SPEED, VELOCITY, ACCELERATION

- Average speed: $\frac{\text{Total distance}}{\text{total time taken}}$

  (Speed : scalar quantity)

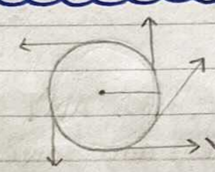
> Velocity may change though the speed remains constant if the direction only changes.
>
> But if speed changes v changes

- Velocity

(i) Average velocity: rate of change of displacement.

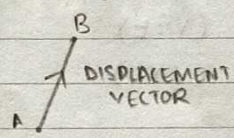
$v = \frac{\Delta x}{\Delta t}$ $\qquad \frac{\text{total displacement}}{\text{total time}}$

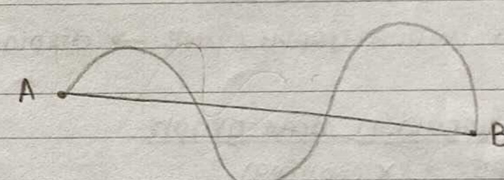
(V : vector quantity)



(ii) Instaneous velocity : velocity of a body at a given instant of time.

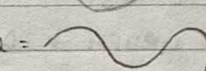
- Displacement : shortest distance between 2 points / directional distance.
  (vector quantity).
  eg. 150 m due north
  eg. 150m +ve direction.
  The final position / location.



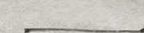


- Distance : length of path travelled by body
  (scalar quantity)
  eg. 150 m

Distance =



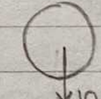
Displacement =



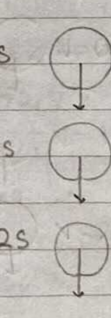
- Acceleration : rate of change of velocity.

(i) Average acceleration = $\frac{\text{change in velocity}}{\text{time taken}}$

$a = \frac{\Delta v}{\Delta t}$ $\qquad a = \frac{\Delta}{\Delta t}\left(\frac{\Delta x}{\Delta t}\right)$ $\qquad a = \frac{v-u}{t}$



velocity of the body changes by 10 m/s every second



FORMULAE

$v = u + at$ (as $a = \frac{v-u}{t}$) for constant a.

s or $x = ut + \frac{1}{2}gt^2$

$v^2 = u^2 + 2ax$

↓

if $u = 0$, $s = \frac{1}{2}at^2$ and $v = at$.

Δt = time interval

Vector and scalar

Vector quantities: physical quantities with magnitude and a direction. $\overline{V}$, $\overline{a}$, $\overline{p}$

Scalar: quantities: physical quantities with only magnitude. m, t

Distance: summation of all individual displacements btwn 2 points.

speed: magnitude of velocity.

Acceleration

Positive acceleration:

(i) acceleration in which the velocity increases

(ii) acceleration in the velocity's direction

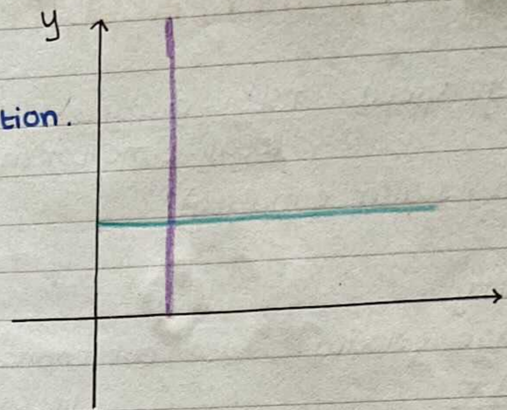
Negative acceleration:

(i) acceleration in which the velocity decreases.

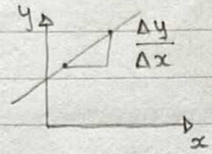
(ii) acceleration in the opposite direction to the velocity.

2.02

MOTION GRAPHS (UNIFORM MOTION)



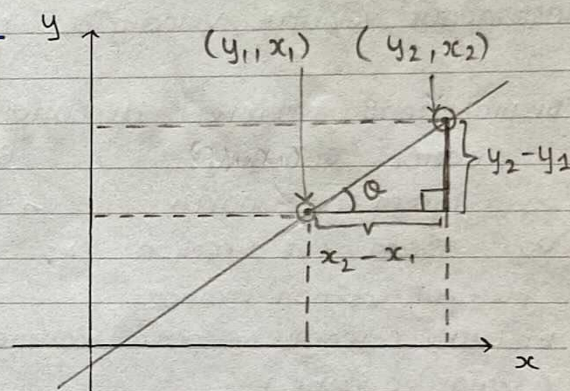
- every straight line can be expressed as a linear equation.
  $y = mx + c$
  m: slope and c = y interupt
- Slope = $\frac{\Delta y}{\Delta x}$ or $\frac{y_2 - y_1}{x_2 - x_1}$



To calculate it, take ANY 2 points (on a straight line) and solve $y_2 - y_1 \div x_2 - x_1$.

y is constant slope = 0
x is constant slope = ∞

—— x —— x —— x —— x ——



<u>Velocity time graph.</u>
SLOPE → acceleration. $(v \div t)$
AREA UNDER GRAPH / LINE → displacement $(v \times t)$

<u>Acceleration time graph</u>
SLOPE → x (nothing)
AREA UNDER GRAPH → Δ velocity. $(a \times t)$.

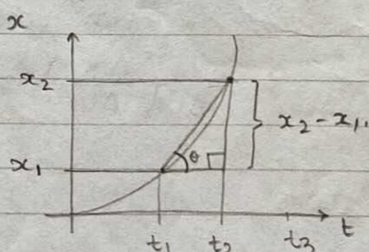
$\tan\theta = \frac{y_2 - y_1}{x_2 - x_1} = \frac{y_1 - y_2}{x_1 - x_2}$

$\tan\theta$ = slope.

<u>Displacement time graph</u>
SLOPE → velocity

—— x —— x ——

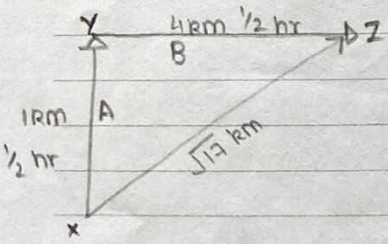
<u>DISTANCE - TIME graph</u>
SLOPE → speed.



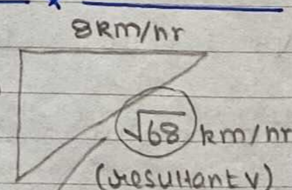
avg. v = $\frac{x_2 - x_1}{t_2 - t_1}$

<u>Speed time graph</u>
SLOPE → acceleration
AREA UNDER GRAPH → distance.

—— x —— x —— x —— x —— x ——



- A and B are displacement vectors
- From x to y $(\overline{XY})$, from y to z $(\overline{YZ})$
  Overall disp = $\overline{XZ}$
- velocity$_{X}^{Y}{\uparrow}$ = $\frac{1}{0.5}$ km/hr = 2 km/hr



Different answers

★ Avg. velocity: $\frac{\text{Disp}}{\text{total time}}$.
↓
Total time taken to cover the distance. No pythogoras for the time.

velocity$^{Y \to Z}$ = $\frac{4}{0.5}$ km/hr = 8 km/hr

- Avg. velocity = $\frac{\text{DISP}}{\text{TOTAL time}}$ = $\frac{\sqrt{17}}{1/2 + 1/2}$ = $\frac{\sqrt{17}}{1}$ km/hr

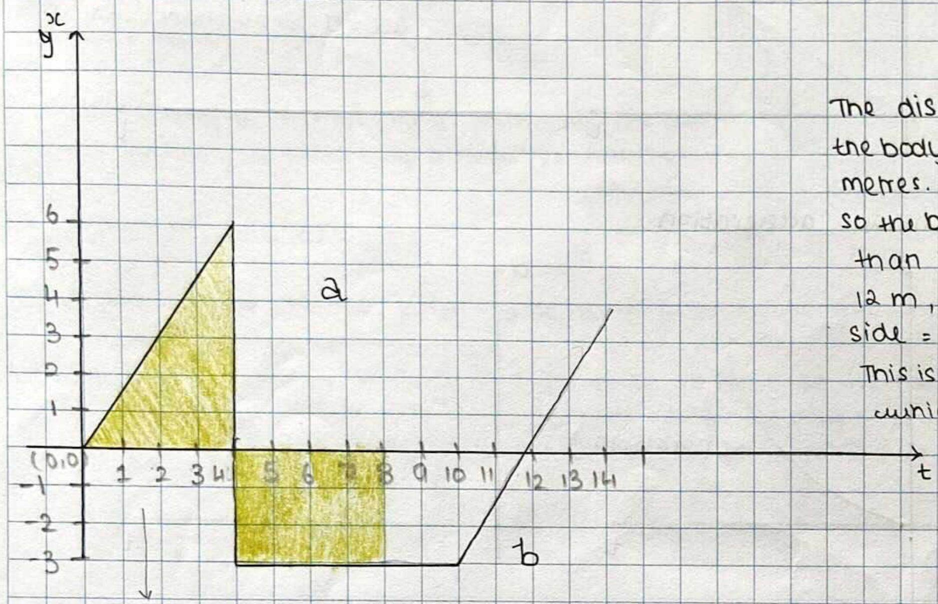
GRAPHS

Solving problems

① If the body is at $x = 0$ and at $t = 0$, when will it return to origin?

