan\theta = \frac{v^2}{mg}$$

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

F and f be the applied force and force of friction respect. W be the work done and 's' be the displacement.

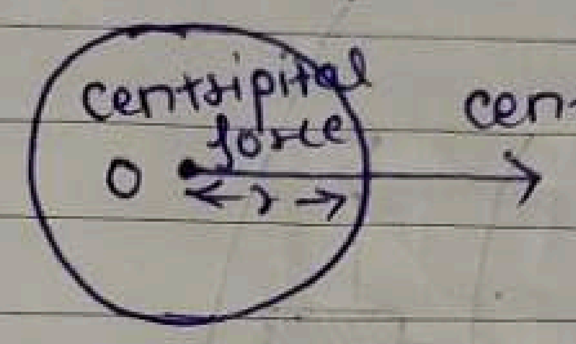
$$W = FS$$
$$W = \mu R.S$$
as, $R = mg$
$$W = \mu mg.S$$

Friction is necessary evil :- 1) walking without friction is not possible.
2) Writting on blackboard and paper is not poss.
3) No to body will stick to each other withou friction.
4) Nuts and Bolts for holding the parts of machinery together will not work.
5) Friction always opposes the relative motion. So, some part of energy loss.
6) Friction causes wear and tear of the parts of machine. So, these lifetime reduces.
7) Friction causes production of heat which damage the machine.

* Circular motion :- If a body moves along the circumference of a circle, then the motion is called circular motion.

* There are two types of force acting in circular motion

1) Centripital force :- It is the force which is required to move a body in a circular path. It acts along the radius and directed towards the centre of the circle.



Consider a body of mass 'm' moves along a circle of radius 'r'. 'a' be the centripital acc.

$$a = \frac{v^2}{r} \quad \text{-i)}$$

where 'v' is the velocity of body
'f' be the centripital force acting on body
as we know,
$$F = ma$$
from eqn (i)

$$\left[F = \frac{mv^2}{r}\right]$$ is called centripetal force.

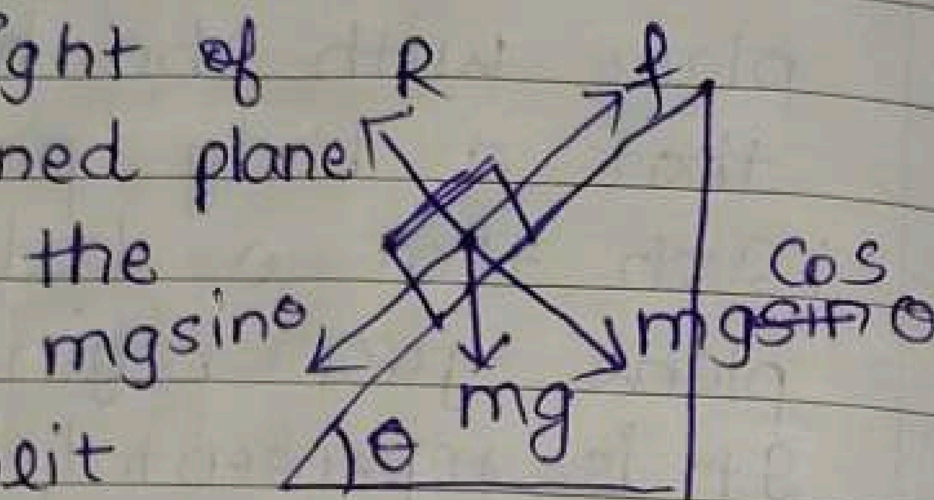
* The force exerted by body which acts outward (away from centre) is known as centrifugal force.
Centrifugal force is given by,
$$F = \frac{mv^2}{r}$$

This method is used in churning of Milk. and also used to seprate some impurties from a given liquid soln.

Date.
Page.

Acceleration of a body moving down an inclined plane :

Let 'mg' be the weight of body placed on inclined plane to slide down. θ be the angle of repose.



The weight 'mg' split into two component.

$mg\cos\theta \rightarrow$ along vertical
$mg\sin\theta \rightarrow$ along horizontal.

