FORCE + MOTION

2.1 Linear Motion

definition

distance - total length travelled by an object
- a scalar quantity

displacement - shortest distance btw the initial position + the final position is a specific direction
- a vector quantity

velocity - vector quantity for speed

acceleration - non - uniform velocity

formula

1. speed = rate of change of distance travelled

$$= \frac{\text{distance travelled, } d}{\text{time taken, } t}$$

$$v = \frac{d}{t} \rightarrow \text{rate of } \Delta \text{ distance, } d$$

2. velocity = rate of change of displacement

$$= \frac{\text{displacement, } s}{\text{time taken, } t}$$

$$v = \frac{s}{t} \rightarrow \text{rate of } \Delta \text{ displacement, } s$$

3. acceleration = rate of change of velocity

$$= \frac{\text{final velocity, } v - \text{initial velocity, } u}{\text{time taken for change of velocity, } v}$$

$$a = \frac{v-u}{t} \rightarrow \text{rate of } \Delta \text{ velocity, } v$$

notes

If $a < 0$, decceleration

If $a > 0$, acceleration

If ←

$v = -v$

If →

$v = v$

key

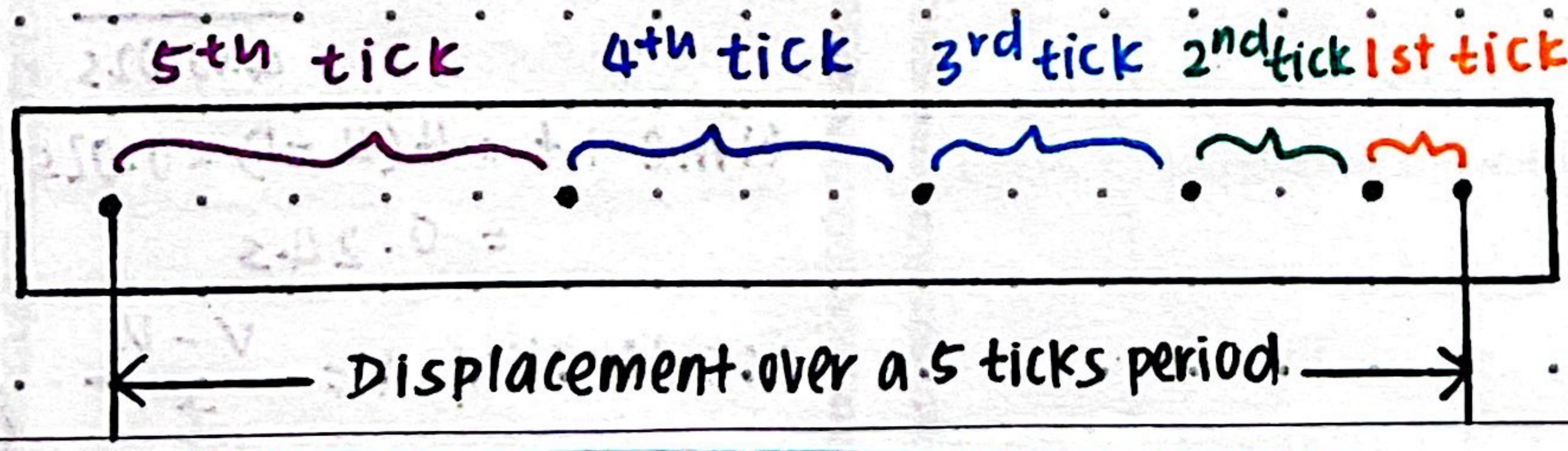
Δ → change in

Ticker Timer + Ticker Tape

↳ works on alternating current of frequency 50 Hz,

Thus, 1 s = 50 ticks

$$1 \text{ tick} = \frac{1}{50} \text{ s} = 0.02 \text{ s}$$

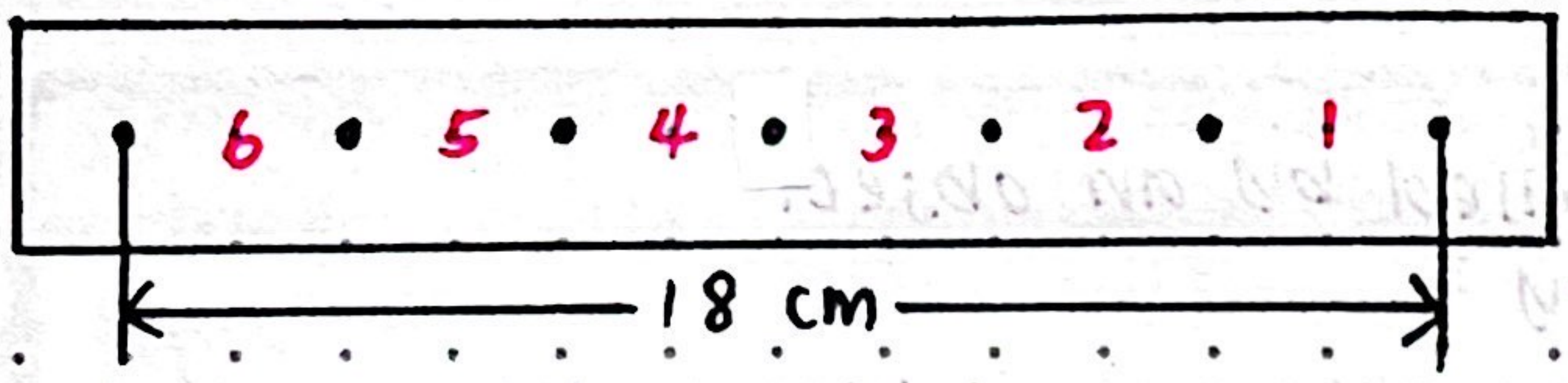


Direction of motion →

Time = 5 ticks = 5 × 0.02s = 0.10s

Typo

calculating velocity



Displacement, $s = 18$ cm

Time taken, $t = 6$ ticks

$= 6 \times 0.02$ s

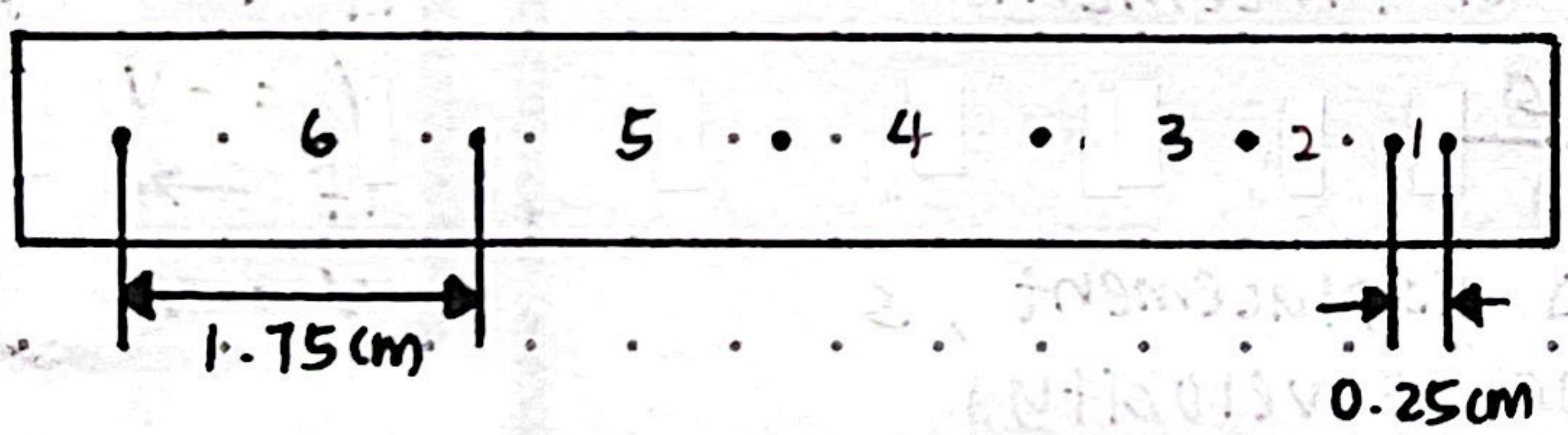
$= 0.12$ s

Velocity, $v = \frac{s}{t}$

$= \frac{18\text{ cm}}{0.12\text{ s}}$

$= 150\text{ cm s}^{-1}$

calculating acceleration



Initial velocity, u = velocity at the first tick

$= \frac{0.25\text{ cm}}{0.02\text{ s}}$

$= 12.5\text{ cm s}^{-1}$

Final velocity, v = velocity at the sixth tick