↓

Find out when the displacement is cancelled out.

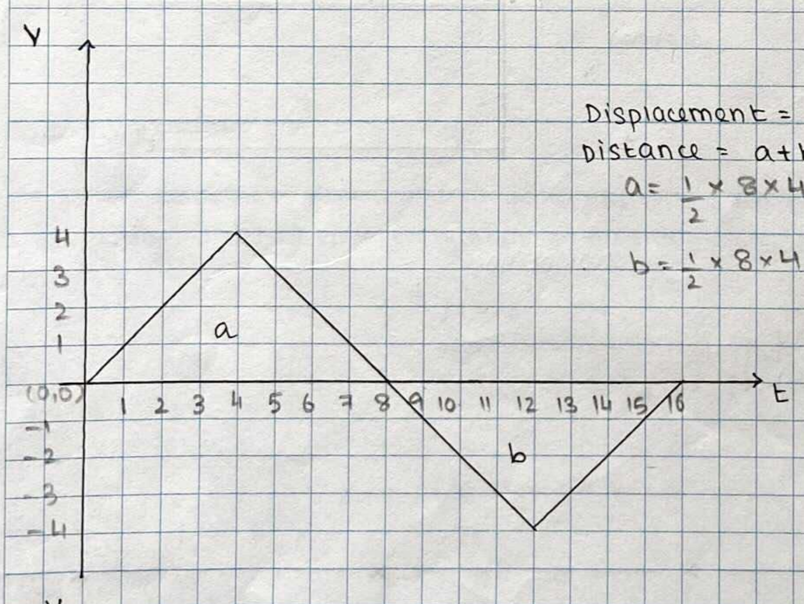


The displacement at a is positive → so the body is moving to the right - and is 12 metres. The displacement at b is negative → so the body moves to the left (towards its origin) - and is more than 12 m. When the disp on b reaches 12 m, the positive side = 12 m and negative side = - 12 m so it cancels out.

This is when the body is at 0 m $(12 + (-12)) = 0$ which is its origin. This is at $t = 8$ seconds.

Area $= \frac{1}{2} \times 4 \times 6 = 12$ m.

② Find the distance and the displacement.



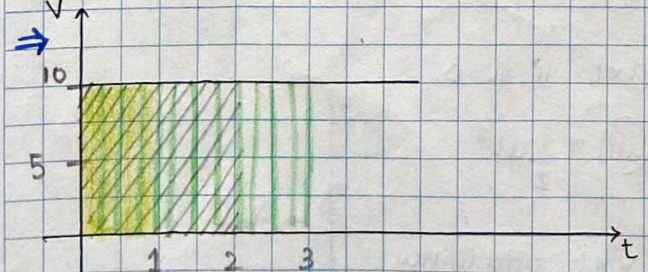
Displacement = a - b ⇒ $16 - 16 = 0$ m

Distance = a + b.

$a = \frac{1}{2} \times 8 \times 4 = 16$ ⇒ $16 + 16 = 32$ m.

$b = \frac{1}{2} \times 8 \times 4 = 16$

⇒



→ t1 → $10 \times 1 = 10$ m

→ t2 → $10 \times 2 = 20$ m

→ t3 → $10 \times 3 = 30$ m

negative and positive velocity means the direction the body is travelling in.

↓

negative velocity = reversed direction (left)

positive velocity = forward direction (right)

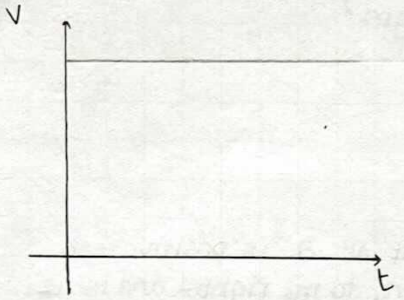
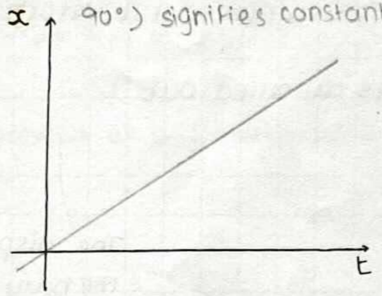
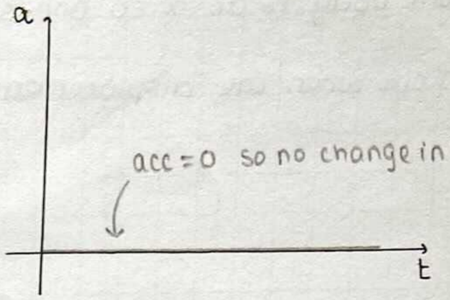
in some case posite v is taken as left

In the negative quadrant the '−' sign doesn't mean a literal -ve velocity! So −10 m/s means 10 m/s in the reversed direction / opposite direction.

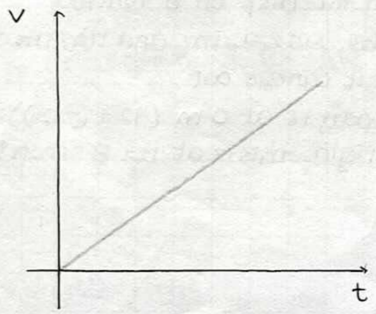
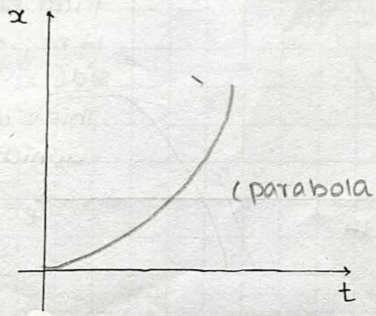
cases.

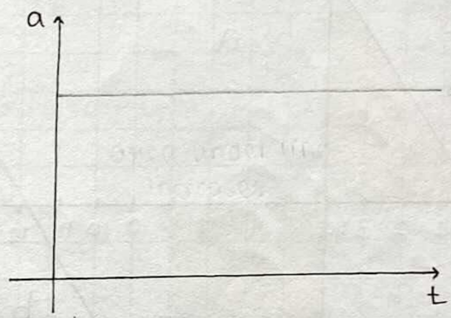
CASE (i) constant velocity

a straight line making any angle with the x axis (except 90°) signifies constant v

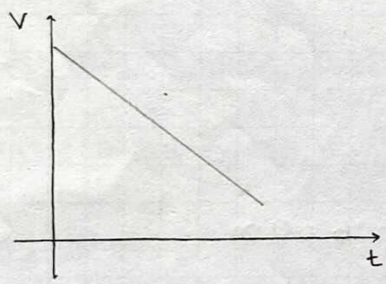
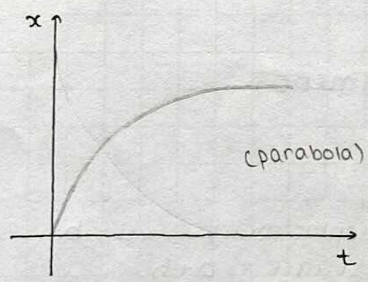




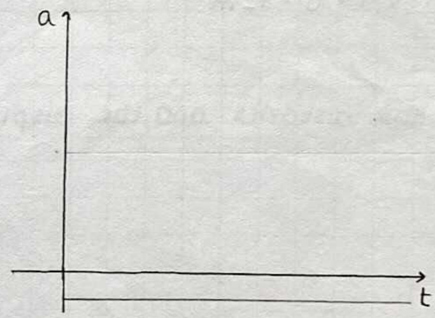
CASE (ii) increasing velocity , constant acceleration

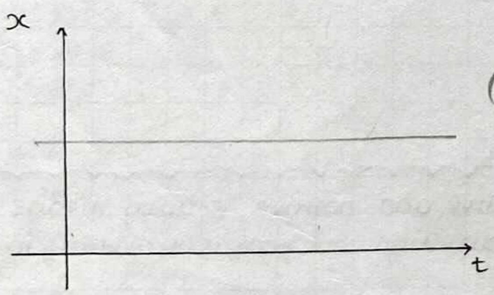


CASE (iii) Decreasing velocity , constant acceleration

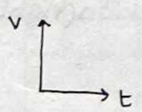
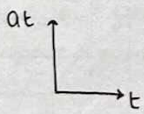





CASE (iv) VELOCITY = 0.



x ———— x ———— x ———— x ———— x ———— x ————

 = 

as $a = \frac{v-u}{t} \Rightarrow v = a \times t$ if $u = 0$.

disp = $\frac{1}{2} \times b \times h$: $b = t$ $h = v = at$.

