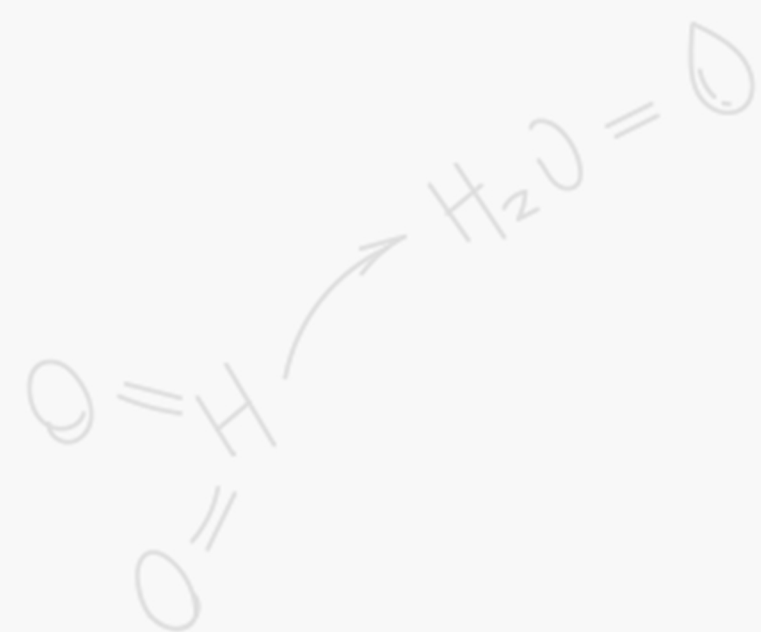




VISUAL
PHYSICS



V I S U A L P H Y S I C S

SHORT NOTES



C H A P T E R

Newton's Laws of Motion



+91 9999021287



www.visualphysics.in



Newton's Law of Motion

Force → Force is the external form of push or pull which:
→ produce motion of body at rest.
→ stops a moving body
→ changes the direction
→ change in shape

↓
Contact forces

↓
These forces act between bodies in contact.
e.g. Tension, normal reaction.

↓
Non-contact forces

↓
Forces that act without any actual contact.
e.g. gravity, electrostatics

Frame of reference

↓
Inertial frame of reference

↓
frame of reference, without acceleration.

i.e. steady or moving with constant velocity.

→ Also known as unaccelerated frame

→ Ideally, no inertial frame exists.

*if acceleration is negligible.

↓
Non-inertial frame of reference

↓
a frame accelerating frame of reference.

i.e. having some acceleration

For falling objects, Earth can be referred as 'inertial frame'.

→ Newton's law of motion can only be applicable in 'Inertial frame'.

Newton's first law of motion:

→ A body continues to be in its state of rest or uniform motion along a straight line unless it is acted upon by some external force to change the state.

Inertia of rest: It is the inability of a body to change by itself, its state of rest.

This means a body at rest remains at rest and cannot start moving by its own.

Inertia of motion: It is the inability of a body to change its state of uniform motion.

↓
constant velocity.

linear momentum: It is the quantity of motion in a body.

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

direction of $\vec{p}$ is same as $\vec{v}$

Newton's second law:

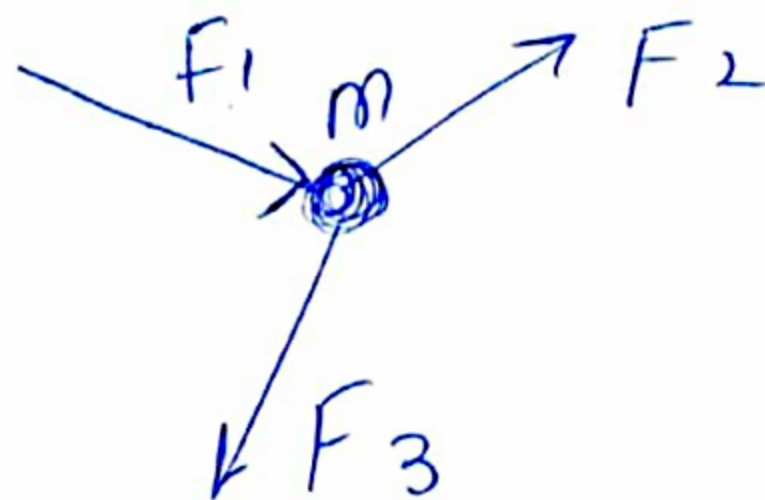
$$\vec{F}_{\text{ext}} \propto \frac{d\vec{p}}{dt}$$

$$\Rightarrow \vec{F}_{\text{ext}} = \frac{d\vec{p}}{dt} = \frac{d(m\vec{v})}{dt} = \frac{dm}{dt} \vec{v} + m \frac{d\vec{v}}{dt}$$

if m is constant
 $\frac{dm}{dt} = 0$

$$\Rightarrow \boxed{\vec{F}_{\text{ext}} = m\vec{a}}$$

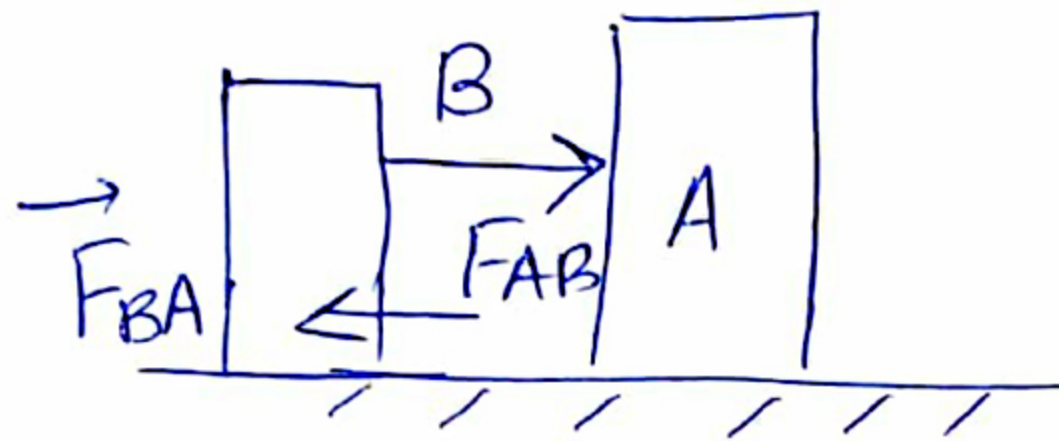
Net external force on a body.



$$\text{So, } \boxed{\vec{F}_{\text{ext}} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3}$$

Newton's third law:

To every action, there is always opposed an equal reaction.