$= \frac{1.75\text{ cm}}{0.02\text{ s}}$

$= 87.5\text{ cm s}^{-1}$

Time between the final and initial velocity, t

$= (6 - 1)$ ticks

$= 5$ ticks

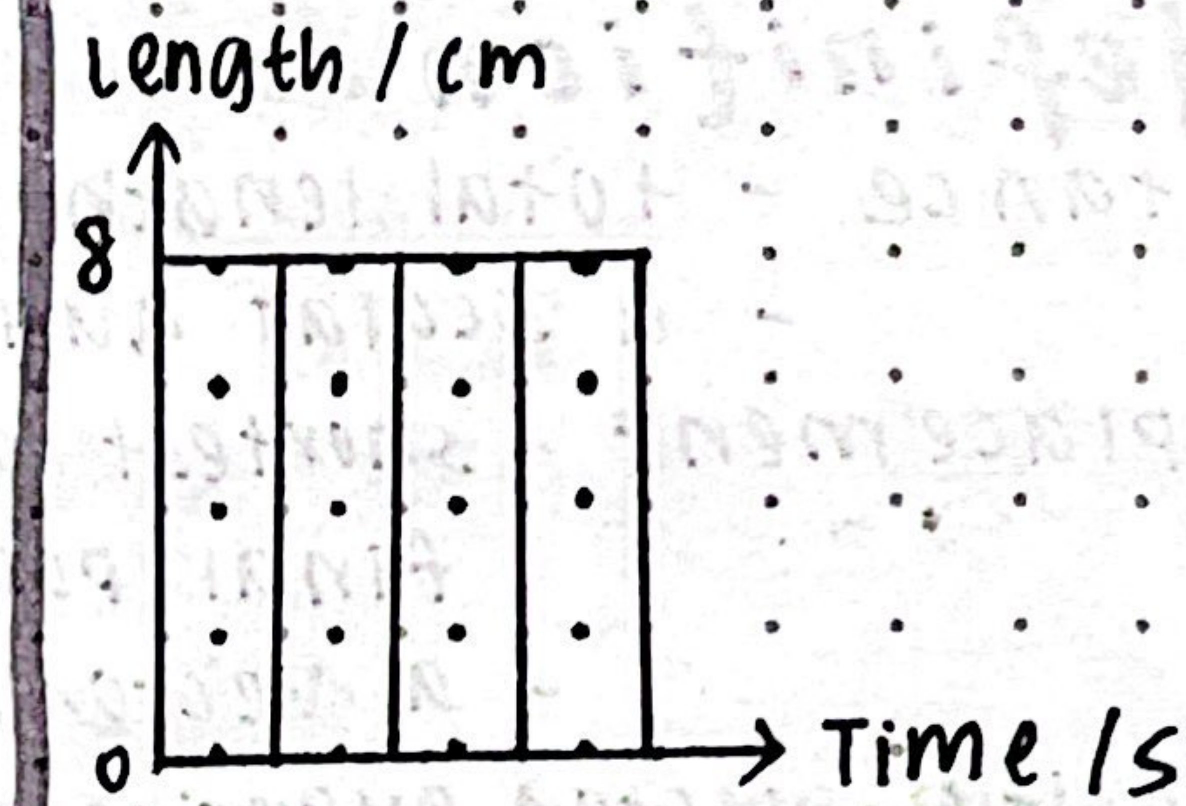
$= 5 \times 0.02$ s

$= 0.10$ s

Acceleration, $a = \frac{v - u}{t}$

$= \frac{(87.5 - 12.5)\text{ cm s}^{-1}}{0.10\text{ s}} = 750\text{ cm s}^{-2}$

ticker timer chart



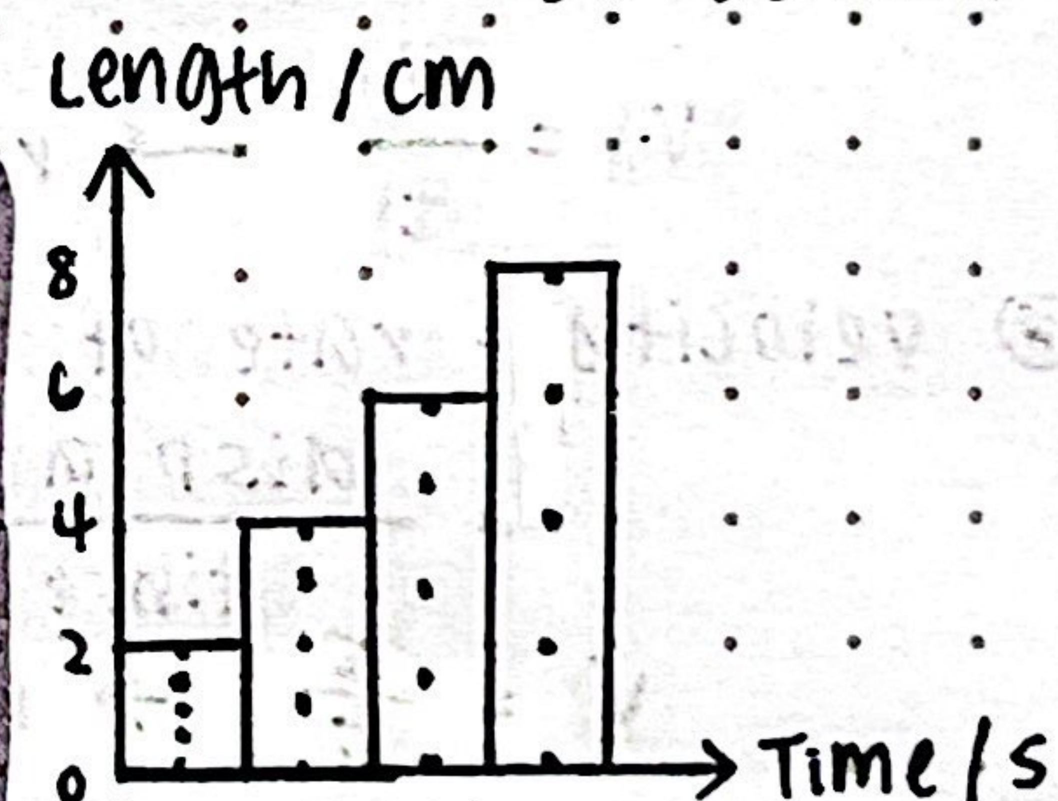
Uniform velocity

time, $t = (4 \times 3) \times 0.02$

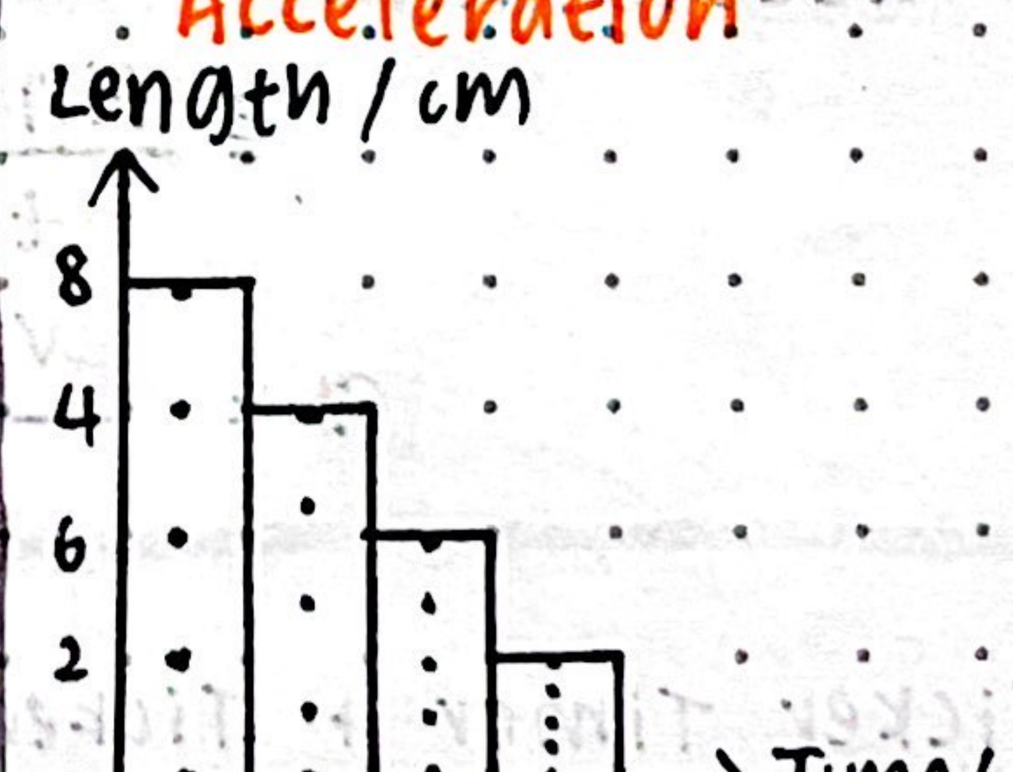
$= 0.24$ s

velocity, $v = \frac{8\text{ cm}}{0.24\text{ s}}$

$= 33.33\text{ cm s}^{-1}$



Acceleration



Deceleration

Final velocity $= \frac{\text{last tt.}}{4 \times 0.02\text{s}}$

initial velocity $= \frac{\text{First tt.}}{4 \times 0.02\text{s}}$

time, $t = 4(4-1) \times 0.02$s

$= 0.24$ s

acceleration, $a = \frac{v - u}{t}$

Force & Motion

Linear motion equations

① First linear motion equation

$$\text{acceleration}, a = \frac{\text{Final velocity} - \text{initial velocity}}{\text{Time taken for change of velocity}}$$

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

$$at = v - u$$

$$v = u + at$$

② Second linear motion equation

Displacement = Average velocity × time

$$\text{Displacement} = \left(\frac{\text{Initial velocity} + \text{final velocity}}{2}\right) \times \text{time}$$

$$s = \frac{1}{2}(u + v)t$$

③ Third linear motion equation

Substitute equation (1) into equation (2)

$$s = \frac{1}{2}[u + (u + at)]t$$

$$s = \frac{1}{2}(2u + at)t$$

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

④ Fourth linear motion equation

Square equation (1)

$$v^2 = (u + at)^2$$

$$v^2 = u^2 + 2uat + a^2t^2$$

$$v^2 = u^2 + 2a(ut + \frac{1}{2}at^2)$$

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

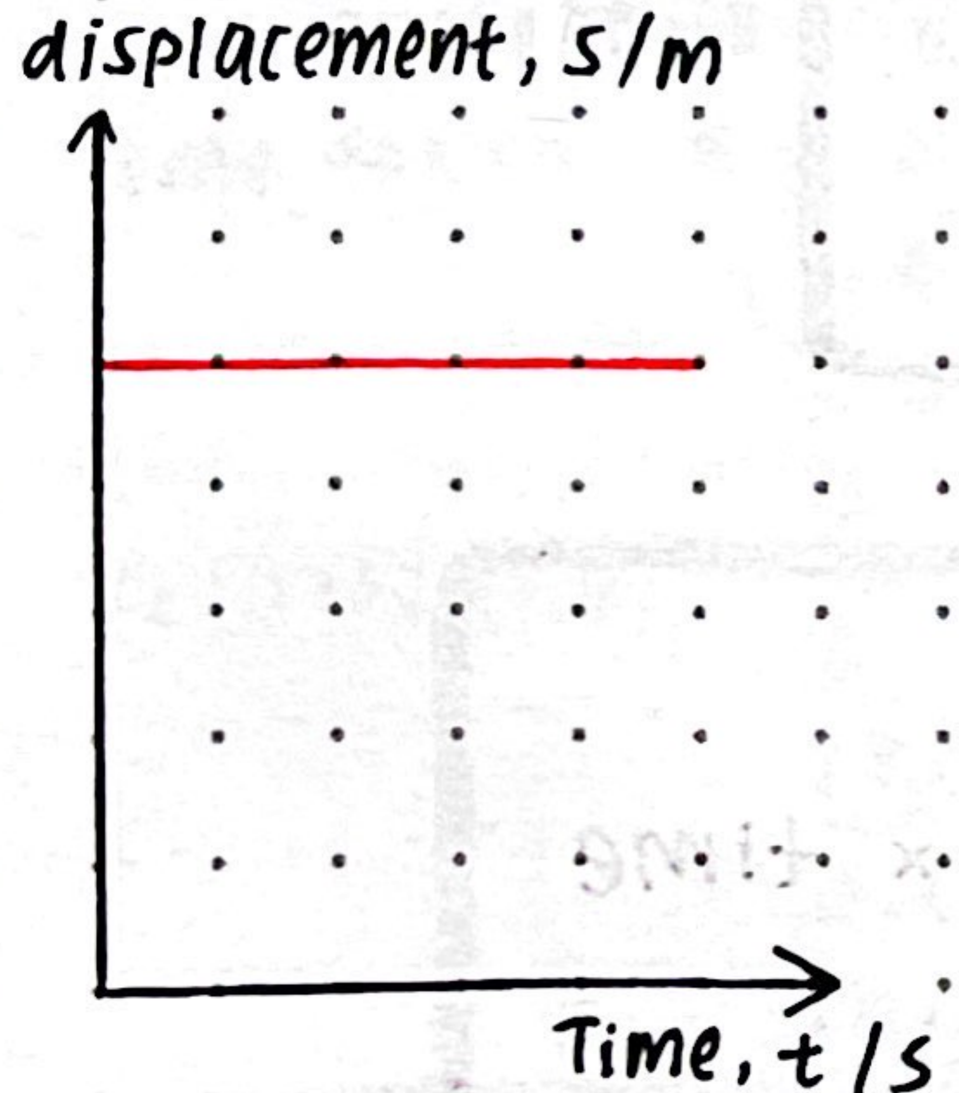
From equation (3)