$x = \frac{1}{2} \times t \times at = \frac{1}{2} at^2$

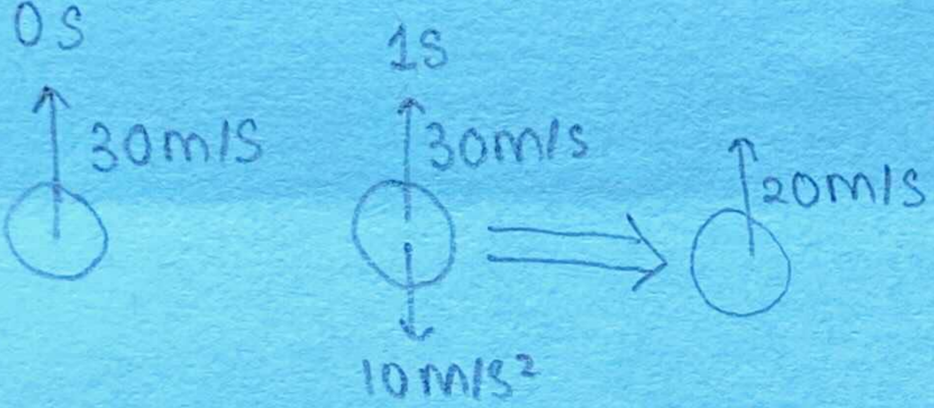
] $u = 0$

$x = ut + \frac{1}{2} at^2$

disp = $v \times t$, and initial velocity (v) = u.

] $u \neq 0$

2.04

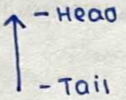


- Direction of acceleration = same direction as the net force.
- a = downwards here as the net force = mg = weight which acts downwards (mg : m is scalar, g is ↓)
- (Balanced Forces : Fnet = 0 : a = 0)
- $a = \frac{F}{m} = \frac{-mg}{m} = -g = -10 m/s^2$ $\quad$ $30 m/s + (-10 m/s) = 20 m/s.$

taking downward velocity as -ve.

MORE ABOUT VECTORS

- Representation of a vector quantity :



To add 2 vectors you have to know the direction and magnitude.

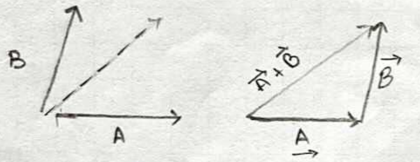
vector x vector = vector
vector x scalar = vector

If we multiply a number by a positive no. the direction of the resulting vector remains the same.
If we multiply a vector by a negative number the direction is reversed.

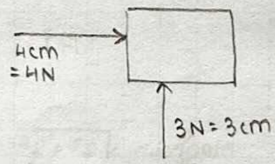
Addition of 2 vectors

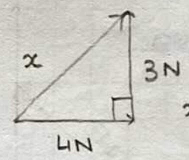
A vector can be shifted parallely to itself (keeping length unchanged and direction unchanged)

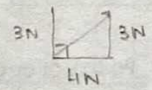
Triangle law: shift vector $(\vec{B})$ parallel to itself so its tail joins A's head.
Join the remaining ends : resultant vector $(\vec{A}+\vec{B})$. Its tail should join the free tail and head the free head.



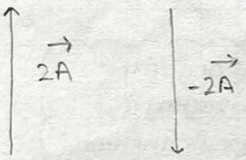
EG:





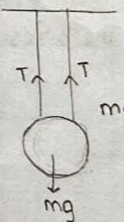


$x \rightarrow$ pythagoras theorem.

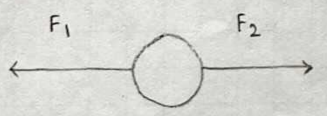


Force diagrams

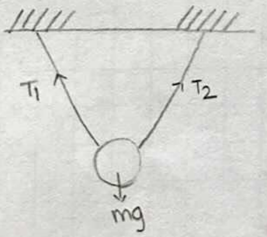
- A string developes a tension when a force acts on it. Tension in one string is unique to the string. The tension must be equal everywhere on the string.



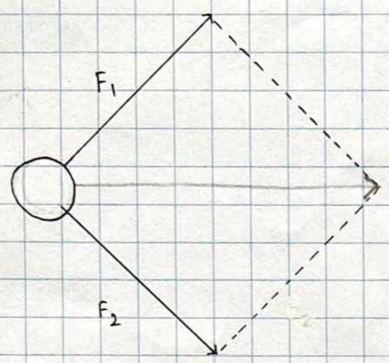
mg = 2T



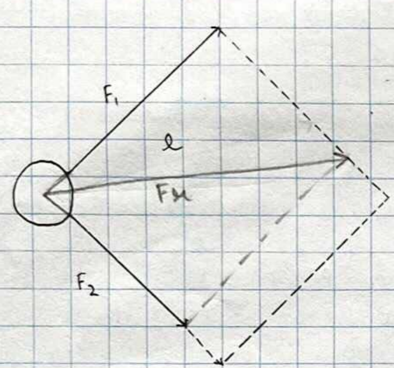
$F1 = F2$
when acceleration = 0 , no change of uniform motion
So Fnet = 0 and $F1 = F_2$ $(F_1 - F_2 = 0)$. $(F_1 + F_2 = 0$; take one of the forces as -ve due to opp direction in this case)



Symmetrical figure as strings' lengths are equal/same height.



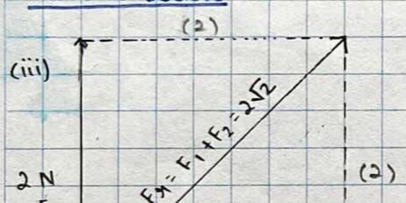
When you pull the strings with an equal force the ball moves diagonally so a quadrilateral is formed somewhere.
$F_1 = F_2$



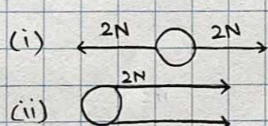
F_{r} = resultant force.
l → length of vector = magnitude of resultant.

• Parallelogram law of vector addition: $\vec{F_{r}} = \vec{F_1} + \vec{F_2}$
$F_1 > F_2$

Parallel vectors



Diagonal $= \sqrt{2^2+2^2} = \sqrt{8} = \sqrt{4\times 2} = 2\sqrt{2}$ N

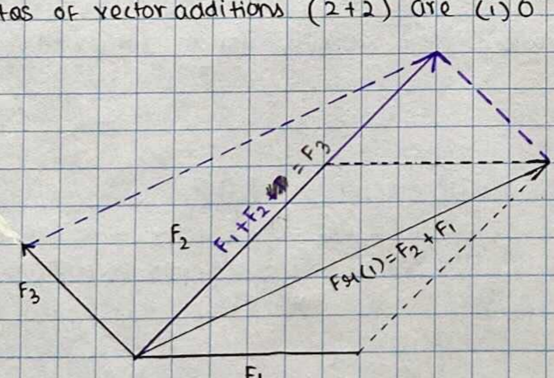


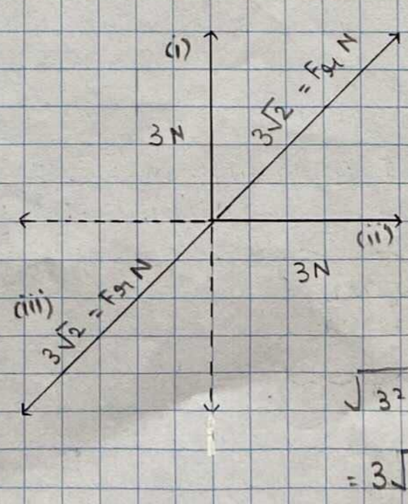
(i) $F_r = 2N + (-2N) = 0$

(ii) $F_r = 2N + 2N = 4N$

-2N as one of the forces is acting in the opposite direction.

The 3 results of vector additions $(\bar{2}+\bar{2})$ are (i) 0 (ii) 4N (iii) $2\sqrt{2}$ N, so: $0 \le \bar{2}+\bar{2} \le 4$





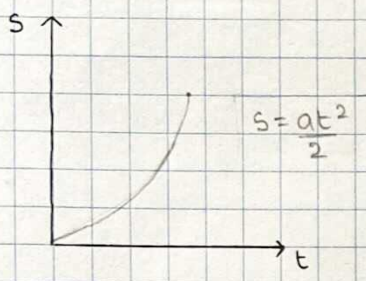
It is possible for a number of concurrent forces to = 0. (concurrent forces act on the same point).
$\Sigma \bar{F_i} = 0$ $F_1 + F_2 + F_3 \dots + F_n = 0$
(i = any no. of forces)

$\sqrt{3^2+3^2} = \sqrt{18} = \sqrt{9\times 2}$

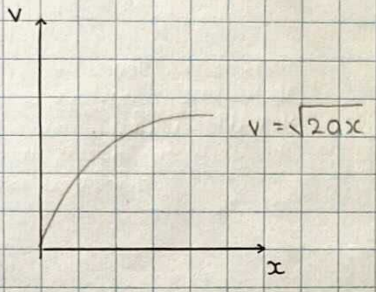
$= 3\sqrt{2}$ N

MORE MOTION GRAPHS (PARABOLAS, CURVES)

Parabolas.
($y = ax^2 + bx + c$)



Displacement(s) is parabolic with respect to time for uniform accelerated motion.



uniform acceleration, so the graph is a parabola.