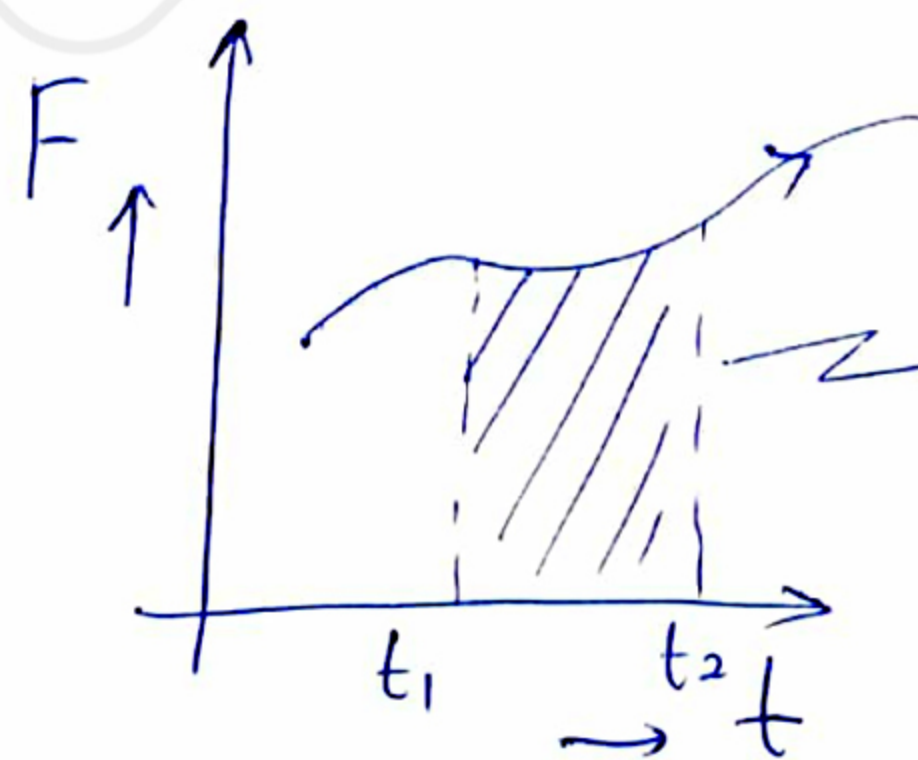
$\vec{F}_{AB} \rightarrow$ Force on A due to B
 $\vec{F}_{BA} \rightarrow$ Force on B due to A

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

IMPULSE:

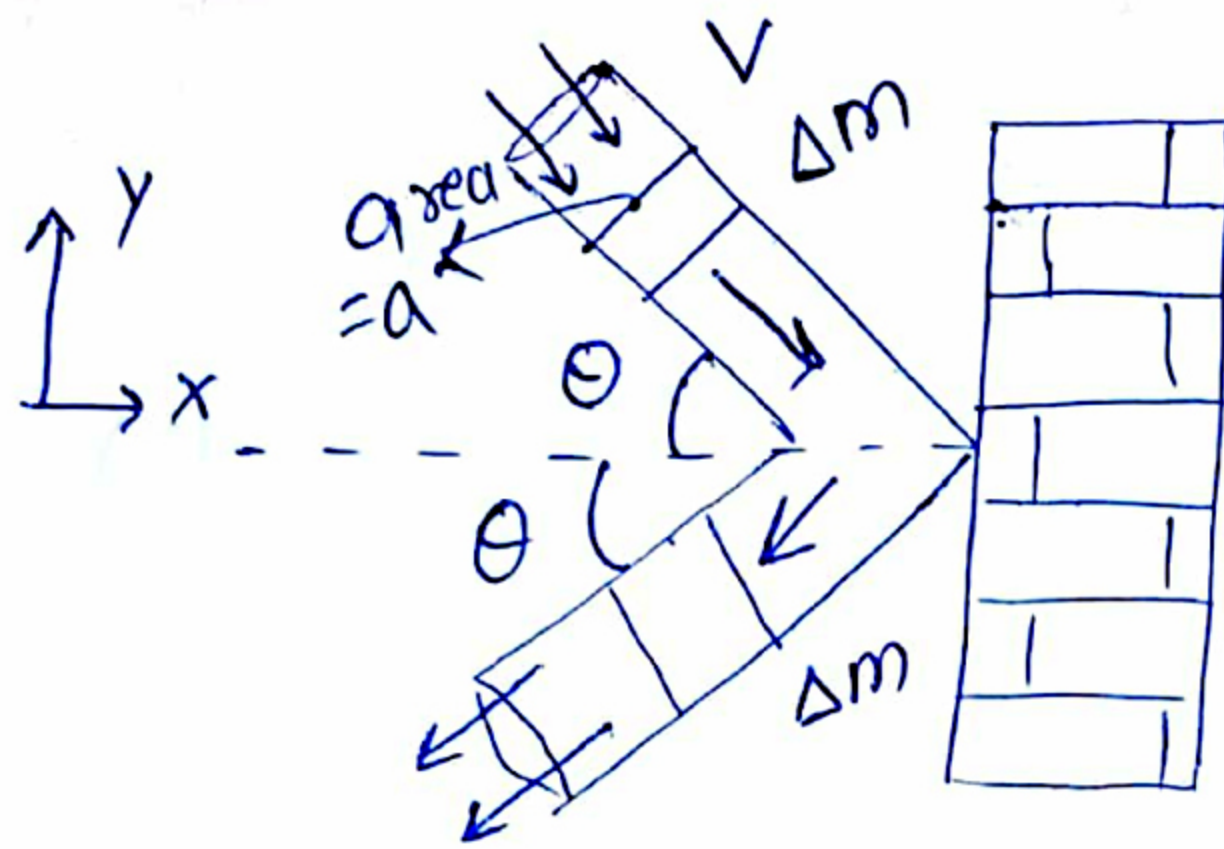
Impulse $\rightarrow \boxed{J = \int_{t_1}^{t_2} \vec{F}_{ext} dt = \Delta \vec{p}}$

$\boxed{\vec{F}_{ext} = \sum F}$ $\Delta \vec{p} = \vec{p}_f - \vec{p}_i$



Area of $F-t$
 $= \text{Impulse}$

Impulse of force Exerted by liquid jet on wall



$$(\Delta P_x)_{\text{wall}} = 2\Delta m v \cos \theta$$

$$\begin{aligned} \text{and } (\Delta P_y)_{\text{wall}} &= m v \sin \theta \\ &\quad - m v \sin \theta \\ &= 0 \end{aligned}$$

$$F = \frac{[\Delta P_x]_{\text{wall}}}{\Delta t}$$

$$\begin{aligned} F &= \frac{2\Delta m v \cos \theta}{\Delta t} \\ &= 2v \cos \theta \left(\frac{\Delta m}{\Delta t} \right) \end{aligned}$$

now $\Delta m = \rho \Delta V$
 ΔV → Volume of water striking for Δt time.