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

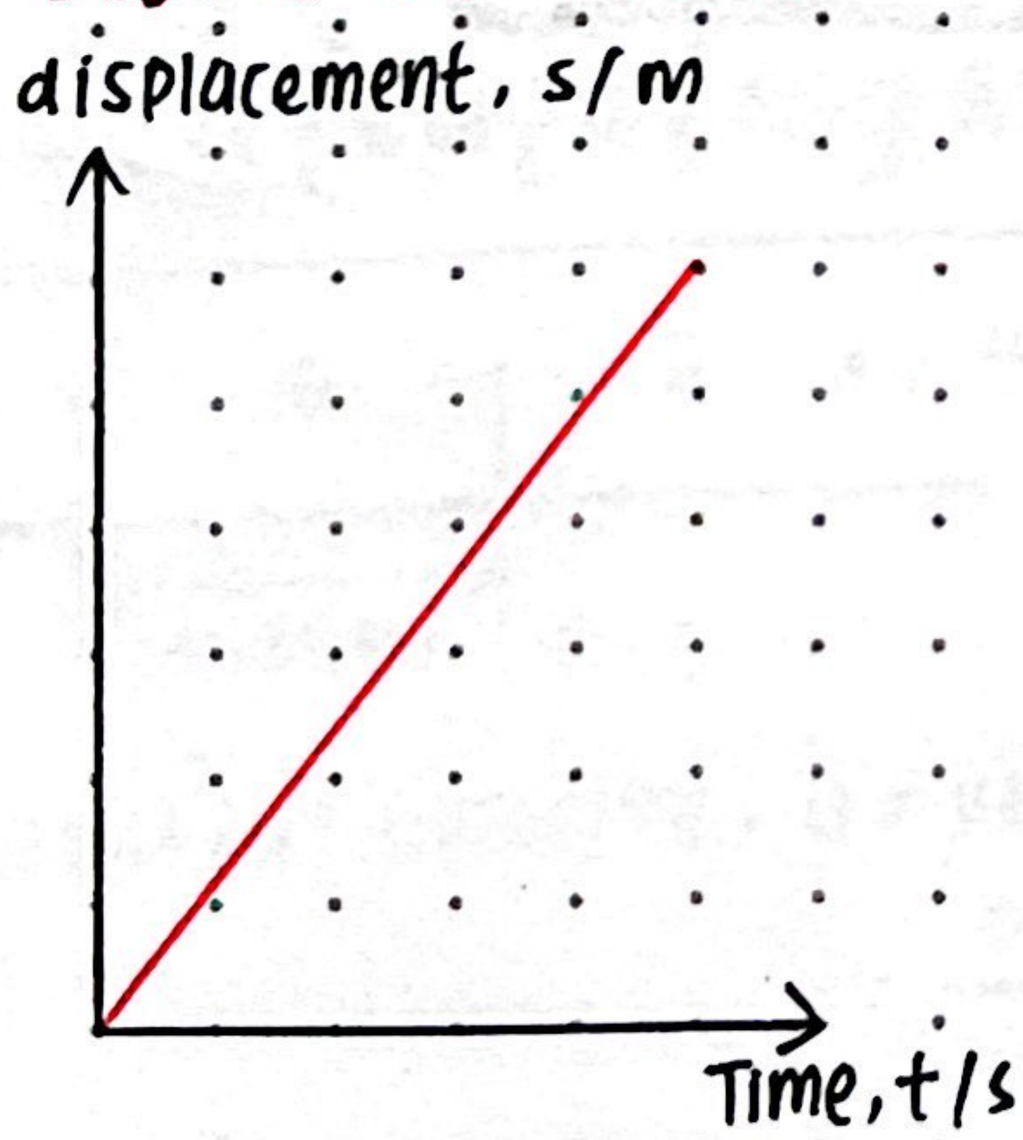
Typo

linear motion graph

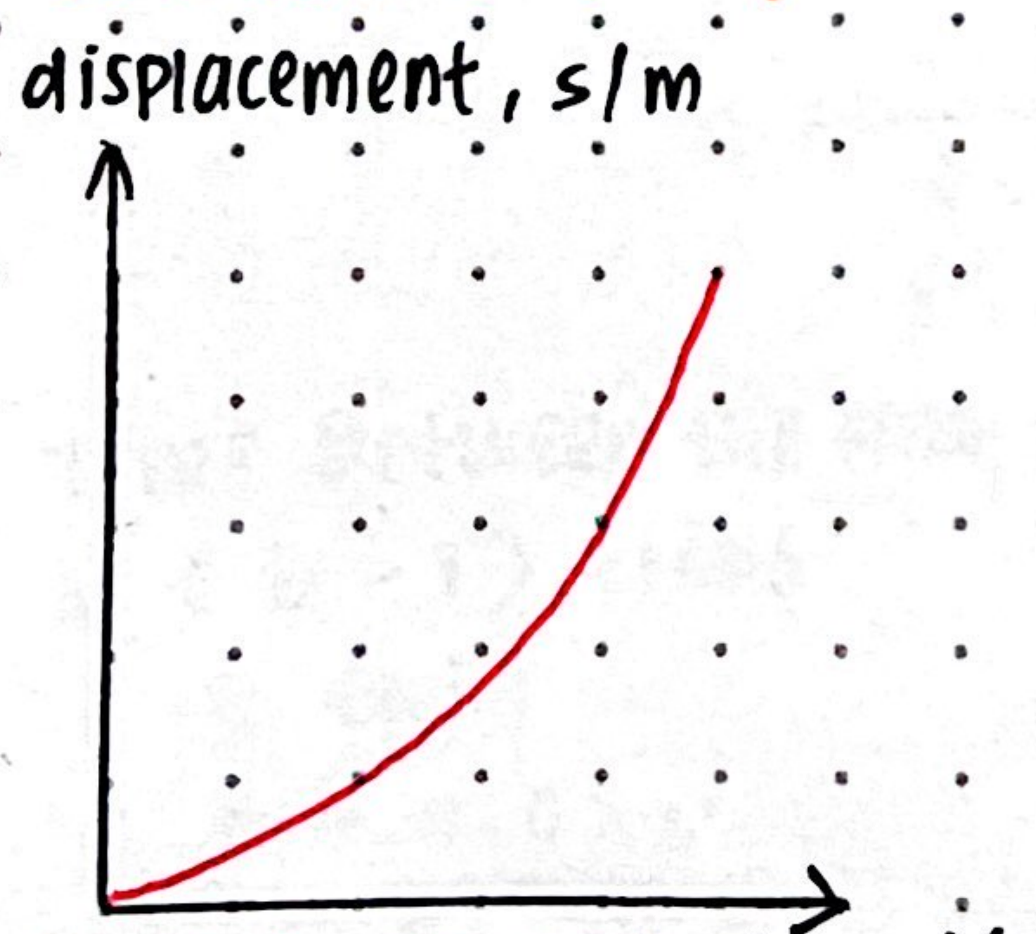
displacement-time graph



Object at rest

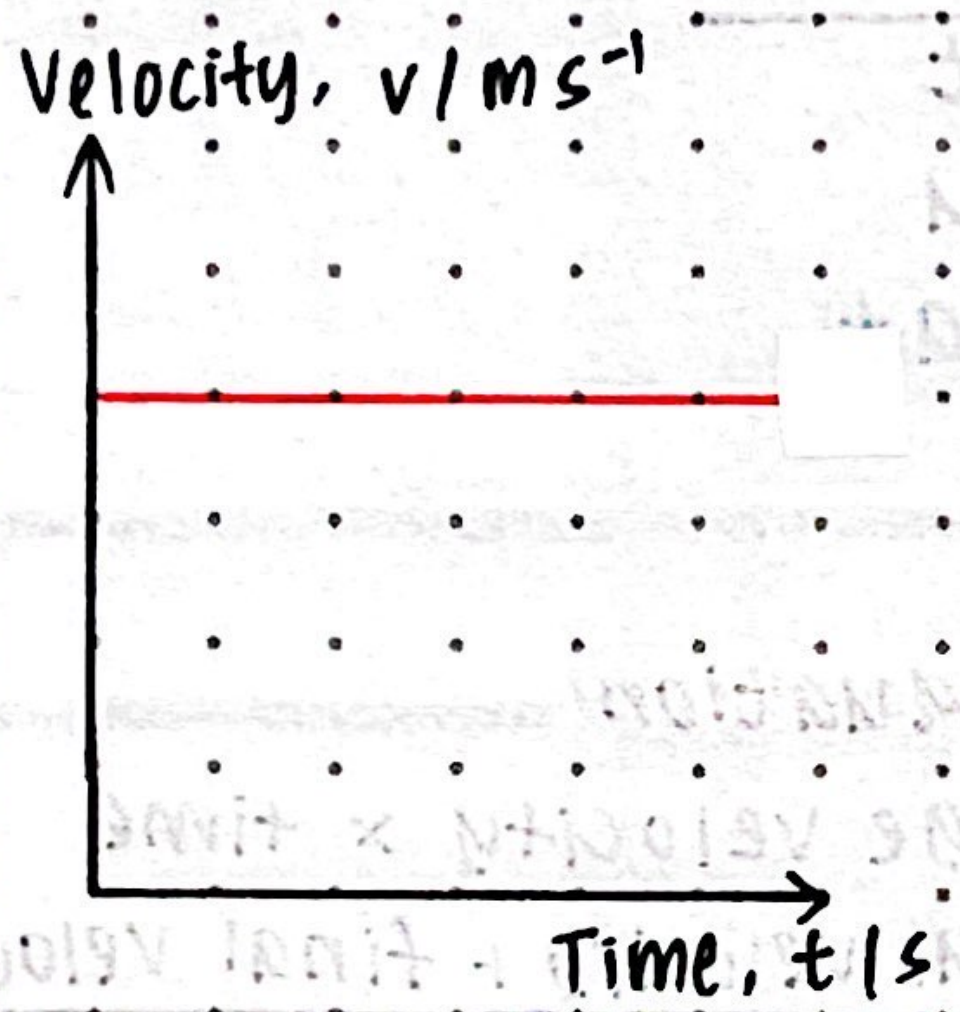


object movimg w/ constant velocity

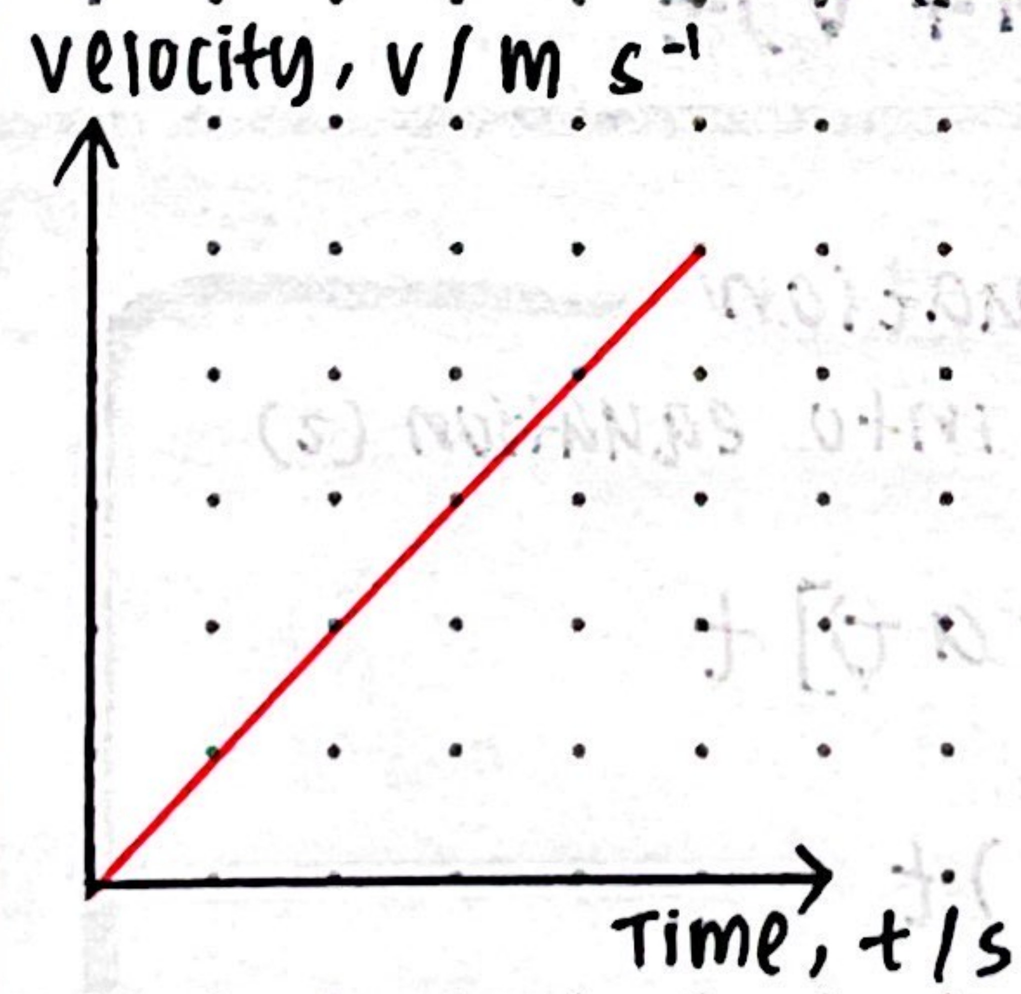


Object moving w/ acceleration

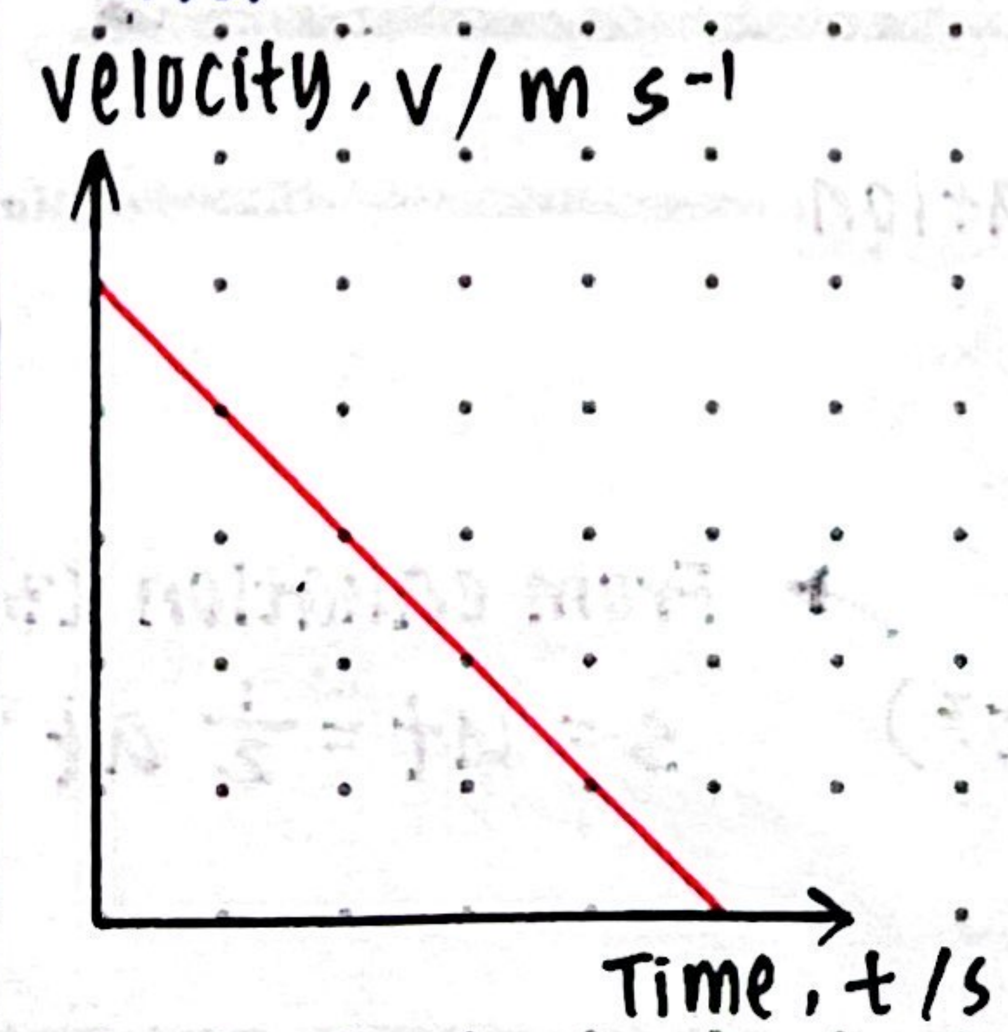
velocity-time graph



object moving w/ uniform velocity

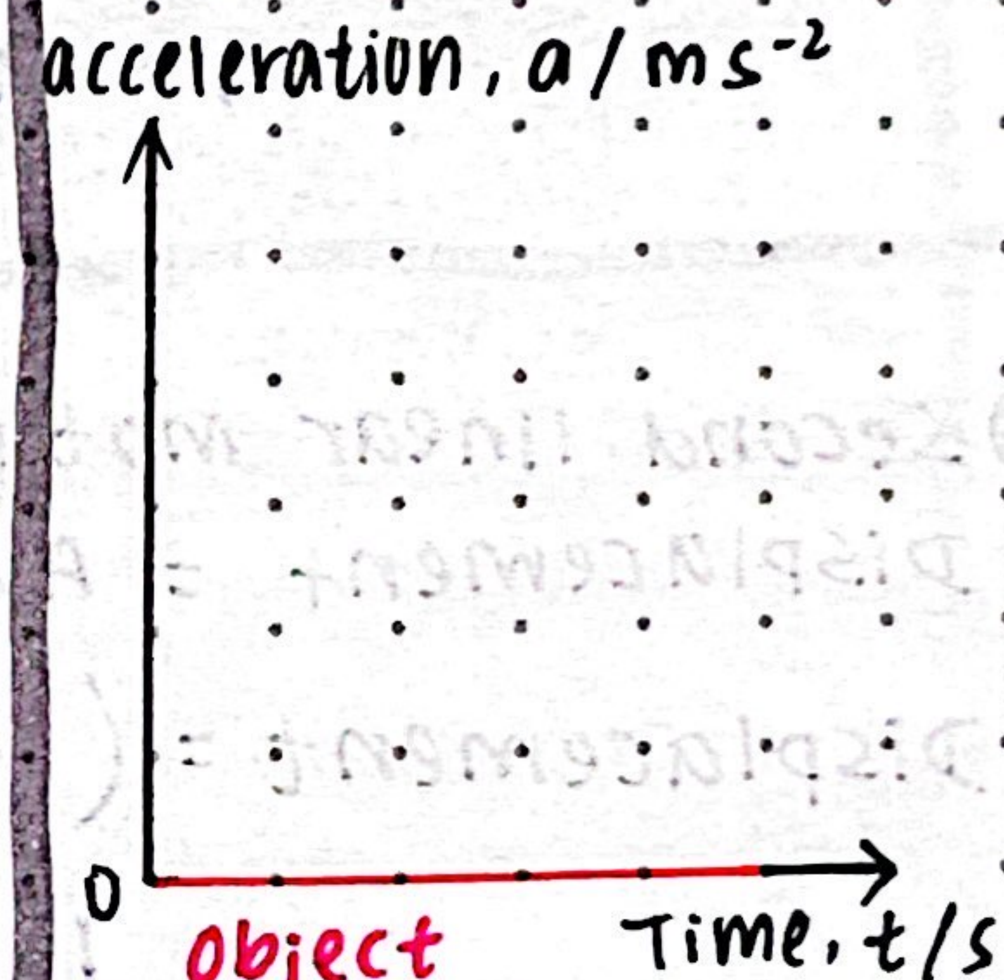