$v^2 = u^2 + 2ax$
$v^2 = 2ax \quad u = 0$
$v = \sqrt{2ax}$

the equations such as $s = \frac{at^2}{2}$ show that the ratio increase is calculated through a formula and is not random. so, the equations show that the graph is a parabola.

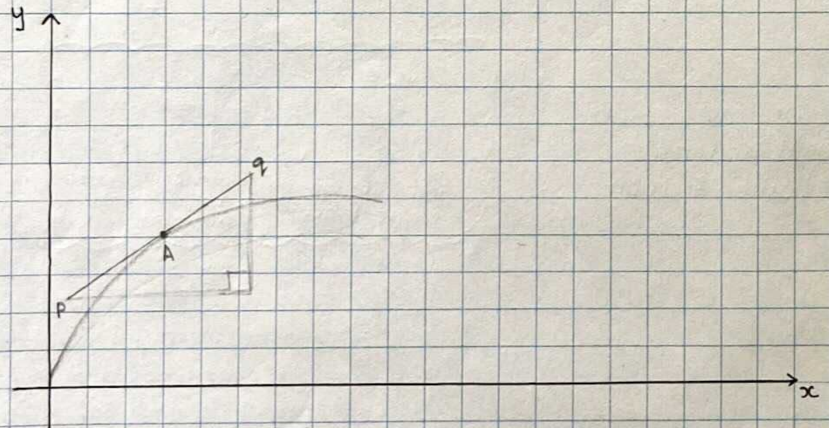
(A curve is a combination of infinity small, straight line segments (tangents) inclined at some angle)

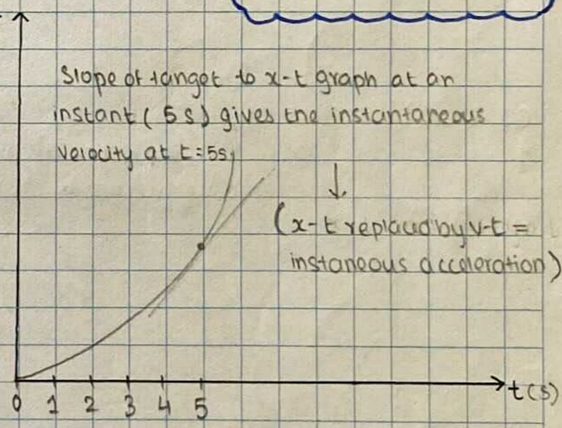
Slopes

(i) INSTANTANEOUS

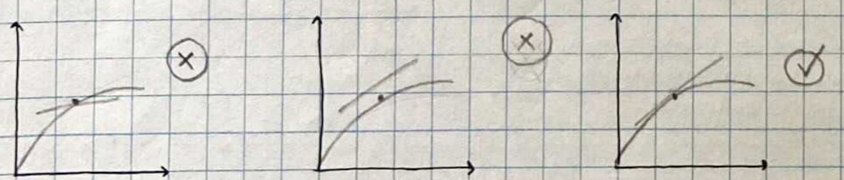
The slope of a curve is found at a specific point by drawing a tangent.
A tangent is a straight line touching the curve at that given point.

Specific point could be at a specific instant of time. eg at 2s.





The slope of the tangent (p, q) gives the slope of the curve at that point.

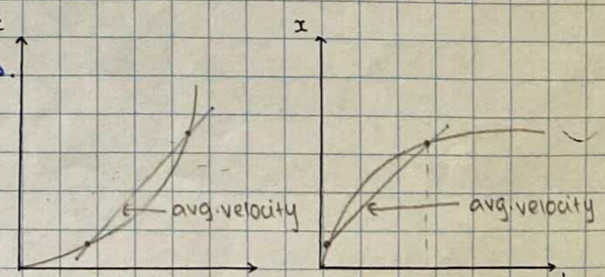


✗ = not a tangent
✓ = tangent

(ii) AVERAGE

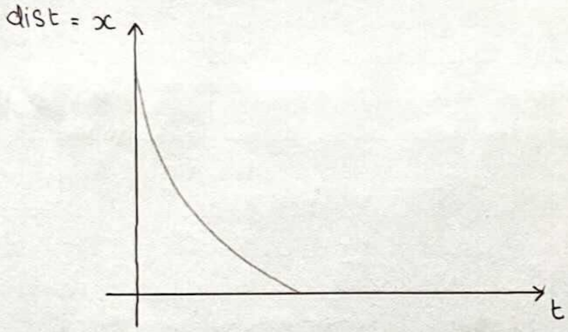
Draw a seacant.
A seacant is a straight line that cuts a curve at two points.

Slope of seacant to x-t graph between 2 instants gives the average velocity between the 2 instants.



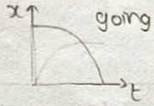
Cases

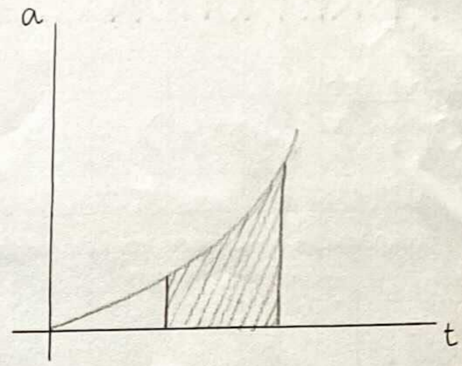
case (i) Decreasing speed



- Decreasing velocity as well

Increasing speed = increasing magnitude of velocity. However the velocity's direction is decreasing (going back to origin)

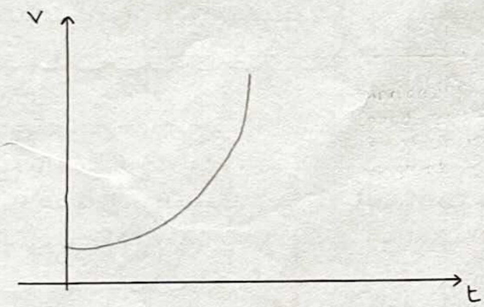


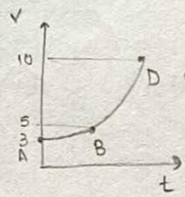


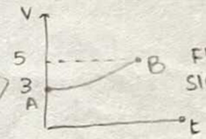
$$a = \frac{(v_2 - v_1)}{(t_2 - t_1)}$$

$$a(t_2 - t_1) = \Delta v$$

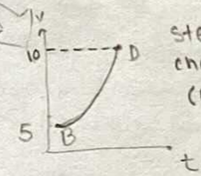
case (ii) Increasing acceleration



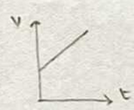




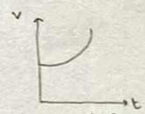
Flat slope, so v hardly changes (5-3=2) so a is less



steep slope so v changes significantly (10-5=5) so a increases

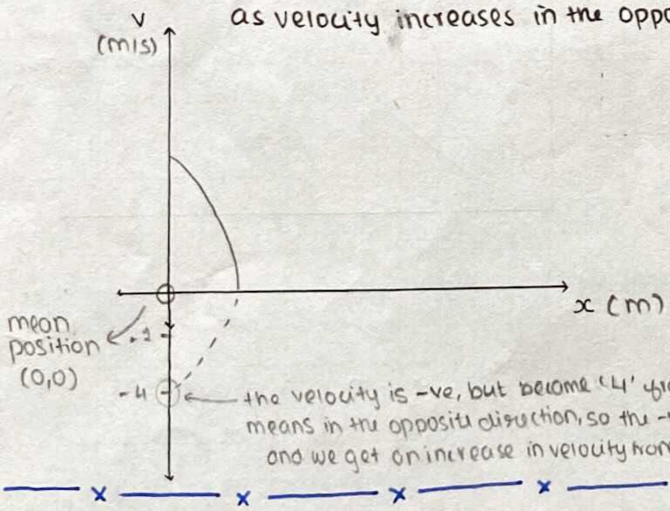


increasing speed, constant acc



Increasing speed, not constant & increasing acc.

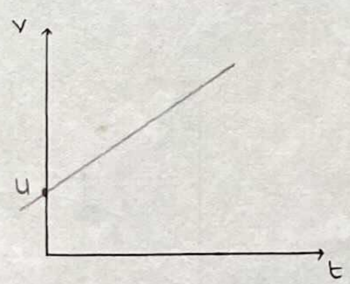
case (iii) Increasing displacement with reducing velocity and then the ~~opposite~~ displacement decreases as velocity increases in the opposite direction.