$$\frac{\Delta V}{\Delta t} = Q = a \vec{v}$$

$\vec{v}$ → velocity
 a → Area

$$\Rightarrow F = 2v \cos \theta \left(\rho \frac{\Delta V}{\Delta t} \right)$$

$$\boxed{F = 2\rho a v^2 \cos \theta}$$

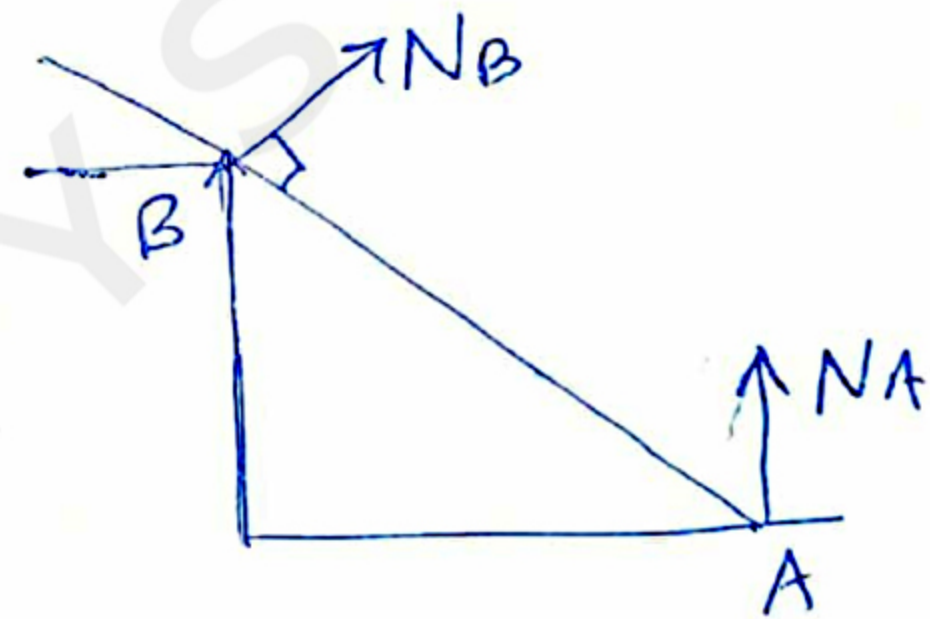
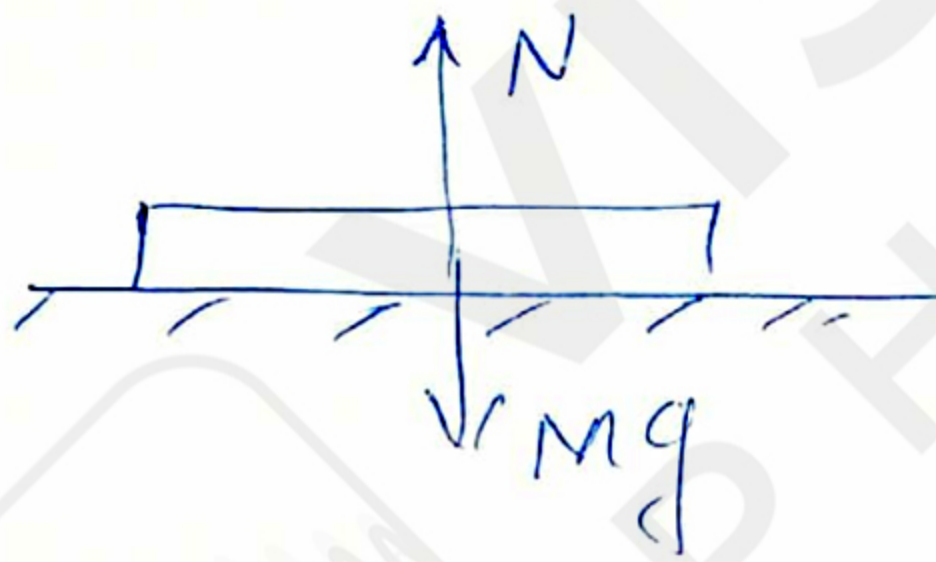
Free - Body Diagram :

The object of interest is isolated from its surroundings, and the interactions between the object and the surrounding in terms of forces.

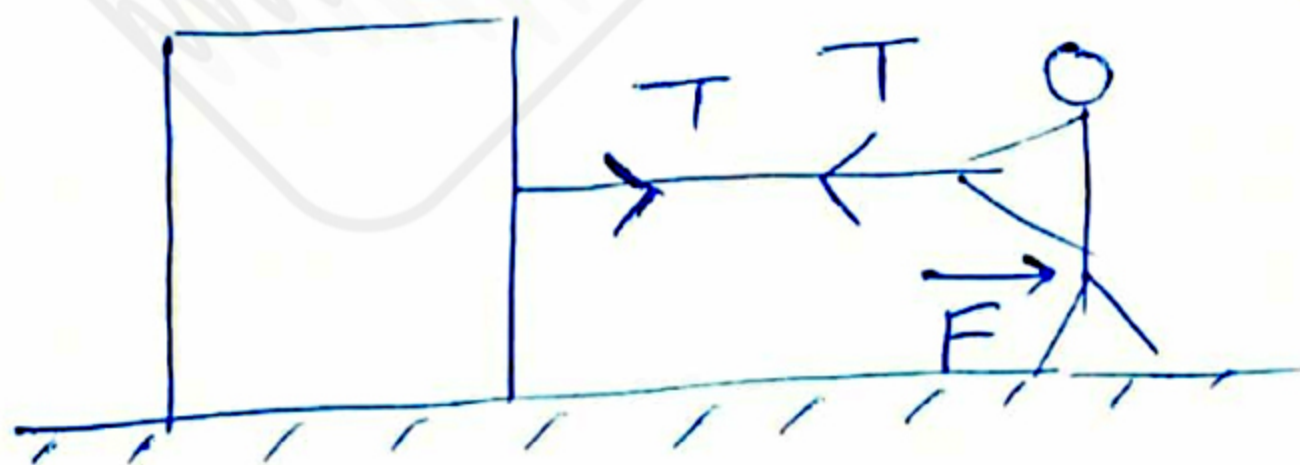
Weight : mg (Reaction of ground)

↳ mass $\times$ acceleration due to gravity.