Object moving w/ uniform acceleration

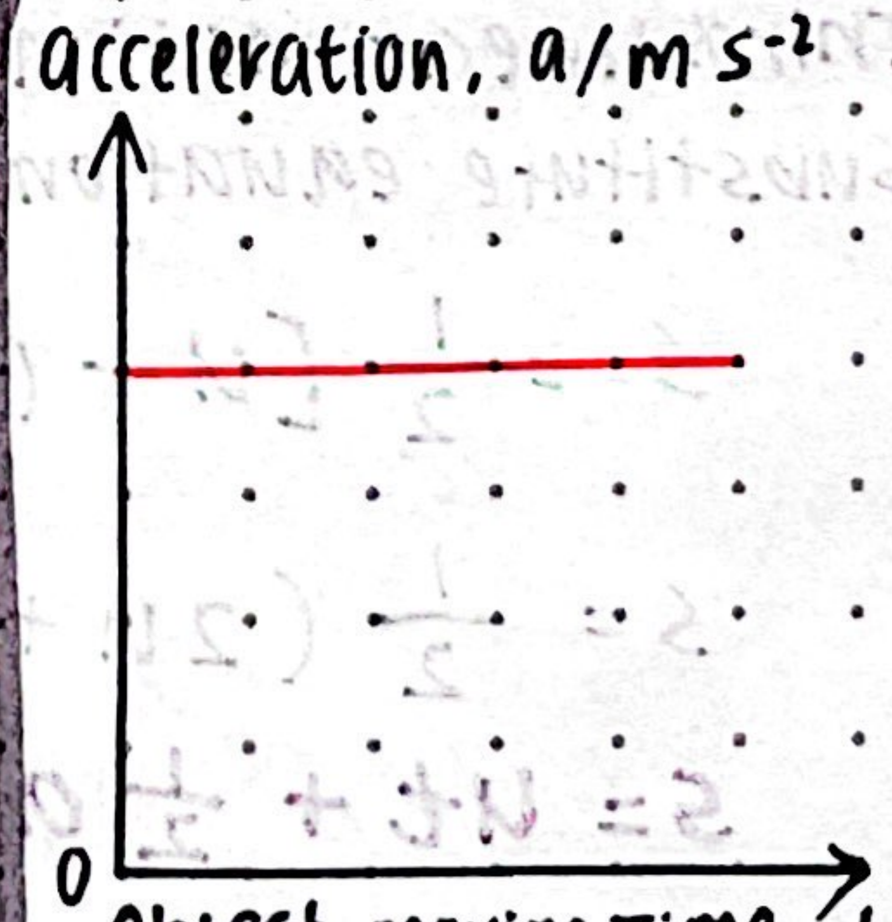


Object moving w/ uniformly deceleration

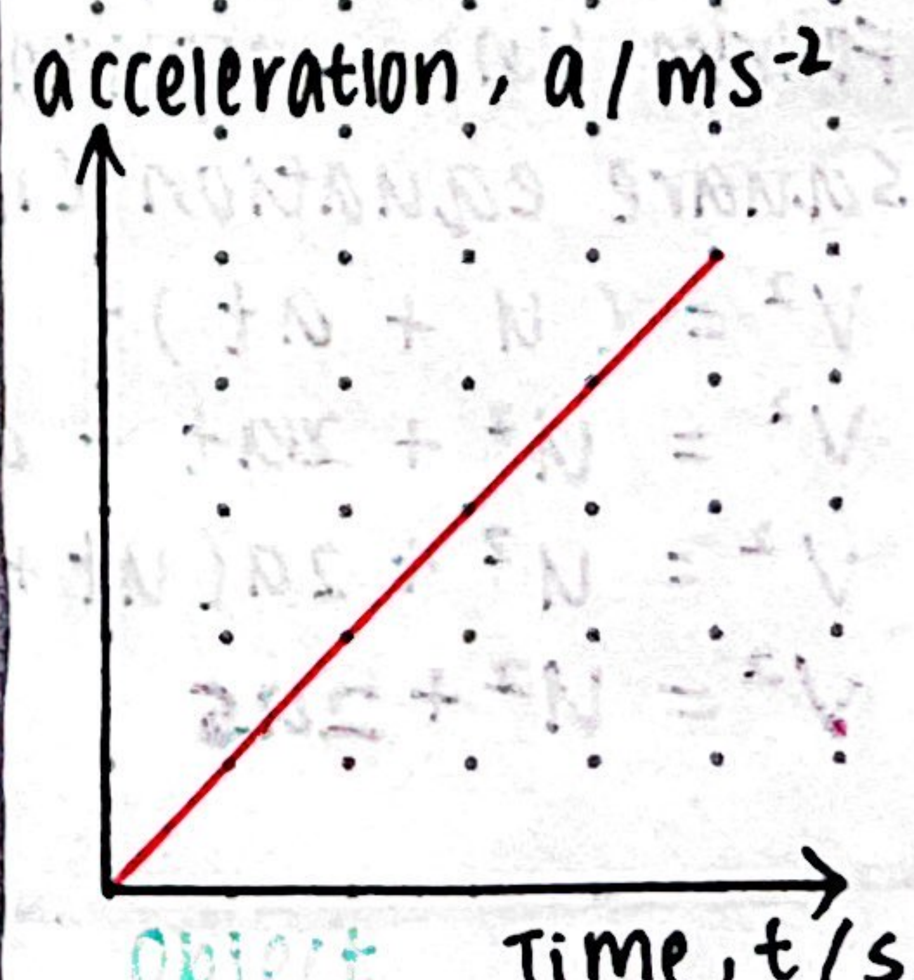
acceleration-time graph



Object moving w/ constant velocity



Object moving w/ uniform velocity



Object moving w/ increasing acceleration

Force + Motion

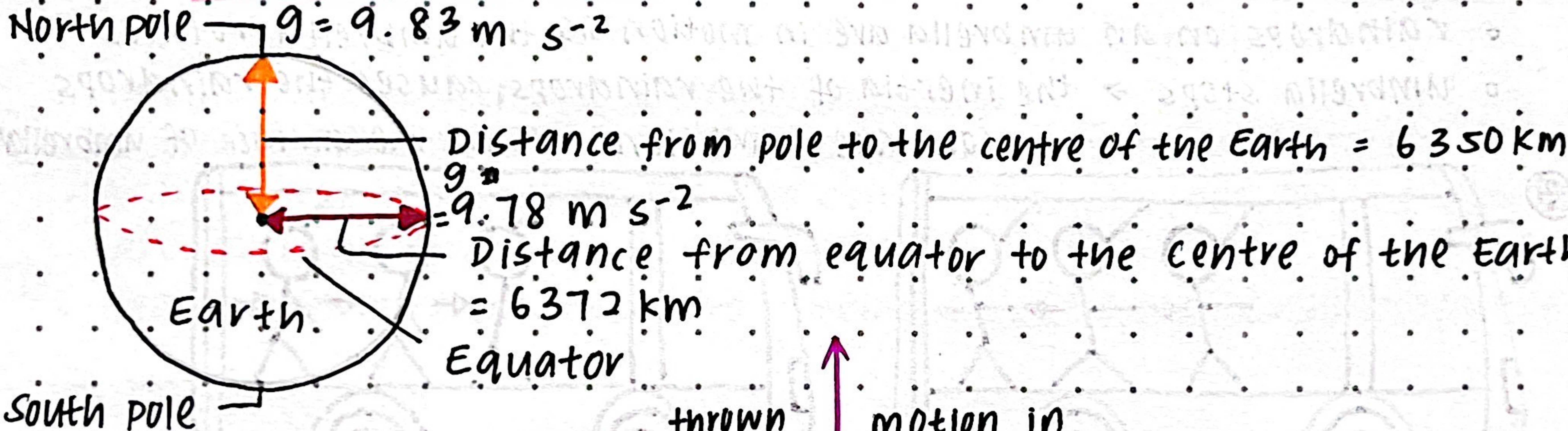
Free Fall Motion

- motion under force of gravity only

Value of Gravitational Acceleration, g

- g at equator = $9.78\ m\,s^{-2}$
- g at Earth's poles = $9.83\ m\,s^{-2}$