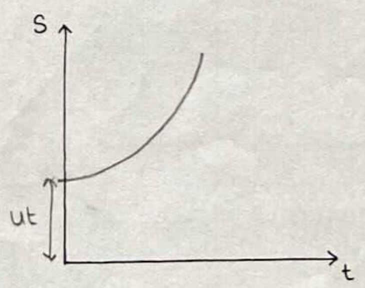
the velocity is -ve, but become '4' from '1'. The -ve simply means in the opposite direction, so the -ve sign can be removed and we get an increase in velocity from 1 to 4. m/s

Eg: throwing up a ball
eg: a pendulum: its velocity is max at mean position. The x signifies its amplitude, which increases as the velocity decreases at the extreme positions.

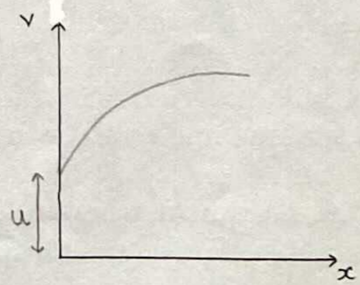
— x — x — x — x — x — x — x — x — x — x — x —



$v = u + at$



$s = ut + \frac{1}{2}at^2$



$v^2 = u^2 + 2as$

Force

Any kind of change that tends to bring about a change in state (state of rest / motion) or shape/ size. Its presence is felt when it has an interaction with matter.

2.06

FORCES IN BALANCE

Newtons 1st law of motion: law of inertia. (in a straight line)

A body continues to be in its state of rest or uniform motion unless an external force is applied on it/ acted upon by an external, unbalanced force.

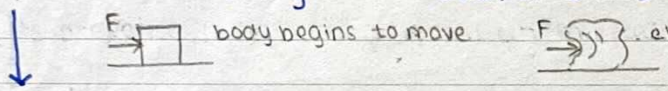
Factors: (i) velocity (uniform motion in a straight line) remains constant.
(ii) velocity changes only if $\Sigma F \neq 0$. net F (summation of F $\neq 0$)

<u>inertia</u>

Resistance of any object to the application of force with respect to its change in state of motion/ rest. In a physical object, <u>mass</u> is the inertia of any object.

<u>Force</u>

- A physical/ non-physical interaction that changes / tries to change the state of rest / motion in a straight line and/or the shape of an object.



- Assumption: no dissipation (loss) of energy.

when energy transforms from 1 form to another, it tends to lose some energy in the form of heat energy, etc.

- Any Δv implies the presence of an acceleration. So, a force brings about an acceleration. Δv = Force involved.
$\bar{F} \propto \bar{a}$ ($\bar{a} \propto \bar{F}$)

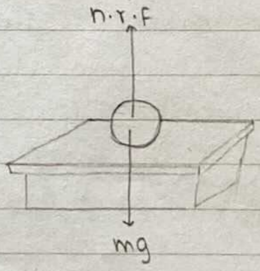
acc. is directly proportionate to the amt. of F applied.

★ net force = m×a.

<u>Forces in balance</u>

when the resultant force = 0.
Forces are in balance when:
(i) either the body is at rest
(ii) there is a constant velocity

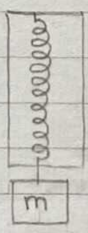
EG.



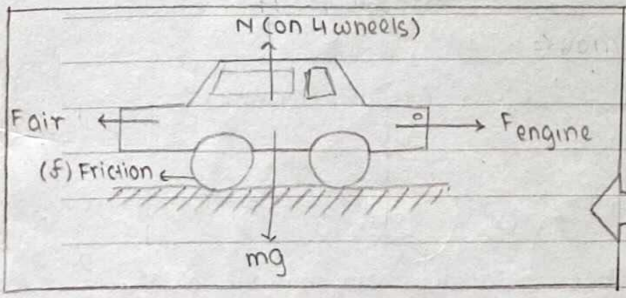
Forces acting:
(i) mg
(ii) normal reaction force
mg = N.r.f

support = normal reaction force.

EG.



Forces acting:
(i) Tension / spring force
(ii) mg
mg = T



Forces in vertical direction are balanced $N = mg$

Forces in horizontal direction are balanced $F_{air} + f = F_{engine}$

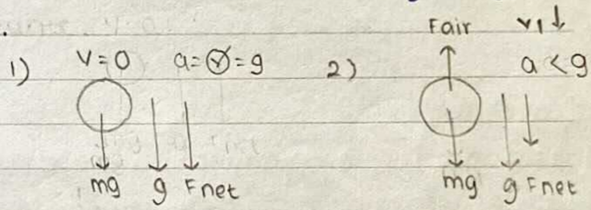
(F_{air} = air resistance)

EFFECT OF AIR RESISTANCE

Air resistance → F_{air} Net force → F_{net}

$F_{air} \propto$ velocity / speed.
$F_{air} \propto$ surface area.

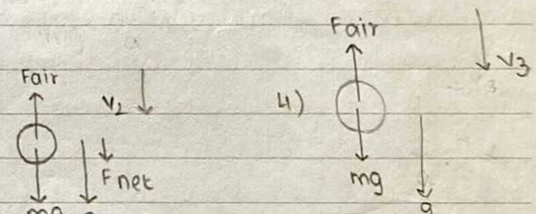
EG. 1) The moment a raindrop is dropped from the cloud: $V = 0$, force acting = mg,
F_{net} : downwards, acceleration: downwards.
↓
F_{net} and a are the same magnitude.



2) As speed increases so does the air resistance.
V = present, $F_{net} < g$

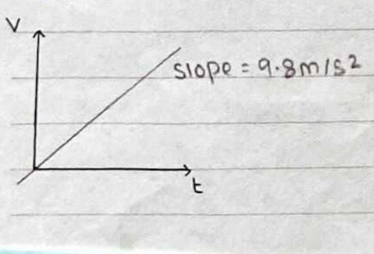
3) The speed further increases (due to a) and the air resistance increases. $F_{net} << g$.
↳ g = constant
a = decreasing ?

4) The forces are in balance, $F_{net} = 0$.
↓
$F_{net} = m \times a$, if $a = 0$ (constant v), then $F_{net} = 0$.
a keeps reducing as $a = \frac{F_{net}}{m}$ and F_{net} keeps decreasing.
Acceleration is zero

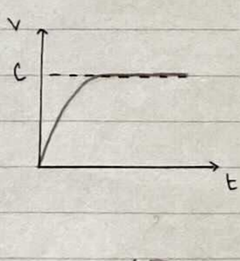


when someone jumps off a plane, their speed ↑ so even Fair ↑, but there is the possibility that the terminal velocity is failed to reach and the person continues to accelerate. Even if terminal velocity is reached, it could be a vv ↑ terminal velocity you fall with dangerous. The speed can't be controlled, but the surface area can. when the person opens his/her parachute the surface area is ↑, so the air resistance is ↑, helping the skydiver to reach their terminal velocity, low T.V and reach and land on the ground smoothly.

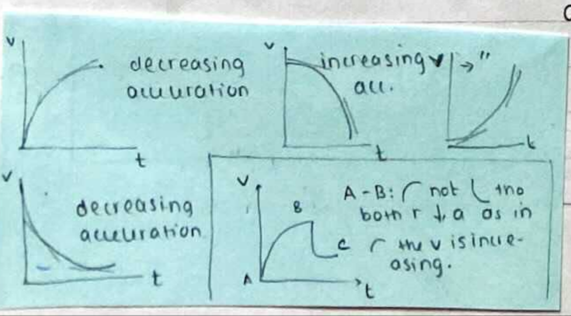
Graphs

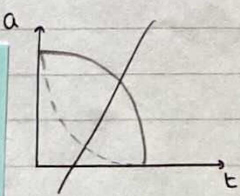


Velocity of a falling body without F_{air}.
$a = \frac{F}{m} = \frac{mg}{m} = g = 9.8\ m/s^2$



Velocity of a falling body with Fair.
(Reaches terminal v)