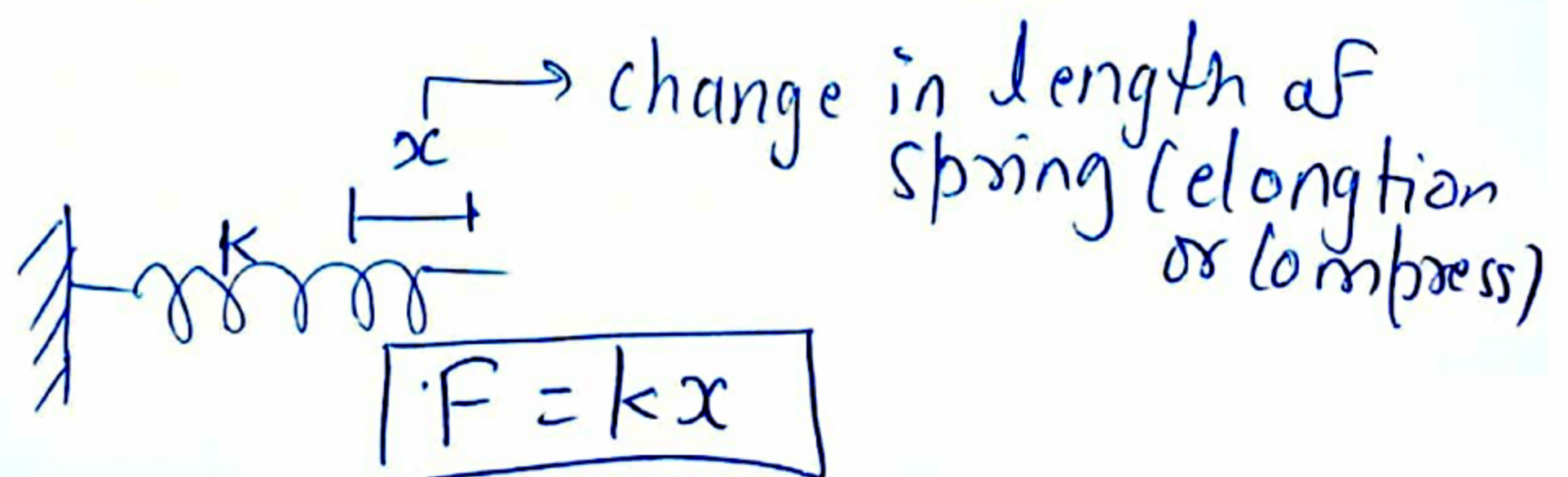
Normal force: Whenever two surfaces are in contact, they press (or push) each other by a force called contact force.



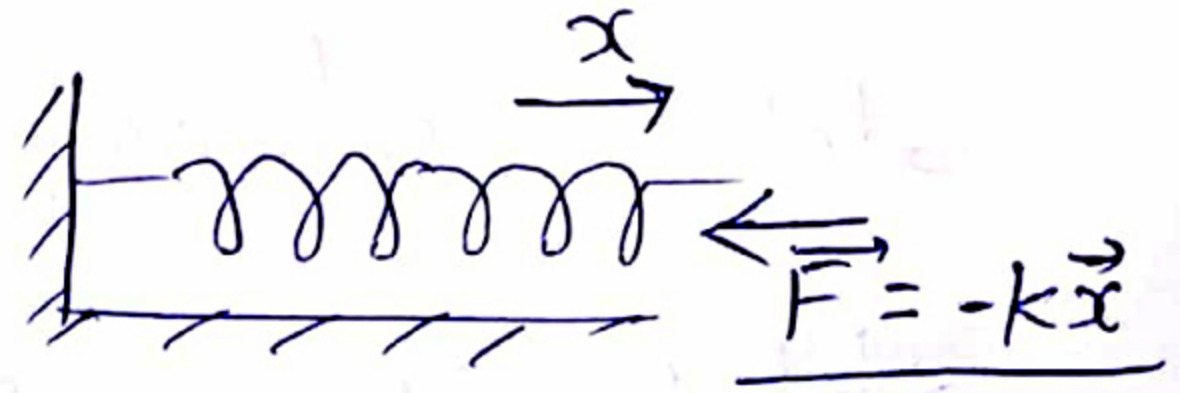
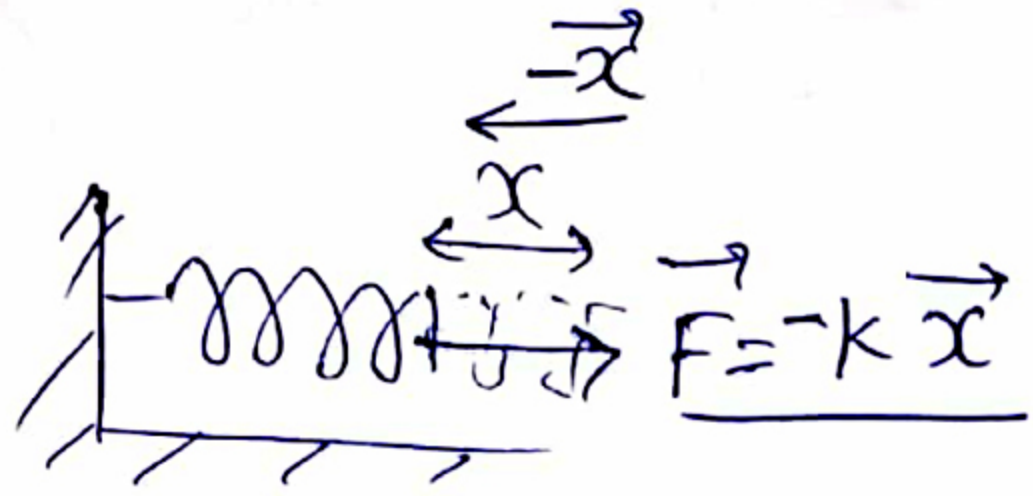
Tension: It is an inter-molecular force between the atoms of a string.