} average = $9.81\ m\,s^{-2}$

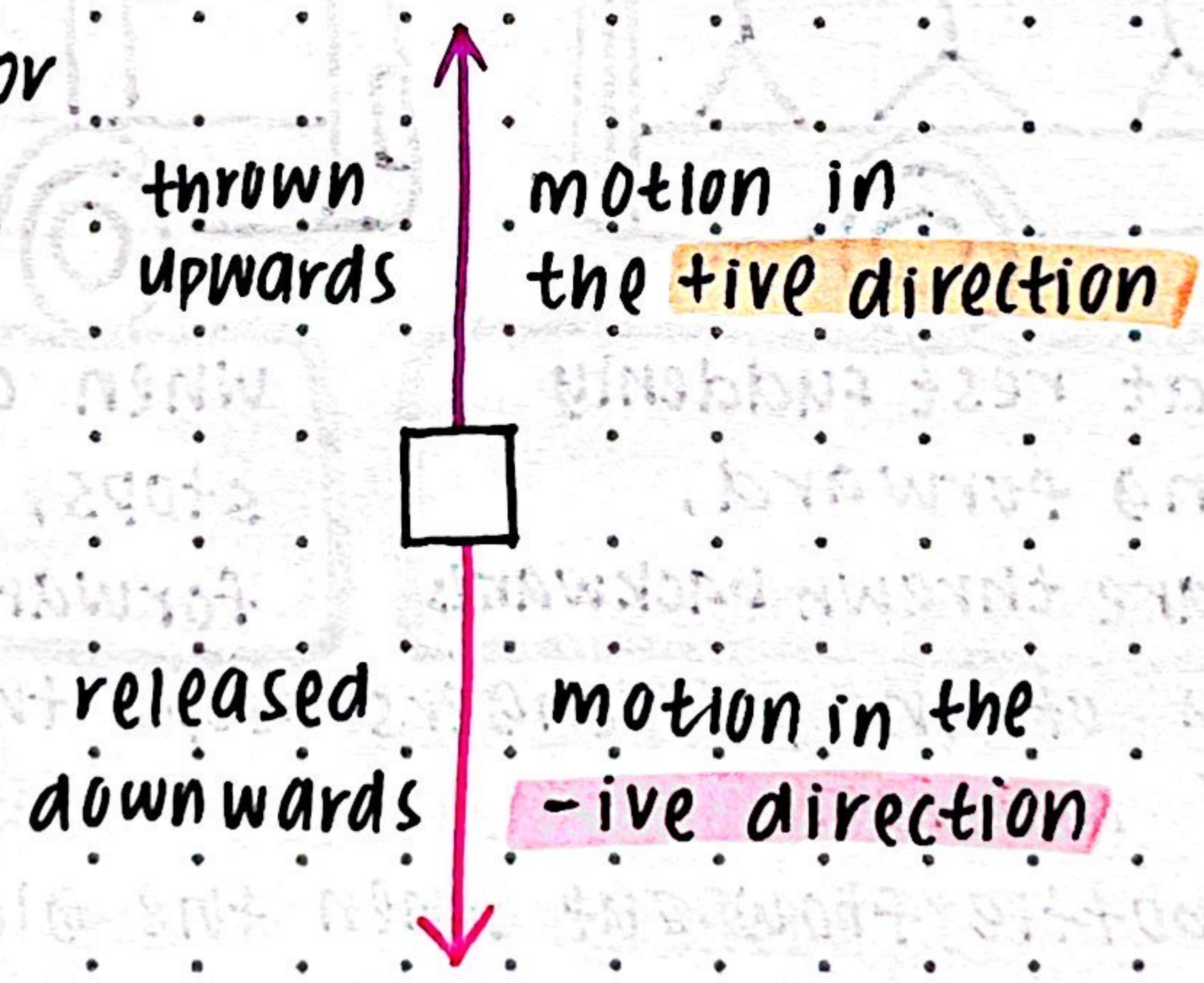


formula

$$v = u + gt$$

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

$$v^2 = u^2 + 2gs$$



2.4 Inertia

- the tendency of an object to resist change / to remain at its original state of motion
- the concept of inertia is explained in Newton's First Law of Motion

newton's first law of motion

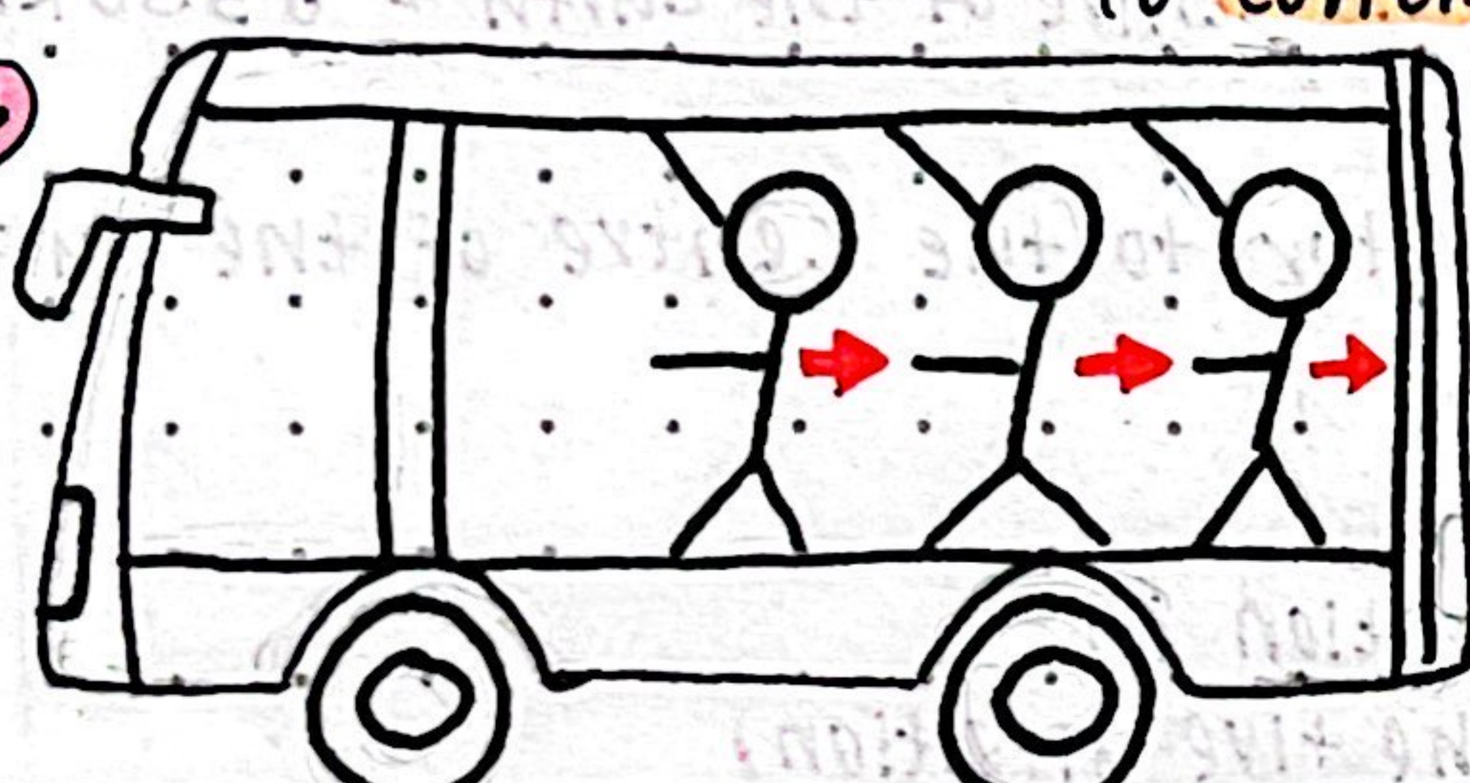
- an object will remain at rest / move at uniform velocity unless acted upon by an external force.