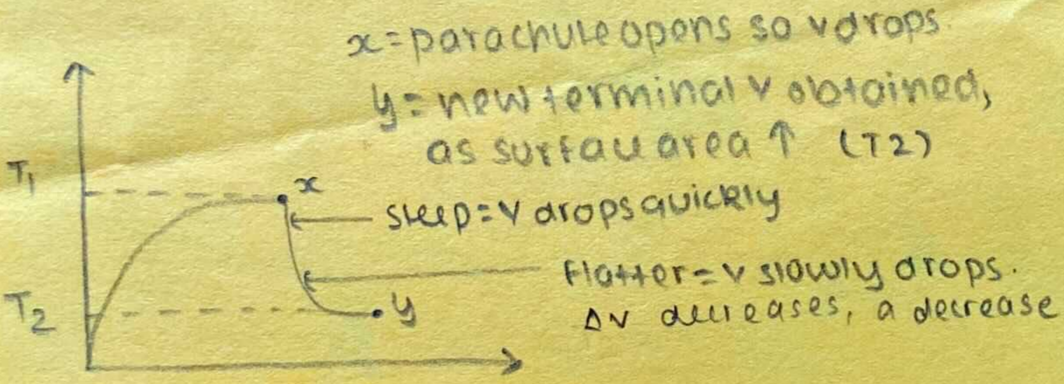


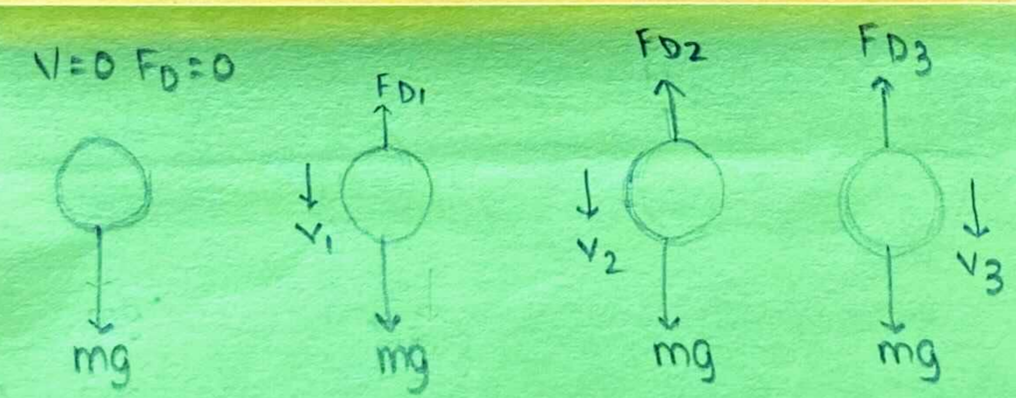
~~with Fair~~
~~acc changes at a slow rate initially as Fair is less due to the less speed~~

Fnet decreases as the particle goes down. At a point Fnet $= 0$, so $a = 0$ and $v =$ constant; particle falls with constant v as the drag forces balanced the weight of the object.

Uniform / constant v = terminal velocity

→ object moved in a fluid which offers some resistance to motion. Here, it is air resistance.





Fnet $= mg$

Fnet $= mg - F_{D1}$
$mg > F_{D1}$

Fnet $= mg - F_{D2}$
$mg > F_{D2}$

Fnet $= 0$
$mg = F_{D3}$

weight (mg) balanced

- 1st case Fnet $= mg - F_D = mg - 0 = mg$.
The net F is maximum

- Last case Fnet $= mg - F_{D3}$ but they are equal, so Fnet $= 0$. $a = 0$
v = constant = terminal v.

$V_3 > V_2 > V_1 > V_0$ $F_{D3} > F_{D2} > F_{D1}$

$V \propto F_D$ (F_D: drag force)

2.07

FORCE, MASS, ACCELERATION

Resultant $F = \frac{mv - mu}{t} = \frac{m(v-u)}{t} = ma$

Newton's 2nd law of motion : $F = ma$. $F_{net} = ma$

Resultant $F \propto mv - mu$

(The resultant force acting on a body is directly proportional to rate of change of momentum of the object. This change takes place in the direction of the resultant / applied force)

The acceleration of an object produced by net force = (i) directly proportional to the magnitude of the net force, (ii) same direction as the net force (iii) inversely proportional to the object's mass.

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

Force to stop smthing $\propto$ to mass and velocity.

Force $\propto$ rate of change of momentum.

↓

$F \propto \frac{\Delta P}{\Delta t}$, $F = k\left(\frac{\Delta P}{\Delta t}\right)$ $k = 1$.

$$F = \frac{\Delta P}{\Delta t} = \frac{P_f - P_i}{\Delta t} = \frac{mv_f - mu}{\Delta t} = m\frac{(v_f - u)}{\Delta t} = ma \qquad F = ma$$

Outcome of force : change in (i) state of rest (ii) velocity
(Δ motion or Δ direction)

2.08

FRICTION

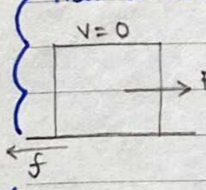
F = applied force

f = friction force.

1. Friction opposes / tries to oppose relative motion or tendency of motion between the surfaces in contact. (and acts in a direction that does so). It is a surface phenomenon.
IT DOES NOT ALWAYS ACT IN THE OPPOSITE DIRECTION!

Friction is a force which acts at the contact of 2 surfaces. It acts equally on both surfaces (due to action x reaction).

If there is no motion F = f. When you apply a force but there is no motion, the object has a tendency to move but doesn't move.



$\Sigma F = 0$

Box: friction in the backward direction -x direction

Ground: Friction in the forward direction +x direction

Relative motion → way, friction ← way

Relative motion: one is fixed and the other is moving.

If friction is successful : no motion If failed : motion

Friction is a self-adjusting force when there is a tendency of motion but no actual motion
↳ static

2• Friction is independant of area of contact.

FRICTION
- STATIC
- DYNAMIC / KINETIC

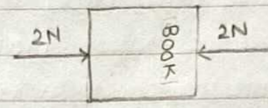
Static friction: Friction acting between 2 surfaces when there is no relative motion between them / object is at rest.

(Friction is ↑ so the object doesn't move.)

BIRD'S EYE VIEW.

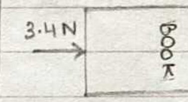
Fnet = 0.

← 2N = f = applied by table surface.



Fnet = 0

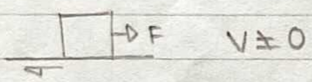
Friction increases, it adjusts its value so the net force = 0.

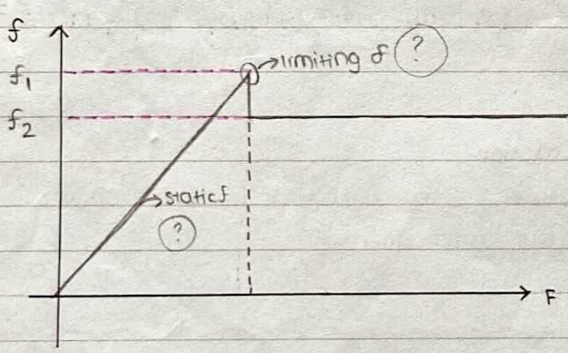


Fnet = ✓ The book starts to move at this point.

A jerk's felt, you can apply a little lower F to keep the object in motion (eg. 3.3 N).

Dynamic friction: friction acting between 2 surfaces when there is a relative motion between them / when the object starts to move. Also called: kinetic friction





f_1 = limiting friction

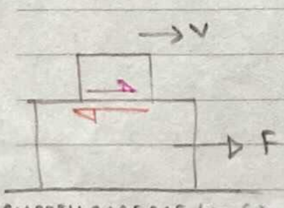
f_2 = dynamic friction

throughout / the object is stationary.

to maintain a body's motion a F (F_1) is required. when the body stops moving the surfaces interlock, the force (F_2) required to remove this interlock is larger.
$F_2 > F_1$

- when the f drops, F remains constant.
- when a body is in motion f = constant as long as the surface is the same.
  (dynamic friction remains unchanged)

- limiting friction: maximum frictional force. A surface cant infinitely apply / provide f.
  limiting friction > dynamic friction static f $\xrightarrow{\text{limiting } f}$ dynamic F it is not static f.
- Factors for friction: (i) Nature of material (ii) Normal motion.



- both boxes move in → direction, although there is no external F applied on the top box. The F that keeps it from falling (when the bodies are moving slowly the top box doesn't fall) is friction.
- If there was no f, the top box would fall ( ).
- The top box tries to remain at rest → inertia.

applied by the big box on the small box

applied by small box on the big box

FRICTION

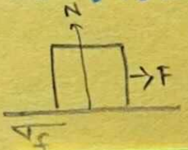
- f independant of :
(i) $\bar{v}$, $\bar{x}$, $\bar{a}$
(ii) area of contact

Nature:
wet/dry/
rough/smooth

- f is dependant on :
(i) Nature of surfaces in contact.(of material)
(ii) Normal reaction.

Fundamental difference btwn static and dynamic f: static f is a self adjusting force while dynamic f is constant.

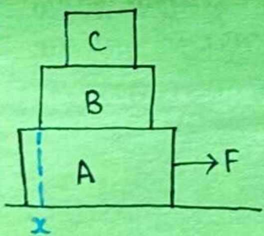
static f = F applied, hence called a self - adjusting force.



↑f so the object is static

F = ma
↓
Dicipative force is absent.
Even if the force is very less, and the mass is very great there will be movement.
↓
some amount of acceleration, according to the formula, will be possible.