Spring force:



change in length of spring (elongation or compression)

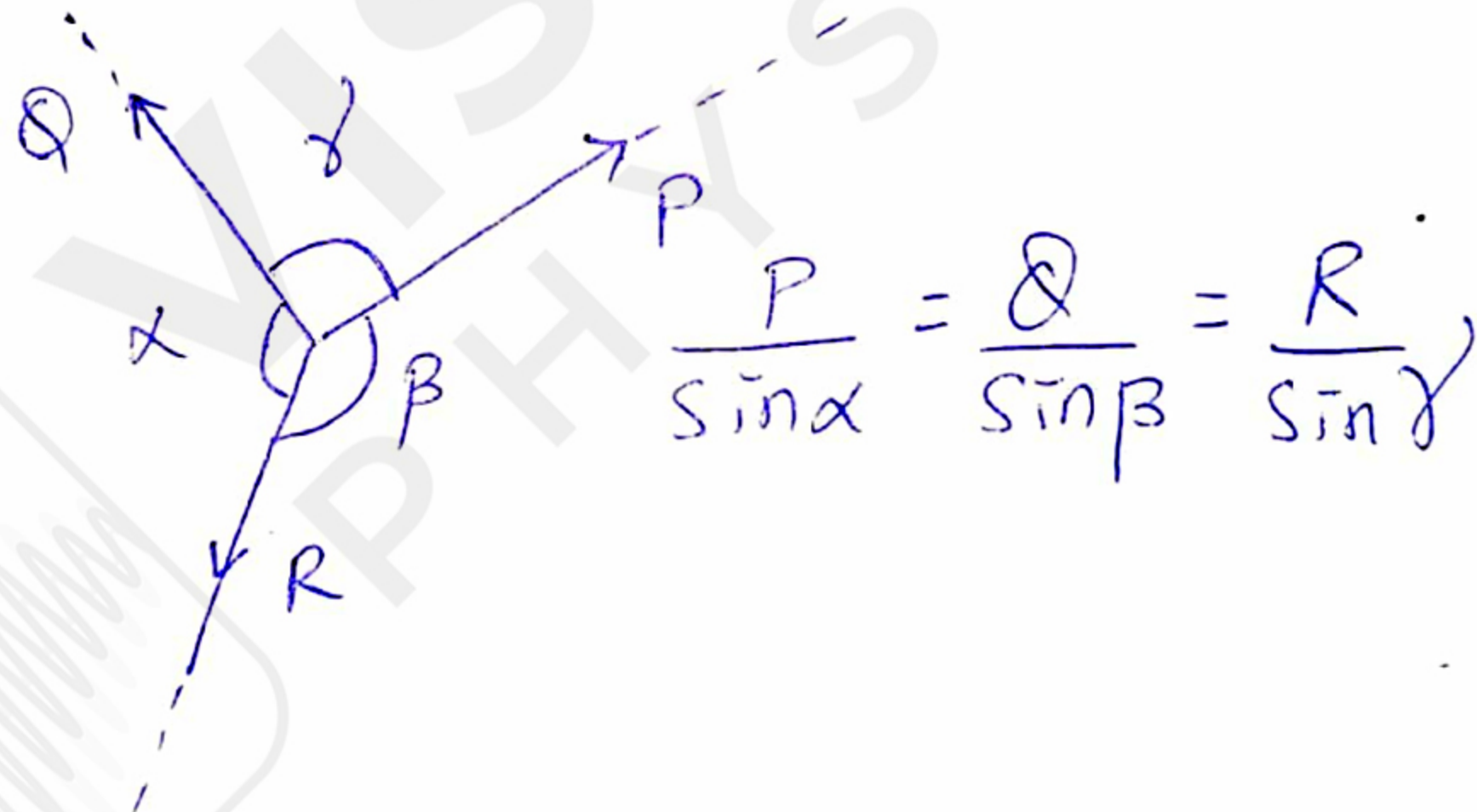


$\vec{F}$ & $\vec{x}$ are opposite

Equilibrium of a particle: No net external force on an object.

$$\Rightarrow \boxed{\sum \vec{F}_{\text{ext}} = 0}$$

Lami's Theorem:



Concurrent forces $\rightarrow$ if more than two forces act on same particle.

Steps of solving:

Step 1: Draw FBD

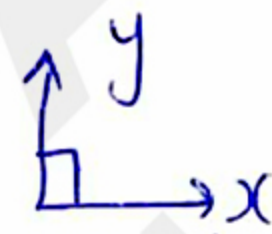
Step 2: apply Newton's second law

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

now apply that.

~~for~~ Resolve the forces acting on the objects and apply $\vec{F} = m\vec{a}$.