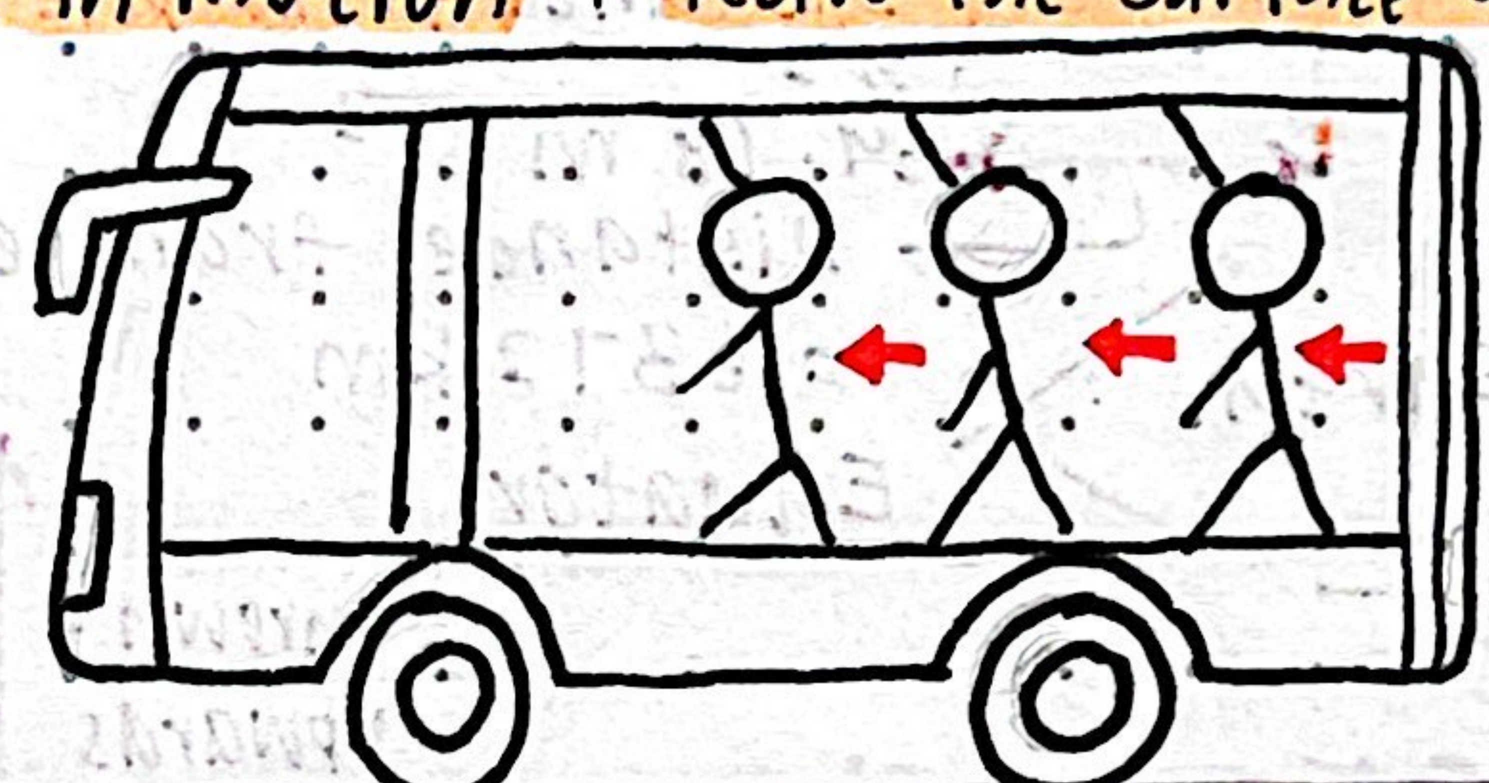
The relationship between Inertia + Mass

- inertia × influenced by gravitational force
- The larger the mass of an object, the larger the inertia of the object

Typo

Effects of Inertia in Daily Life

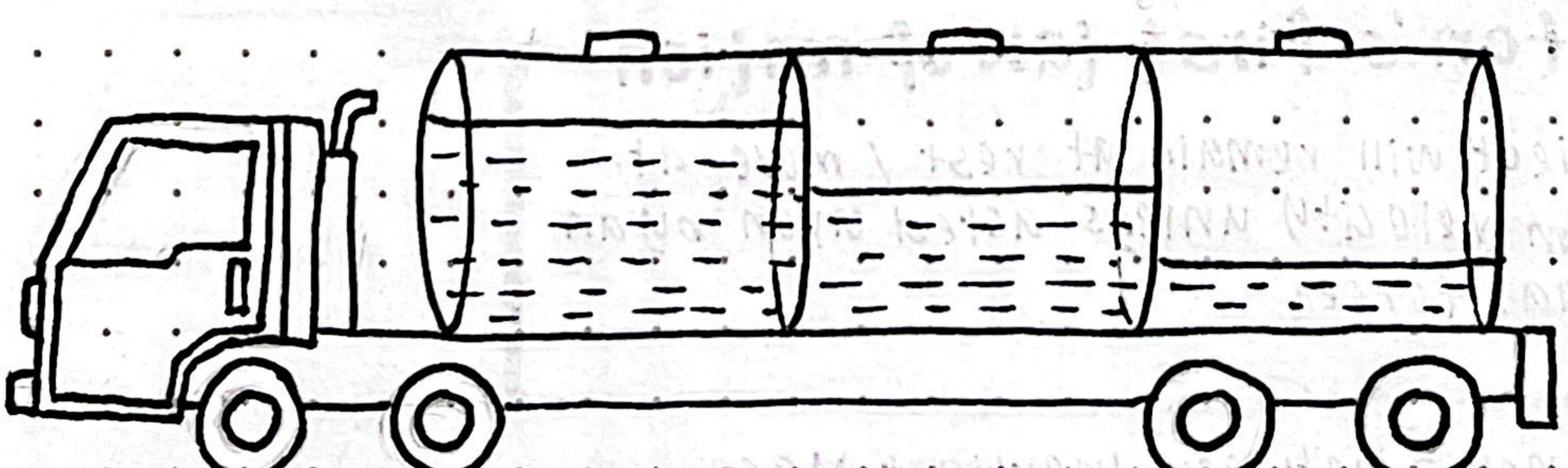
1. Astronauts in a spaceship use inertial balance to measure mass → the periods of oscillation of astronauts determine their mass
2. Raindrops spun off when a wet umbrella is rotated and suddenly stopped
   - raindrops on an umbrella are in motion as the umbrella rotates
   - umbrella stops → the inertia of the raindrops causes the raindrops to continue in motion + leave the surface of umbrella
3. 

   When a bus at rest suddenly starts moving forward, passengers are thrown backwards

   When a moving bus suddenly stops, passengers are thrown forward.

   - the inertia of the passengers keeps them in their initial state of rest / motion
4. Sauce in a bottle flow out when the glass is moved quickly downwards + then suddenly stopped.
   - inertia of the sauce causes it to continue moving downwards + out of the bottle
5. Oil tanker track has its storage tank divided in 2 separate tanks

   - oil tanker trucks have large inertia
   - the separated tanks reduce the impact of the inertia of the petrol

6. Riders on roller coaster are assigned to seats thru a specialised safety system.
   - the roller coaster carriage moves at sudden changes of speed + direction
   - when the carriage of the roller coaster changes its direction of motion suddenly,
     → the inertia of the riders keeps them in their original state of motion
   - the safety system ensures the riders remain in their seats + x thrown out during the motion
7. Driver + passengers of a car are advised to wear seatbelts.
   - when a car stops abruptly, the driver + passengers in the car are thrown forward bcuz of inertia
   - seat belts prevent them from being thrown forward + hurting thems.

2.5 Momentum

definition

- product of mass + velocity
- Sir Isaac Newton described it as "quantity of motion"
- a vector quantity
- direction of momentum = direction of velocity
- high velocity + large mass = large momentum
- larger momentum = more difficult to stop

formulae

- $p = mv$, where p = momentum
  m = mass
  v = velocity
- S.I. unit : $kgms^{-1}$
- unit for momentum = Ns

Principle of Conservation of Momentum in Collisions + Explosions

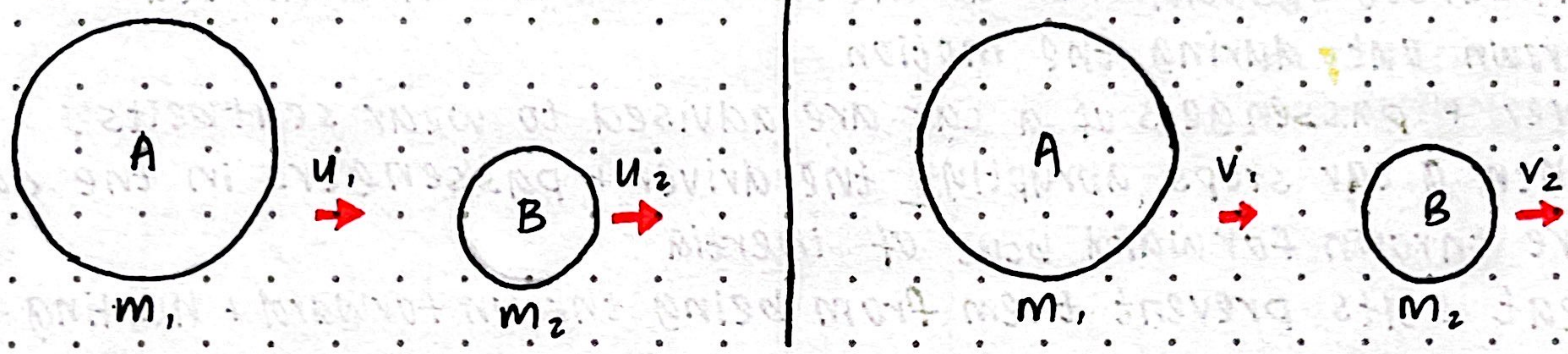
collisions

→ total momentum before collision = total momentum after collision → if x external force / in enclosed syst.