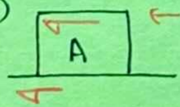
static friction - amt. of applied force, so its called self adjusting force. It adjusts itself according to the F, to match the F



(Friction is present)

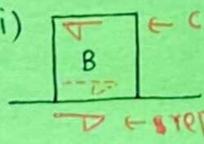
B's aim/tendency: to remain at the same point, x.

(i)



← as b tries to pull A back to this ← side.

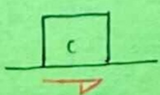
(ii)



← c tries to pull B back to ←side.

← represent like this, but it acts on B.

(iii)



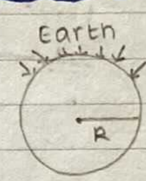
2.09

FORCE, WEIGHT, AND GRAVITY

- $F = m \times a$, but ma is not a force.
- $F = mg$ $a \Rightarrow g =$ ~~acceleration by Earth = 9.8 m/s²~~ (i) acc. due to gravity (9.8 ms-2) (ii) gravitational Field strength (10 N/kg).
  $g =$ ~~acceleration due to gravity.~~

we use 'g' as 'a' when the object is very close to the Earth's surface.

- if $h << R$ then g = constant
  (h: height, R: Radius of Earth = 6400 km, $<<$ = lesser than lesser than).



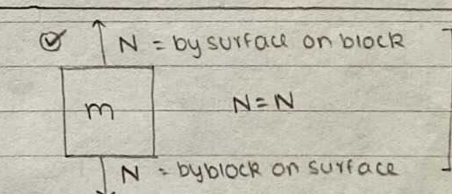
- $w = mg$.
  The weight of an object changes with g, so the weight of an object will be different on different planets. Mass never changes.
  EG: on moon: g's value = 1/6 th of it on Earth.
  ↓
  smaller the mass, smaller the gravitational pull (gravitational force, weight)

2.10

ACTION AND RE-ACTION

acting on different bodies.

Newton's 3rd law of motion:
Every action has an equal but opposite re-action and the action and reaction forces act on 2 different objects.

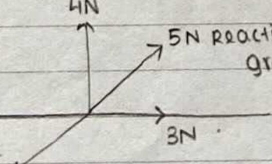


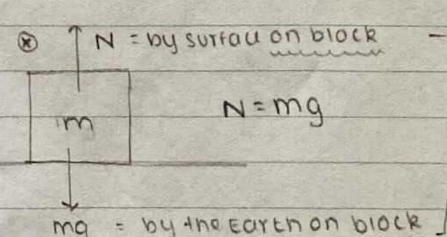
When you press a wall, you feel a force on your arm. When the force you apply to press the wall increases, the force you feel in your arm also ↑.

NOTE: The block (m) is actually on the table's surface, but has been separated / isolated to clarify the forces acting.

EG. Walking ⇒ press a force backwards.

→

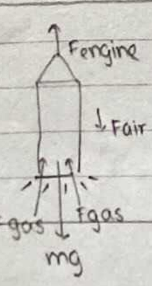




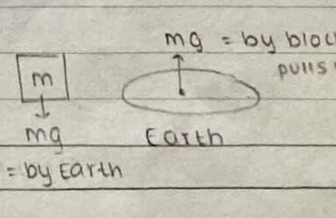
They are =, opposite, but not action and reaction as they act on the same body

FREE BODY DIAGRAM (all F acting on object shown)

→



Rocket exerts F on the gas causing it to move out
Due to '=' opposite reaction the gas applies a F on the rocket (Fgas). This is shown.
→ Exerted on the gas, not object / rocket, so not shown.

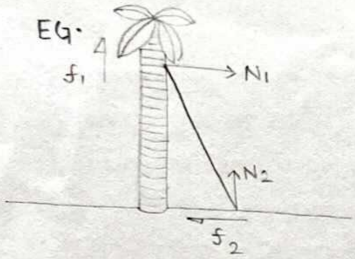


Normal reaction

The force exerted by a surface on an object pressing against it.

- Any F acting against a surface will create a reaction, that will act in a direction perpendicular to the surface and not on the direction of the applied force.

EG·



Ladder has F which it applies on the tree. The ladder tries to fall but the tree supports it

No tree then ⟶ 

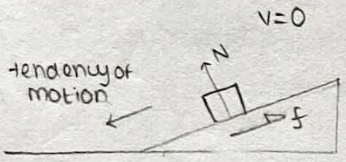
N_1 : Tree exerts on the ladder.

f_1 : without this the ladder would fall DOWN so it must act UP.

f_2 : ← direction as if there was motion of the ladder falling it would be in ⟶ direction

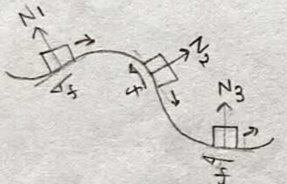
- The normal reaction depends on the orientation of the surface: it is perpendicular to the surface.

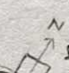
EG·



the f keeps it from falling.

EG·



- Rnough road → f present.
-  for such a curved surface (i) draw a tangent. (ii) draw its perpendicular = Normal (N)

FORCES IN BALANCE : NOTES.

0th order change (No change) : Displacement, x.

1st order change : velocity, $v = \frac{\Delta x}{\Delta t}$ (rate of change of displacement)

2nd order change : acceleration, $a = \frac{\Delta v}{\Delta t} = \frac{\Delta}{\Delta t}\left(\frac{\Delta x}{\Delta t}\right) = \frac{\Delta^2 x}{\Delta t^2}$ (rate of change of velocity)

3rd order change : jerk, $\frac{\Delta^3 x}{\Delta t^3}$ (rate of change of acceleration)

(i) External Force (F_e) acting. $F_e = ma$.

(ii) Friction is acting. $F_e = ma + f$

(iii) Restoring force acting. $F_e = ma + f + F_r$

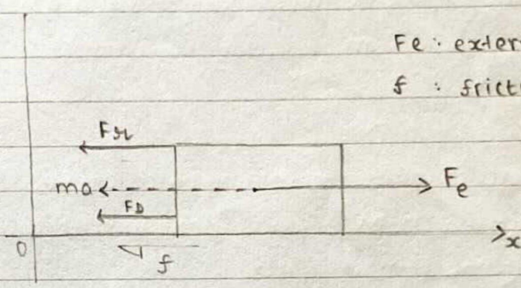
(iv) Drag force $F_e = ma + f + F_r + F_D$

↓

No other F acting beyond these 4.

F_e : external force

f : friction



(eliminating assumptions of F_D, F_r, etc. being absent)

- Restoring force : restores the entire system back to its original form. It is present in springs and in pendulums (that is why the pendulum returns to its mean position).
  $F = kx$

brings object back to Normal.

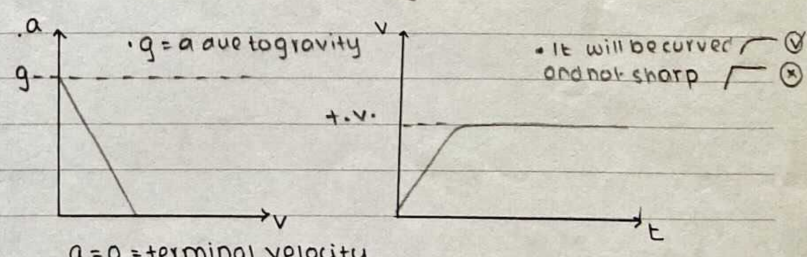
- Drag force: force felt by an object by the virtue of its motion in any viscous fluid.
  $F_D \propto v$ acts in a direction opposite to v.
  (If the object is in a fluid drag force is felt.)
  (thick liquids feel a higher resistance to motion and have a greater viscousity).
  $F_D = \beta v$ (β = constant, beta)

viscous : property of a fluid that resists motion of a solid thru it. oil is more viscous than water. Not related to density, it is a separate property.

FREE FALL

$Fe = m \times \frac{\Delta^2 x}{\Delta t^2} + \cancel{f} + \cancel{kx} + \beta\left(\frac{\Delta x}{\Delta t}\right)$

there is no f or kx during free fall.



$Fe = mg \longrightarrow mg = \beta(\Delta x \div \Delta t) + ma$

$ma = mg - \beta(\Delta x \div \Delta t)$

$a = \frac{mg}{m} - \left[\beta\left(\frac{\Delta x}{\Delta t}\right)\right] \div m$

$a = g - \frac{Bv}{m}$

↳ Bv = drag F → $a = g - \frac{F_{air}}{m}$

$a = g - \alpha v$ (α = constant alpha = $\beta \div m$)

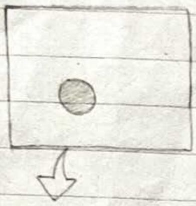
Friction : solid-solid surface

Drag force : solid-liquid surface.

(i) case : air resistance not taken → $\alpha = 0$. $a = g$

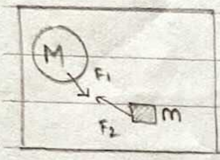
(ii) if $v = 0$ $a = g$ (using the same formula)

NOTES



This is the field: □
This is the mass: ●
The mass brings about a change in the field.