$\vec{a}_x$ and $\vec{a}_y$



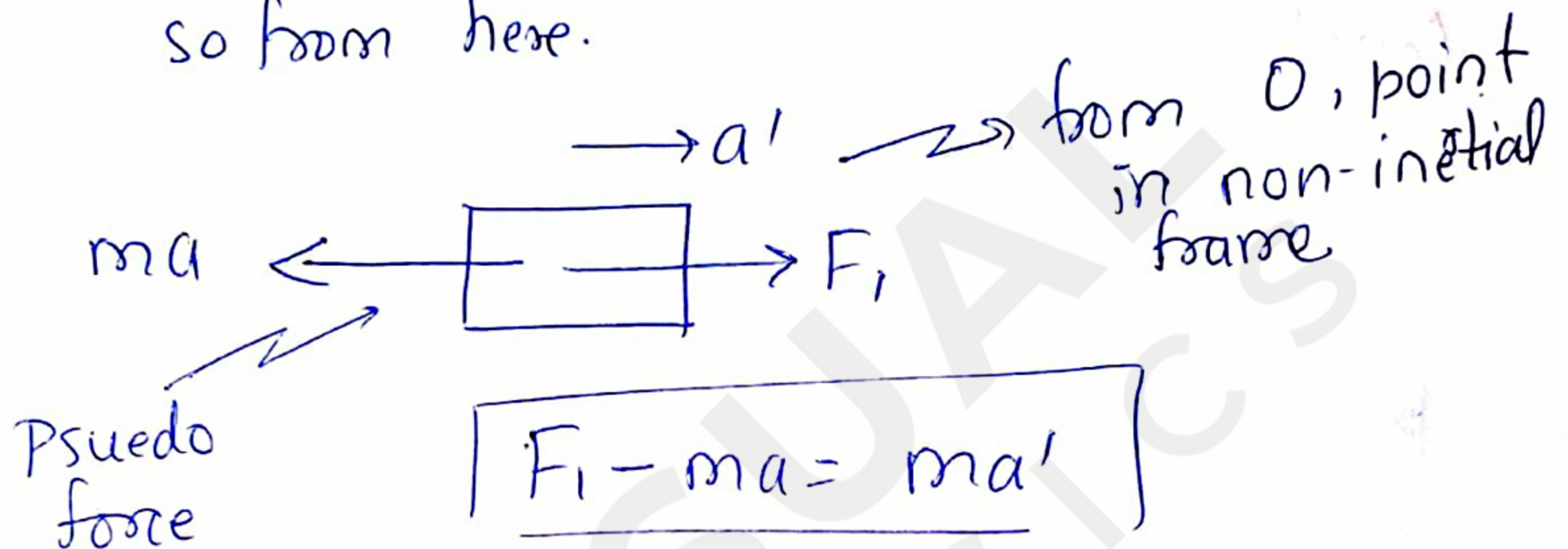
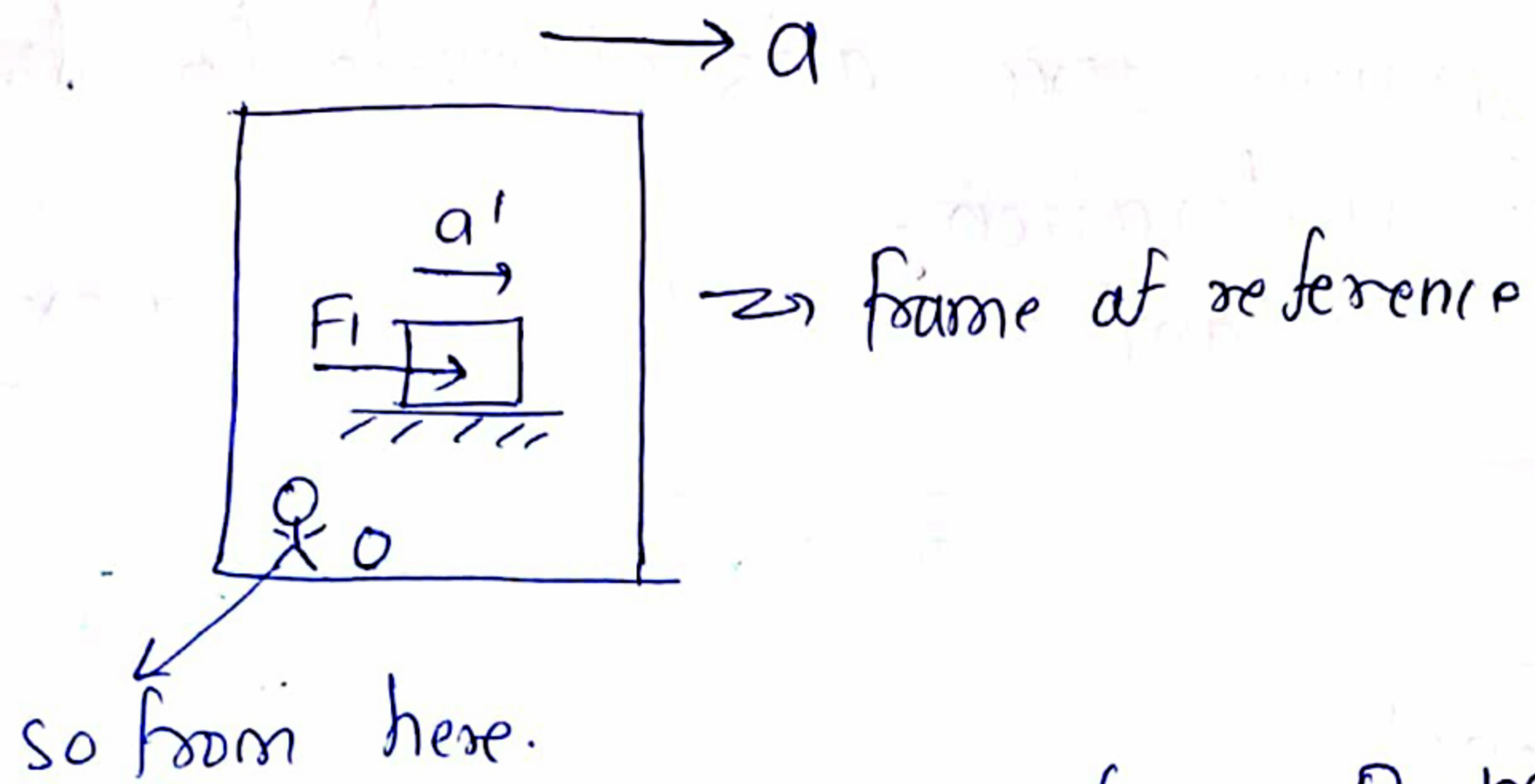
two perpendicular direction and resolve it in these two directions individually.

Step 3: solve the component equations for the unknowns. In each direction.