① Elastic collision

- after collision, 2 objects separate + hv different velocity

Before collision | After collision

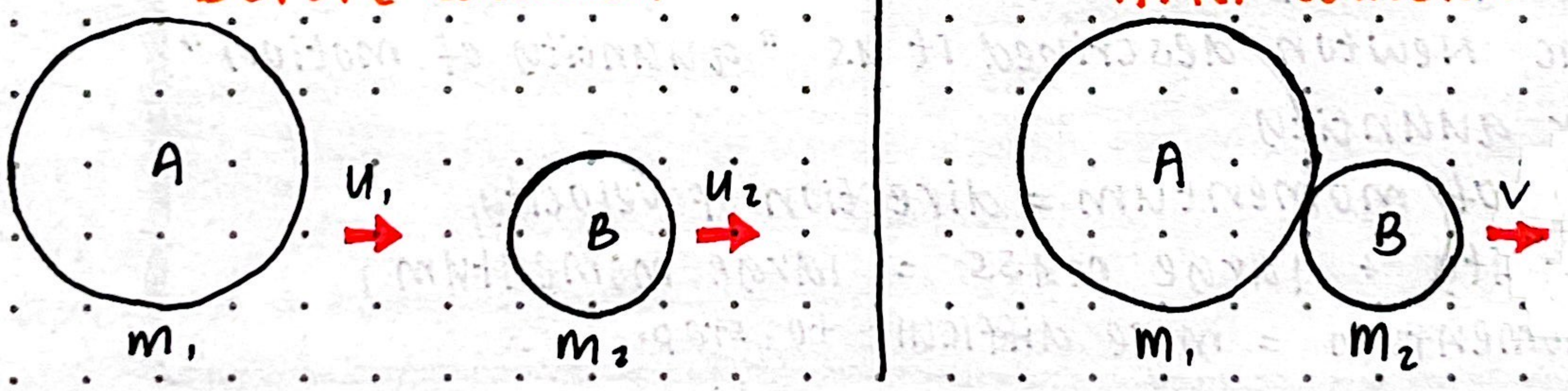


$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

② Inelastic collision

- after collision, 2 objects stick together + hv same velocity

Before collision | After collision

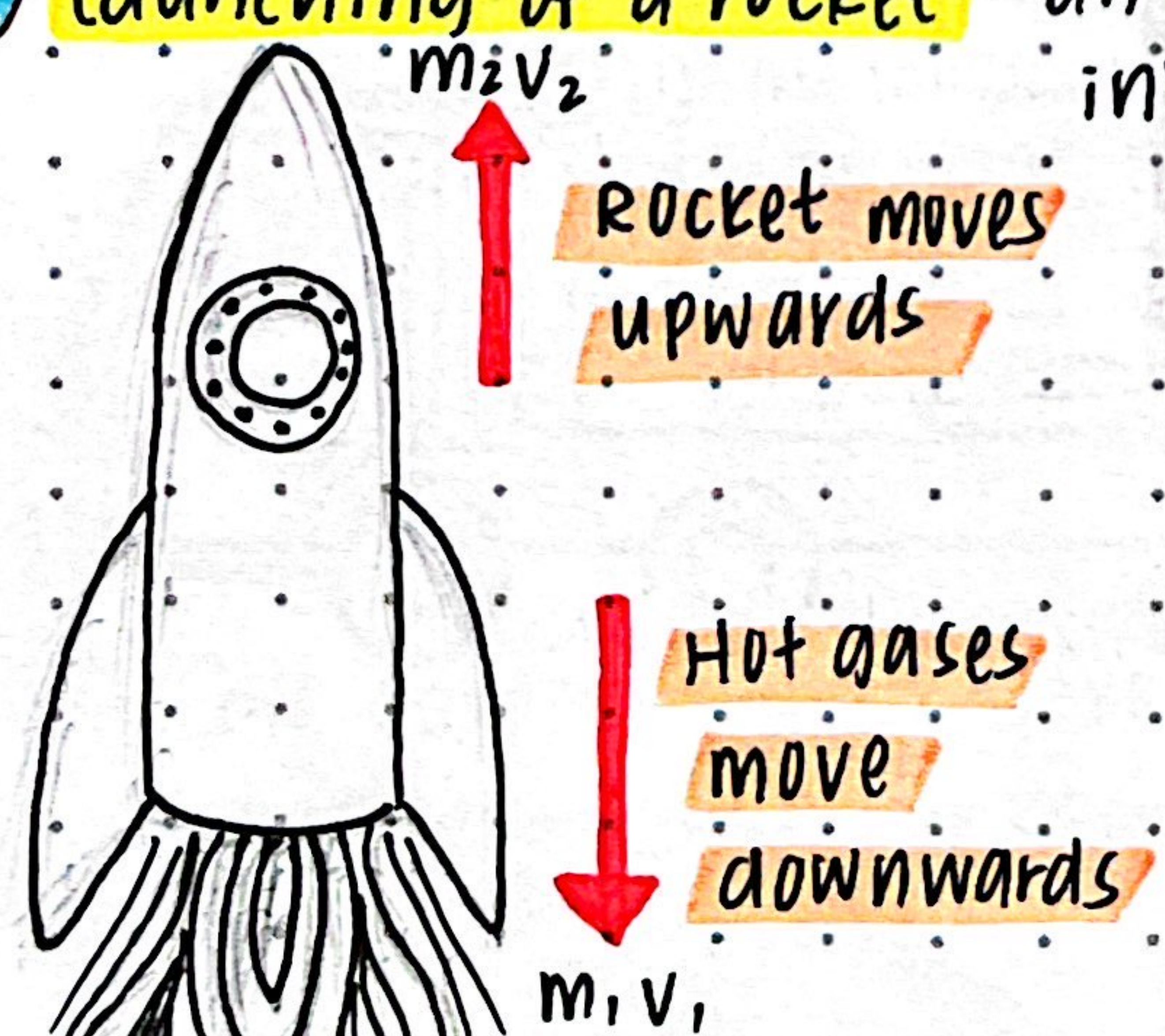


$$m_1 u_1 + m_2 u_2 = (m_1 + m_2) v$$

explosion

→ an object at rest breaks up inz 2 / more parts + x involve external force / in enclosed syst.

① launching of a rocket



Total momentum before explosion = Total momentum after explosion

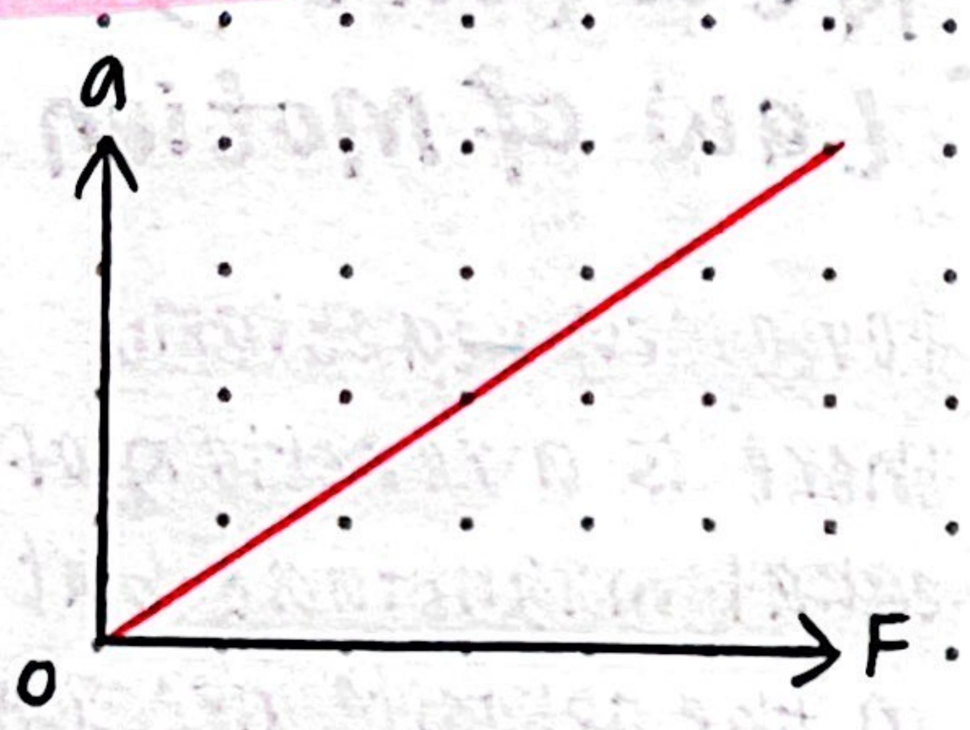
$$0 = m_1 v_1 + m_2 v_2$$

$$m_1 v_1 = -m_2 v_2$$

Before launch, rocket is at rest at the base of lauchpad w/ 0 momentum

2.6 Force

- the acceleration of an object depends on the applied force and the mass of the object

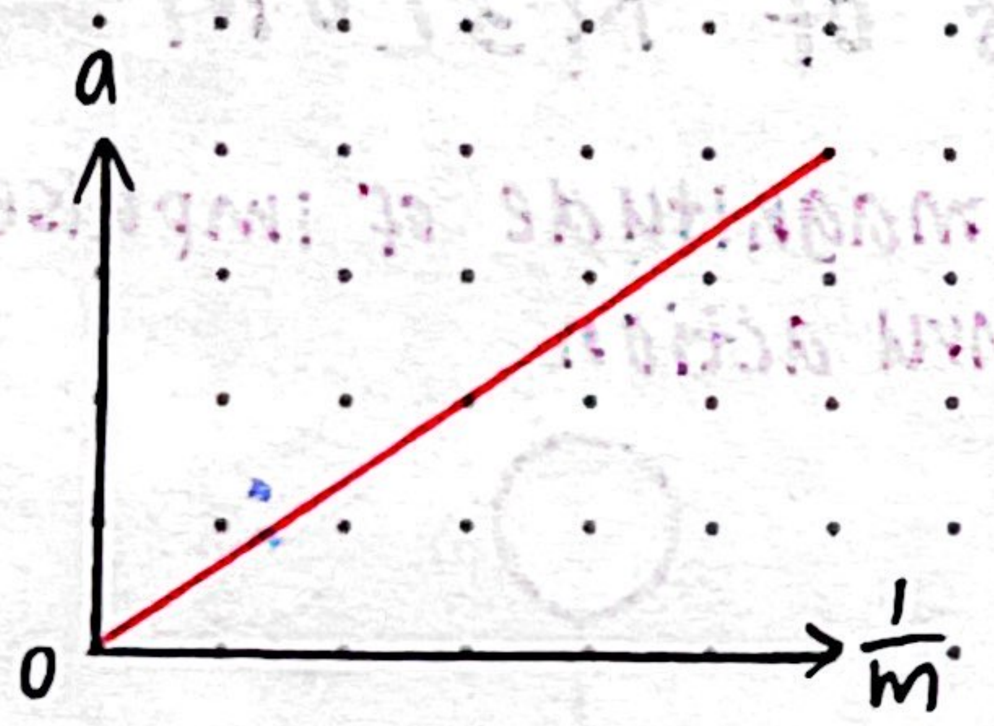


Acceleration - time graph

acceleration is directly proportional to the applied force when the mass of an object is fixed.

→ $a \propto F$

m constant



acceleration - reciprocal of mass graph

acceleration is inversely proportional to mass of an object when a constant force is applied on the object.

→ $a \propto \frac{1}{m}$

F constant

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

$\therefore F \propto ma$

$F \propto ma$

$F \propto m\frac{(v-u)}{t}$

$F \propto \frac{(mv-mu)}{t}$

→ **Newton's 2nd Law of Motion**

the rate of change in momentum is directly proportional to the force and acts in the direction of the applied force :

~~$F \propto ma$~~

~~$F = kma$~~

~~k is constant~~

In S.I. unit, 1N is the force that produces an acceleration of 1 m s^{-2} when applied on a mass of 1kg.

$1 \text{ N} = k \times 1 \text{kg} \times 1 \text{ m s}^{-2}$

$k = 1$

$\therefore F = ma$

Change of momentum

$= mv - mu$

Rate of change of momentum

$= \frac{(mv-mu)}{t}$

2.7 Impulse and Impulsive Force

definition

- impulse → change of momentum
- impulsive force
  → the rate of change of momentum in a collision / impact in a short period of time

Newton's 3rd Law of Motion

- for every ~~reaction~~ reaction, there is a reaction of equal magnitude but in the opposite direction