'F' and 'R' be the force of friction and normal reaction respec. let 'a' be the acc. produced along slide down.

Then net force = $mg\sin\theta = f$

$ma = mg\sin\theta - f$ — i)

as, $\mu = \frac{F}{R}$

$F = \mu R$

put this value in eqn i)

$ma = mg\sin\theta - \mu R$

as $R = mg\cos\theta$

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

$\cancel{m}a = \cancel{m}(g\sin\theta - \mu g\cos\theta)$

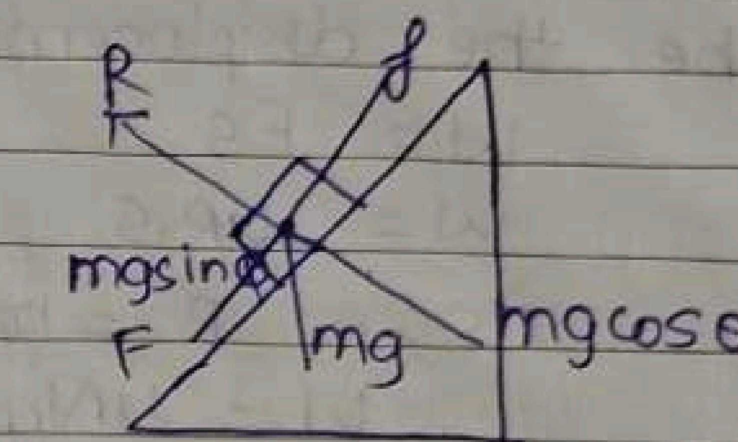
$a = g(\sin\theta - \mu\cos\theta)$

Where μ is called coff. of friction.

Teacher's Signature.........

Date.
Page.

Work done in moving ~~down~~ up on an inclined plane :



Let 'W' be the amount of workdone 'F' be the applied force and 'f' be the force of friction.

The weight 'mg' split into two components

$mg\cos\theta$ — Along vertical
$mg\sin\theta$ — " horizontal.

Then net force will be

$F = f + mg\sin\theta$

as, $F = \mu R$

$F = \mu R + mg\sin\theta$ $\quad \because R = mg\cos\theta$

$= \mu mg\cos\theta + mg\sin\theta$

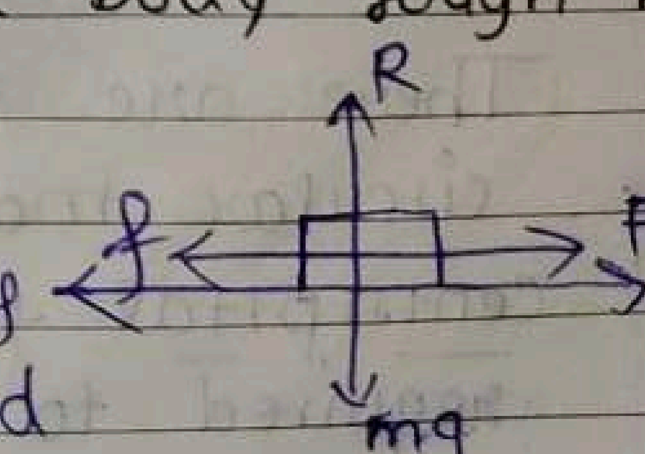
$= mg(\mu\cos\theta + \sin\theta)$

'S' be the displacement and 'W' be the Work done.

$W = Fs$

$W = mg(\mu\cos\theta + \sin\theta).s$

Work done in moving a body rough horiz. surface :



let mg be the weight of body acting in downward direction. R be the normal reaction.

Teacher's Signature.........