Mass → Δ gravitational field.
Charge → Δ electric field
Magnet → Δ magnetic field.



M: huge mass → eg. a galaxy/planet
m: regular object's mass

(i) F_2 → force of attracting acting on m applied by M. It pulls m towards M in ↑ direction.
(ii) F_1 → acting on M applied by m. It is the equal & opposite reaction for F_2 acting on M.
F_1 and F_2 are not contact forces

- $F \propto \frac{1}{r^2}$ more the distance (further apart the objects) = weaker the force of attraction
- $F \propto Mm$ More the masses = stronger the force of attraction.

$F_g \propto \frac{Mm}{r^2}$

$F_g = G\frac{Mm}{r^2}$ [G = universal g.c. (gravitational constant)]

2.11 and 2.12

MOMENTUM(1) and (2)

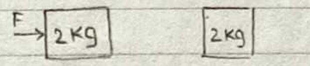
$\bar{p} = m\bar{v}$

- p required = amt. of force required to stop a moving object.
- Impulse $(\bar{J})$ = change in momentum = $\Delta\bar{p}$.

  $\Delta p = mv - mu = F \times t$ $= F \times \Delta t$

  $F = \frac{mv - mu}{t} = \frac{\Delta\bar{p}}{\Delta t} = \frac{\bar{J}}{\Delta t}$ $F\Delta t = m\Delta v$ if m=constant

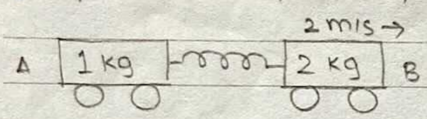
EG. v=0 v=2m/s



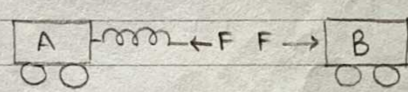
impulse = $m(\Delta v)$ = 2×2 = 4 kg m/s →
$(2-0)$

- conservation principles → momentum of a *system* is always conserved before and after a collision, provided no external forces are acting.

EG:- 2 carts, A and B, are pressed against each other and released.



(i) Pressed ⇒



F = F (3rd law).

F is a contact force (acts only when A and B are in contact) → the time of contact btwn A and B will remain the same for A and for B; F is the same for A and B.
(Impulse = F×t and = $\Delta\bar{p}$. So impulse for A and B remains the same).

-4m/s = opposite direction

- $\Delta\bar{p} = (2\times2) - (2\times0) = 4$ Ns. (final $\bar{p}$ - initial $\bar{p}$)] B
- $4 = m_Av_A - m_A\times0 \Rightarrow v_A\times1 = 4 \Rightarrow v_A = 4$ m/s] A
- $\bar{p}$ before release = $\bar{p}$ after release → $(1\times0) + (2\times0) = (2\times2) + (1\times v) \Rightarrow v = 0 - 4 = -4$ m/s (4m/s left)

NOTE the individual momentum for A and B will change, and there will be a net force on A, B. But taking A and B tog. as a system; Fnet acting on the system = 0.

$F_{net} = \frac{\Delta\bar{p}}{t} \Rightarrow \Delta\bar{p} = 0\times t = 0.$

↓

momentum before release = momentum after release. Thus, when a F_{net} acting on a system = 0, the total momentum of the system remains conserved.

COLLISIONS
- Elastic collision
- Inelastic collision

1. Elastic collision

- The K.E of the system remains conserved, K.E before collision = K.E after collision.

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

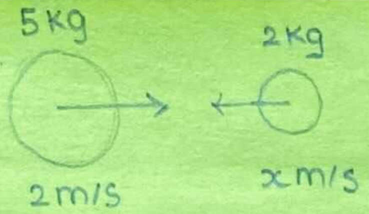
- Total $\bar{p}$ remains conserved

  $m_1v_1 + m_2v_2 = m_1v + m_2v = (m_1 + m_2)v$

  $v = \frac{m_1v_1 + m_2v_2}{m_1 + m_2}$

K.E = $\frac{1}{2}mv^2$ formula.

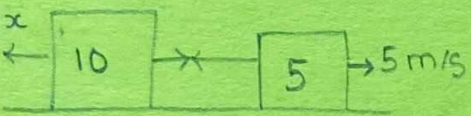
v' = v after collision



(After collision balls come to rest)

$2x+10=0$ $x=-5\,m/s$

($=0$ as final $\bar{p}=0$ as final $\bar{v}=0$)



(initially at rest).

initial $\bar{p} = 0+0=0$ initial $\bar{p}$ = final $\bar{p}$.

Final $\bar{p} = 25+10x$. $25+10x=0$ $x=-2.5\,m/s$

Q1 a ball mass 500g is travelling with a velocity of 72 kmph; the ball is brought to a rest in 0.4 s. Calculate avg. force.

When writing avg. force the '–' sign isn't required.

Method # 1 :

72 kmph = 20 m/s

$a = \frac{\Delta v}{t} = \frac{-20}{0.4} = -50\,m/s^2$

$F = ma = 0.5 \times -50 = -25N$

Method # 2 :

$m = 0.5\,kg$ $u = 72\,kmph$ $v = 0$

$\Delta p = mv - mu \rightarrow F \cdot avg = \frac{\Delta P}{\Delta t} = \frac{m(v-u)}{t}$

$= 0.5(-20)/0.4 = 25N$

under the assumptions:

(i) a = uniform

(ii) constant mass

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

$F \propto$ rate of change of momentum.

If assumption isn't true, $F = m \times \frac{\Delta v}{\Delta t}$,

$F = \frac{\Delta (mv)}{\Delta t}$.

change of $x = \Delta x$

Rate of change of $x = \frac{\Delta x}{t}$

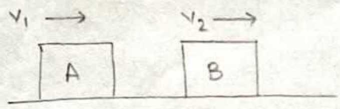
when there is an external force acting on the system the law of conservation of momentum doesn't apply.

↓

law = momentum of a system is always conserved bef. and aft. a collision,

Final $\bar{p}$ = initial $\bar{p}$.

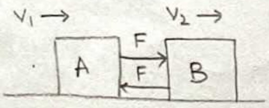
EG. ① BEFORE COLLISION



Frictionless surface

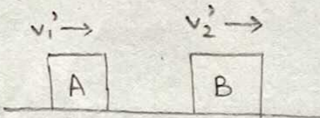
condition for them to collide → $v_1 > v_2$

② DURING COLLISION



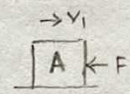
Forces are = and opposite, so momentum of the AB system remains conserved.

③ AFTER COLLISION

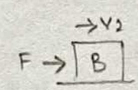


↓ mass = m_1 ↓ mass = m_2

$v_2' > v_1'$ (changed v and changed greatness)



② force acts in the opposite direction to velocity, so the velocity decreases.



force's direction = velocity's direction, so velocity increases. The acceleration will be in the v's direction.

A and B move apart as B's v increases so much they move away.

$m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2'$

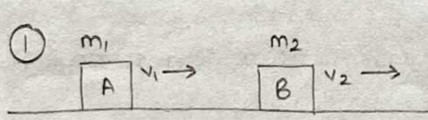
- $\bar{p}$ before collision = $\bar{p}$ after collision
- F_{net} of system = 0

2. inelastic collision

- Loss in K.E → $\left(\frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2\right) - \frac{1}{2}(m_1+m_2)v^2$ = loss.
- Momentum before = momentum after.

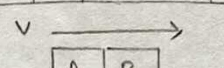
some of the K.E is converted to P.E, you can't get the P.E back.

EG. ①



$v_1 > v_2$

②



A and B stick together and move with the same velocity, v.

Inelastic : deforms permanently (energy lost)
Elastic : doesn't deform OR deforms and reforms (no energy lost)
↓
eg. of partially elastic is dropping a rubber ball.

—— x —— x —— x —— x —— x —— x —— x ——

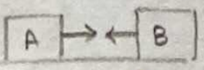
- momentum : answer, either write x kg m/s right or − x kg m/s (towards right).
- 

A $\bar{p}$ = x   B $\bar{p}$ = y

x > y   total $\bar{p}$ after A & B stick tog. and move = x − y in → direction (RIGHT)

$m_1v_1 + m_2v_2 = v(m_1+m_2)$
$(8\times5) + (2\times-5) = 10v$
$v = 30 \div 10 = 3$ m/s +
momentum's direction

total mass after collision = 8 + 2 = 10 kg

- 

A: 8 kg 5 m/s →
B: 2 kg 5 m/s ←

collide, stick tog, move with v
$\bar{p} = (8\times5) - (5\times2) = 30$ kg m/s → $\bar{p} = m\bar{v}$ ⇒ $30 = 10\bar{v}$ ⇒ $\bar{v} = \frac{30}{10} = 3$ m/s →