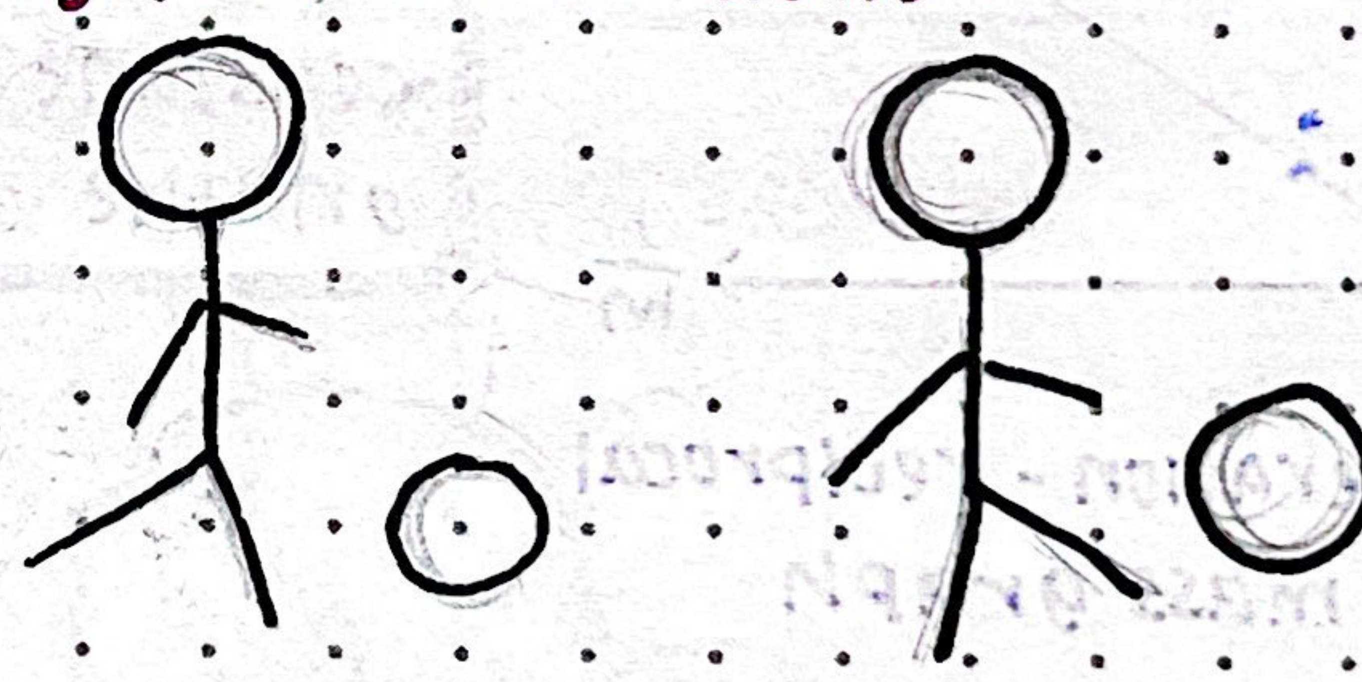
formula

① impulse, $J = mv - mu$
$= Ft$

② impulsive force, $F = \frac{mv - mu}{t}$
↳ if $t \downarrow$, $F \uparrow$
if $t \uparrow$, $F \downarrow$

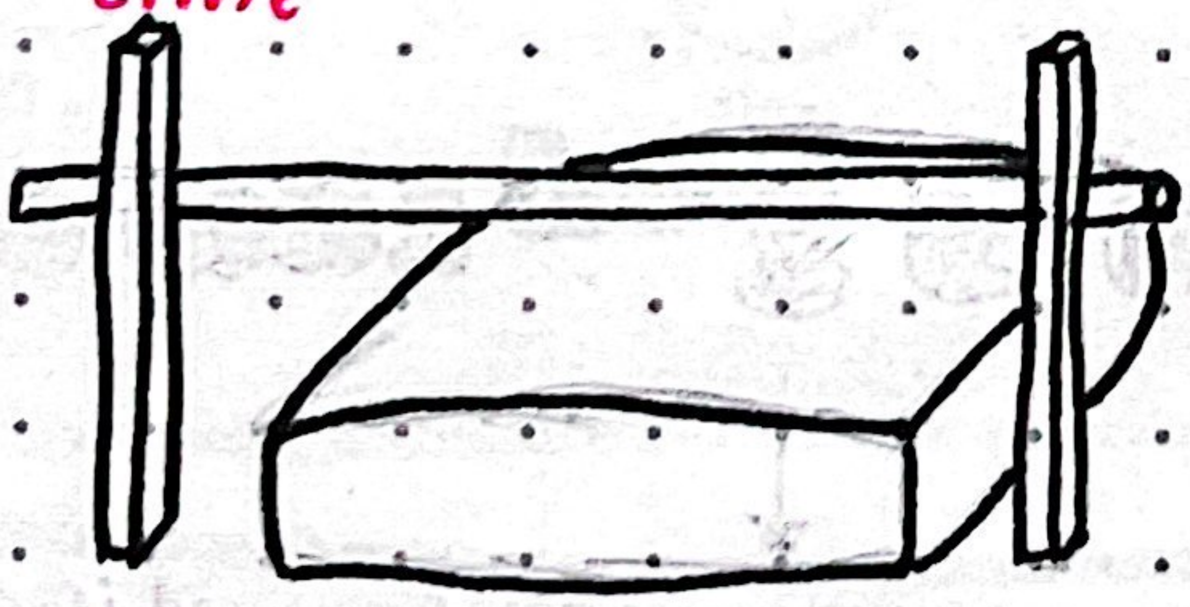
examples of N3LoM

① increasing magnitude of impulse by follow thru action



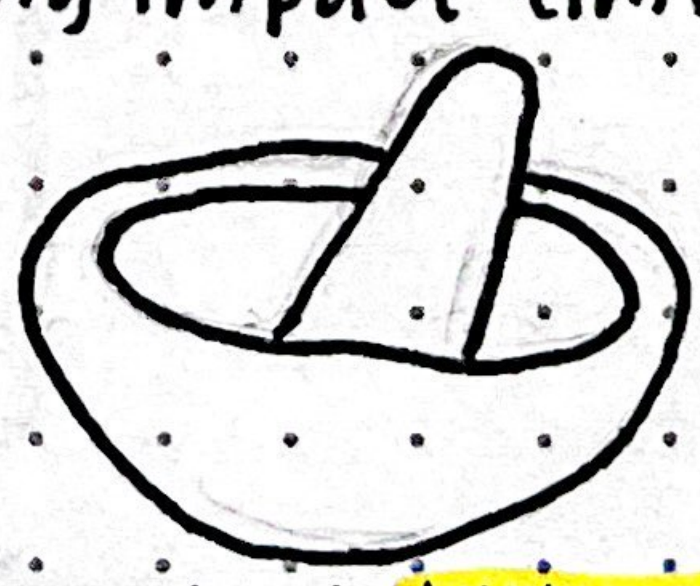
A follow thru action after a strong kick produces a large impulse.
↳ the ball experiences a large change in momentum + moves at a high velocity

② reducing impulsive force by extending impact time



The ~~long~~ high jump athlete lands on soft and fluffy mattress as the mattress can lengthen the impact time during collision.
↳ the magnitude of impulsive force is reduced
↳ athlete will not be hurt

③ increasing impulsive force by reducing impact time



pestle moving at high velocity + is stopped by a hard mortar in a short interval of time
↳ large impulsive force produced

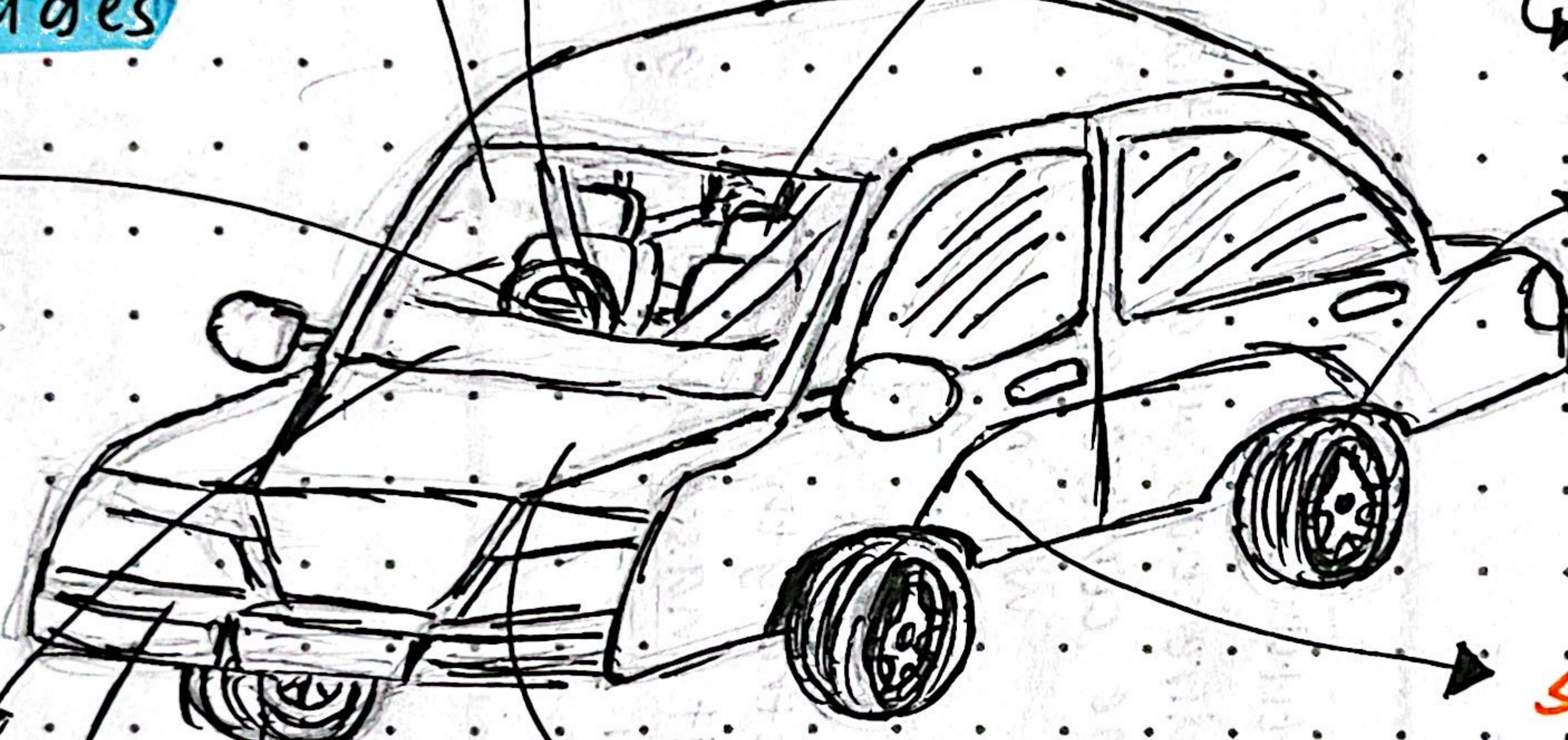
safety Features of a car

shatter proof windscreen
- prevents from shattering + reduces the injuries caused by shards of glass
  - ↳ when it breaks → small pieces + ~~roud~~ round edges

automatic airbag
- acts as a cushion for the head + body in an accident
  - ↳ prevents injuries
    - ↳ lengthen the time of impact

padded dashboard
- increase the time interval of collision
  - ↳ reducing the impulsive force produced during impact

bumper
- absorbs the impact in minor accidents
  - ↳ prevent damage of the car
  - ↳ reducing time of impact



- slows down the forward movt. when car stops abruptly

safety seatbelts
- prevent the passengers from being thrown out of the car

Headrest
- hold our neck / head + body to move together
- when the car is knocked from behind
  - ↳ protect the neck from a severe whiplash injury

Tyres with tread
- drains away water in its grooves on slippery road
- car has more contact
  - ↳ better grip on the road

Strong steel ~~shut~~ struts
- Prevents the collapse of the front + back doors in2 the passanger compartment
- gives good protection from a side-on collision

Anti-lock braking syst (ABS)
- prevent the ~~brakes~~ wheels ~~are~~ from locking when the brakes are applied suddenly
- stop quickly in slippery road
  - ↳ prevent skidding

Crumple zone
- extends the impact time during collision
  - ↳ the magnitude of the impulsive force on the car is reduced
  - ↳ car is less likely to rebound upon impact
    - ↳ reduces the momentum change / impulse
- the passengers sustain minor injuries

2.8 weight

- According to Newton's second Law of Motion :

$$F = ma$$

$$W = mg$$

- Gravitational force acting on the object is its weight, W
- acceleration of the object is gravitational ~~pull~~ acc., g

definition

- weight → a vector quantity
  - → has the same direction w/ gravitational force
    - ↳ towards the centre of Earth
- Unit for weight : N
- Unit for mass : kg

$$W = mg$$

$$g = \frac{W}{m}$$

∴ Unit for g : $N\ kg^{-1}$

- Gravitational field → g strength , g
  - ↳ force acting per unit mass caused by gravitational pull
  - ↳ Earth = $9.81\ N\ kg^{-1}$