Date.|
Page.|

$T_2 + mg = \frac{mv^2}{r}$ — ii)

At high point force of tension should be
$t_2 = 0$

Put this value in eqn (ii)

$0 + mg = \frac{mv^2}{r^2} \quad \left(v_2^2 = gr\right)$

$\sqrt{gr} = v_2$

As total energy of a system remains Constant.
So, energy at point A · Energy at point B

$K.E \text{ at } A = \frac{1}{2}(K.E + P.E) \text{ at } B$

$\frac{1}{2}mv_1^2 = \frac{1}{2}mv_2^2 + mg2r$
$[h = 2r]$

$\frac{1}{2}mv_1^2 = m\left[\frac{v_2^2}{2} + 2gr\right]$

As, we know,

$V_2 = gr$

$\frac{v_1^2}{2} = \frac{gr}{2} + \frac{2gr}{1}$

$\frac{v^1}{2} = \frac{gr + 4gr}{2}$

$v_1 = \sqrt{5gr}$

Thus put value of v_1 in eqn 1st

$T_1 - mg = \frac{m \cdot 5g\cancel{r}}{\cancel{r}}, \quad T_1 - mg = 5gm.$

$T_1 = 5mg + mg$
$T_1 = 6mg$

Teacher's Signature..........

Date.|
Page.|

1) A body of mass 550 gm is moving in circular motion of radius 8cm with velocity of 70cms^{-1} find i) centripital force ii) centri. acc. iii) centrifugal

Soln i) centripetal acc. $= \frac{v^2}{r} = \frac{70 \times 70}{8/2} = \frac{1225}{2} = 612.5$

ii) centripital force $= \frac{mv^2}{r} = 550 \times \frac{v^2}{r} = 550 \times 612.5$
$= 336875N$

iii) centrifugal force = centripital force
$= 336875N$.

2) Find the max. speed at which a car can take a round 30cm on level road. If coffi. of friction b/w tyre and road is 0.4?

Soln $V = \sqrt{\mu rg} \quad \mu = 0.04, \ r = 0.3m, \ g = 10ms^{-2}$

$V = \sqrt{0.4 \times 0.3 \times 10}$

$V = \sqrt{1.2}$

$V = 1.09ms^{-1}$

3) A car travelling at Speed of $7ms^{-1}$ takes a round off radius $5\sqrt{3}$m ~~on~~ a banked road. find angle.

$\tan\theta = \frac{v^2}{rg} \qquad V = 7ms^{-1}$
$r = 5\sqrt{3}$
$g = 10ms^{-2}$

$= \frac{7 \times 7 \times 10}{5\sqrt{3} \times 9.8}$

$\tan\theta = \frac{1}{\sqrt{3}} = 30°$

4) A cyclist moving with a speed of $7ms^{-1}$ takes a turn around a circular path of radius 5m. What is indication of cyclist?

Teacher's Signature..........

$v = 7ms^{-1}$
$r = 5m$
$g = 9.8ms^{-2}$

$\tan\theta = \frac{v^2}{rg} = \frac{7\times7}{5\times9.8} = 1$

$\tan\theta = 1$
$\theta = 45°$

5) In a circus the radius of globe of death is 10m. From what minimum height must a cyclist start in order to go round the globe successfully?

Sol^n – $m.g.h = \frac{1}{2}mv^2$ $\qquad v = \sqrt{5gr}$

$gh = \frac{1}{2}v^2$ $\qquad = \sqrt{5\times10\times10}$

$\qquad v^2 = 5gr$

$gh = \frac{1}{2}5gr$

$h = \frac{5}{2}r$

$\Rightarrow h = 2.5\times10$

$\Rightarrow h = 25m$

Good

Ayadav
27/7/23

Chapter- 1st
Work, Energy AND Power
Unit-4

* Work:- Work is said to be done by a force acting on a body. If it covers some displace. This displacement can be done in the direct. of force. ⊥ to the direction of force, opp. to the direction of force. Work done by a constant force is product of force and displace.

$W = F.S$

Work done is a scalar quantity

$W = fs\cos\theta$, where θ is angle b/w force and displacement

Dimensional formula of work done is $M^1L^2T^{-2}$

* Units of Work:-

i) Absolute units:-

a) S.I unit:- S.I unit of workdone is Joule.

$W = F.S$, $1J = 1Nm$.

When a force of 1N displace a body through 1m then workdone will be one joule.

b) C.G.S unit (~~second~~):- C.G.S unit of workdone is erg.

$W = Fs$

$1 erg = 1 dyne.cm$.

Work done is said to be 1 erg when force of 1 dyne displace a body through 1cm.

Relation b/w Joule and erg

$1J = 10^7 erg$.