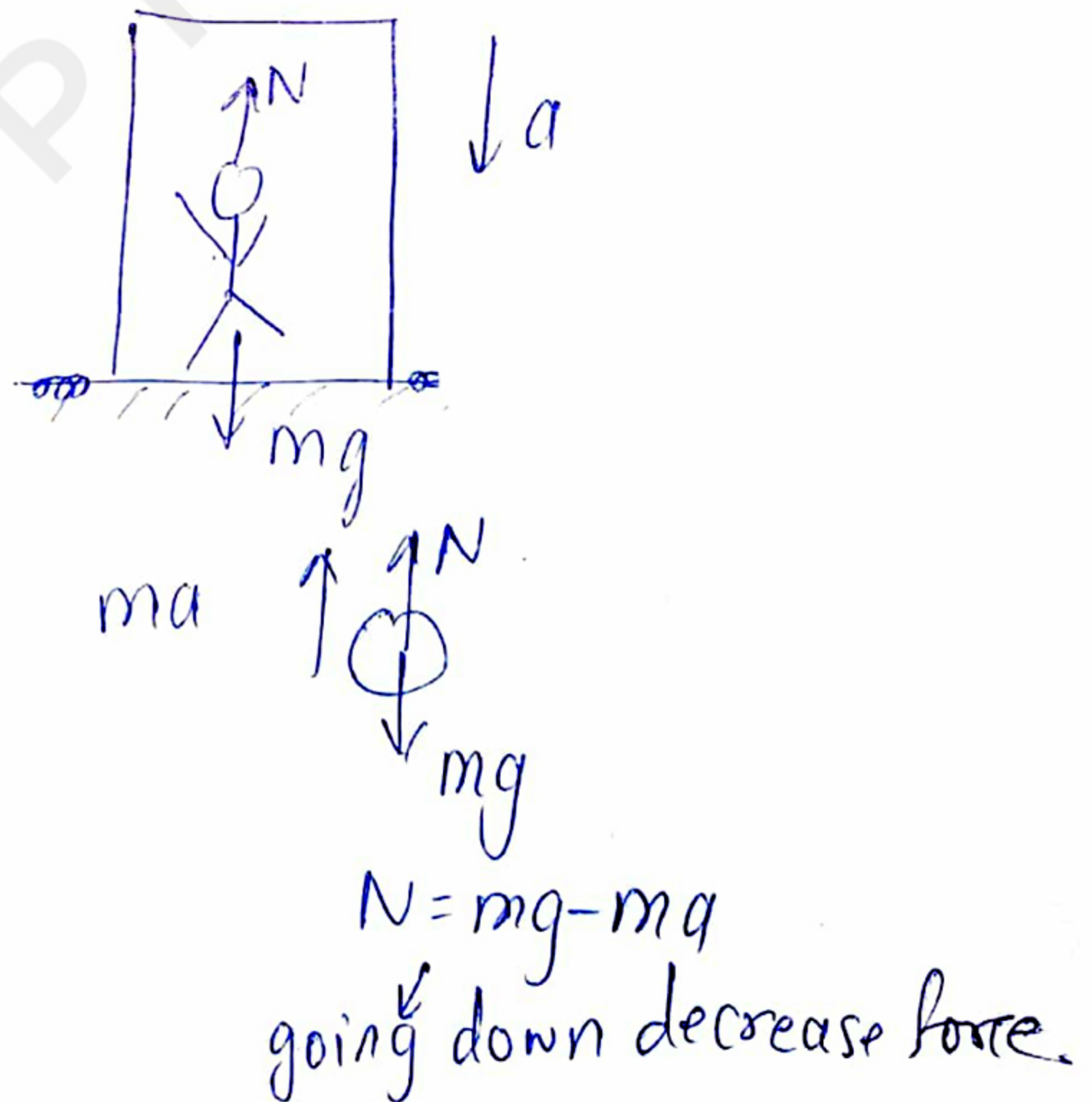
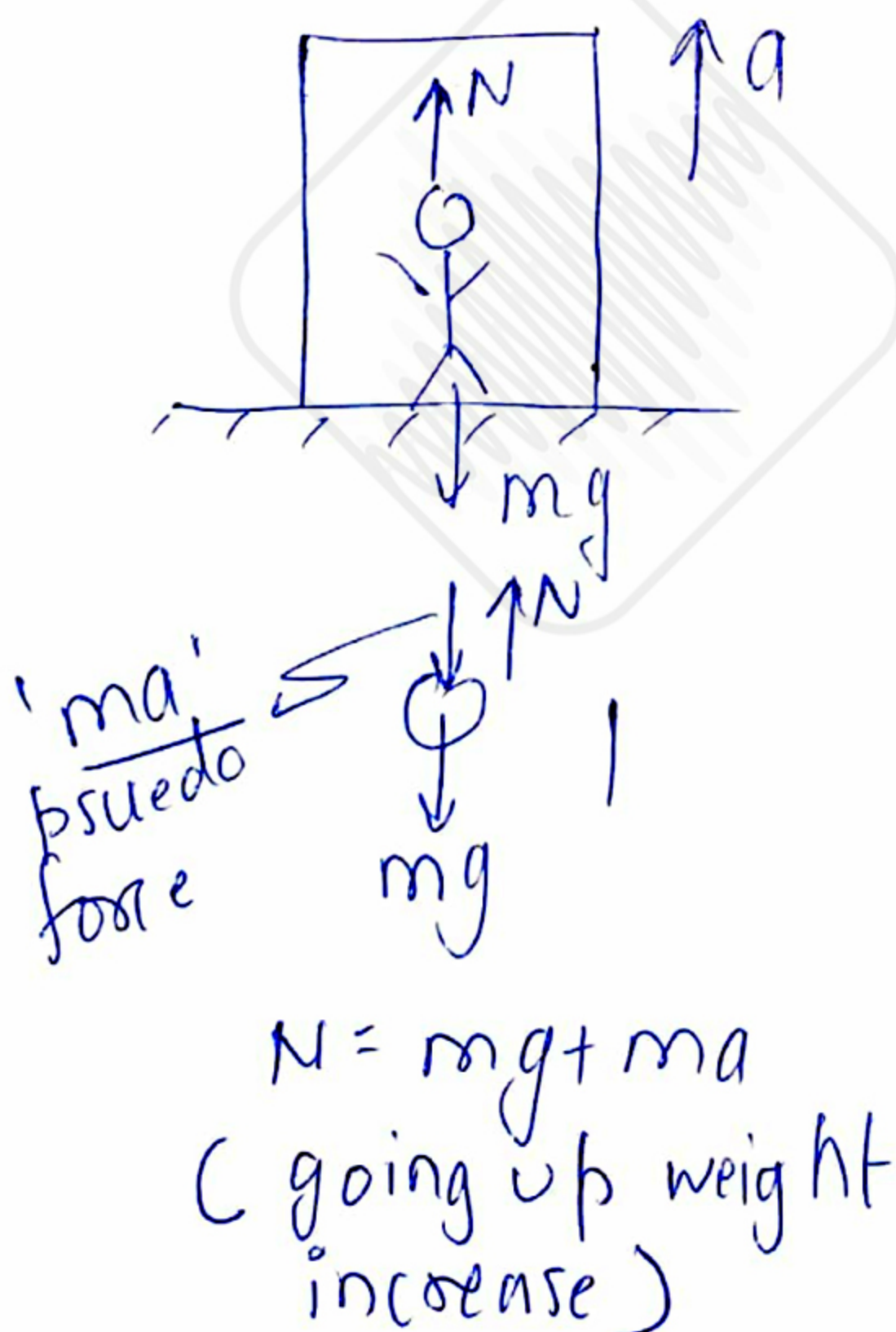
Non-inertial frame of reference and pseudo force:

If frame of reference is non-inertial..

To make the condition so that Newton's law can be applied we need to apply pseudo force.



After applying pseudo force we can apply Newton's law.



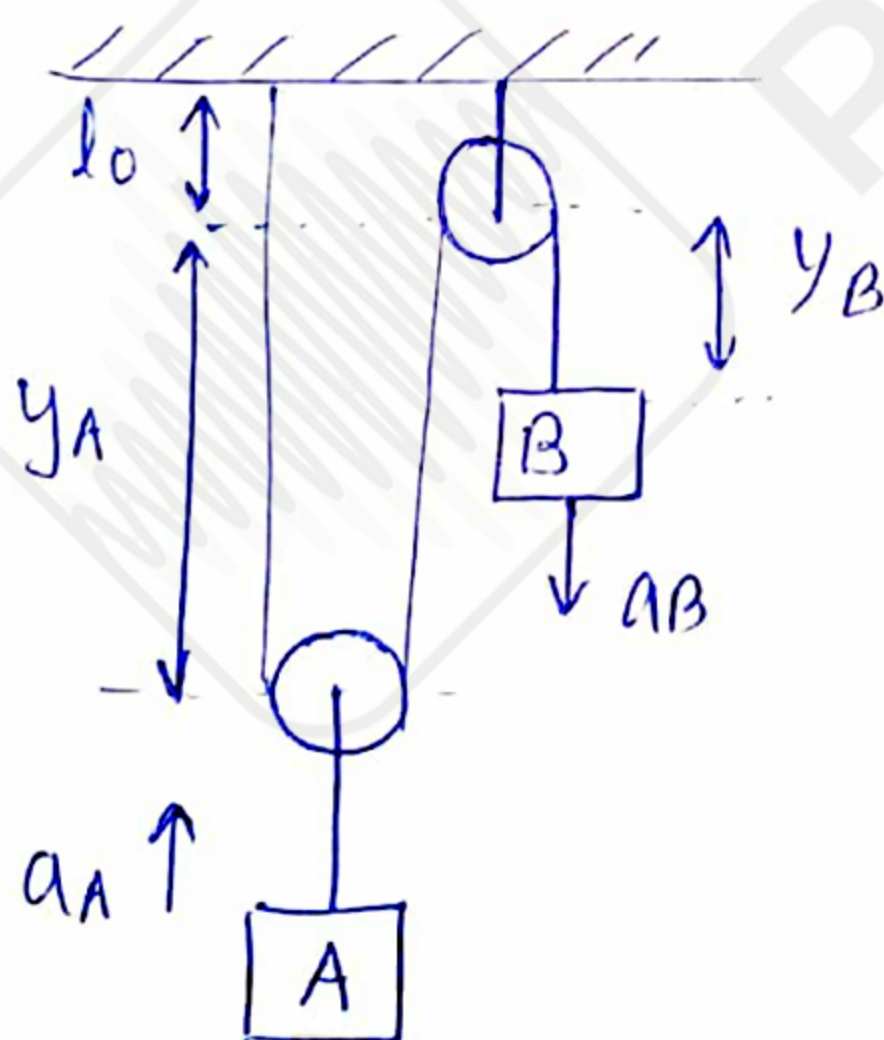
pseudo force acts opposite to direction of acceleration.
and magnitude is $mass \times \text{acceleration of frame of reference}$

Constraint relations

↳ Constraints mean that two bodies are not free to move the way they want.

pulley constraint:

pulley constraints are applicable when the bodies concerned are connected through pulleys and the rope connecting them is inextensible.



net length of string

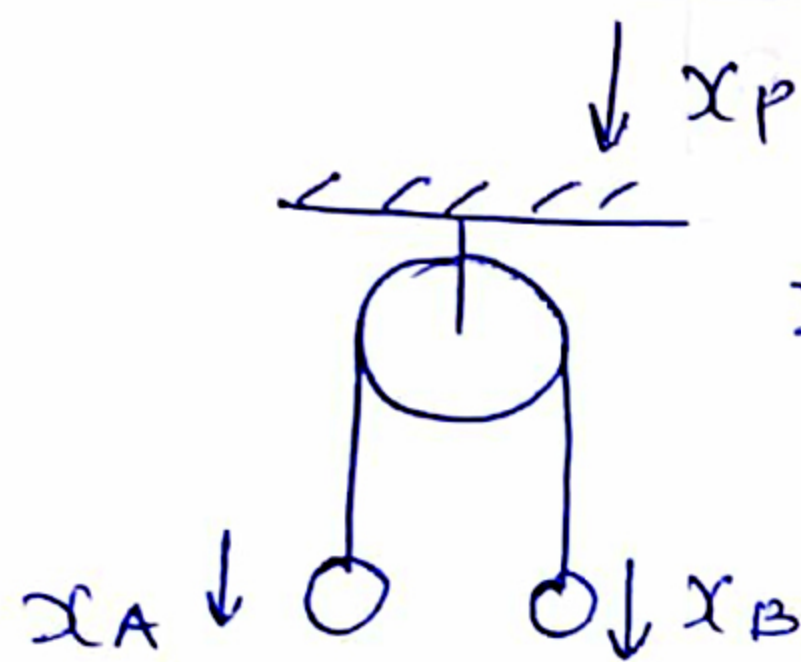
$$y_B + 2y_A + l_0 = 0$$

$$\frac{d}{dt} (y_B + 2y_A + l_0) = 0$$

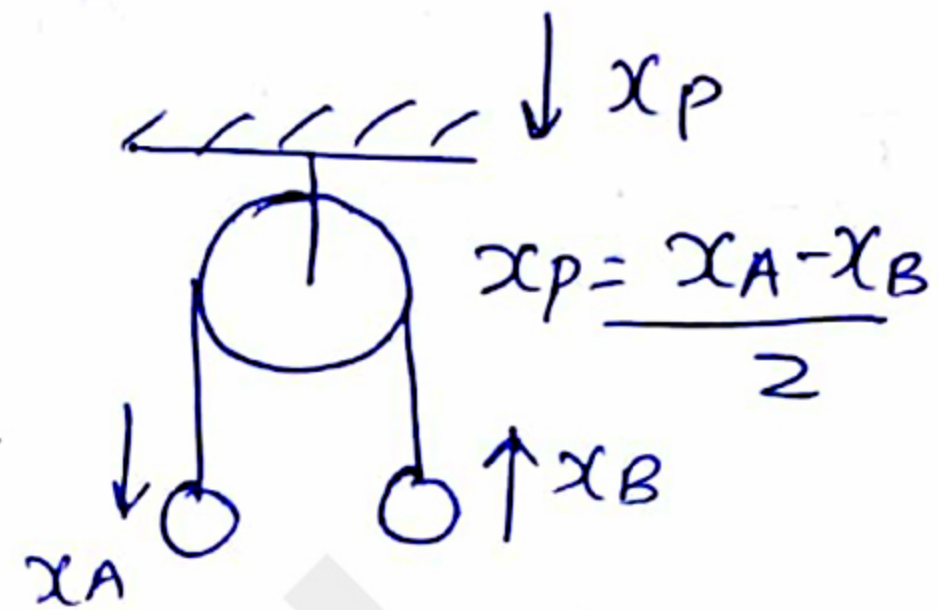
$$\Rightarrow \boxed{V_B = -2V_A}$$

$$\Rightarrow \boxed{a_B = -2a_A}$$

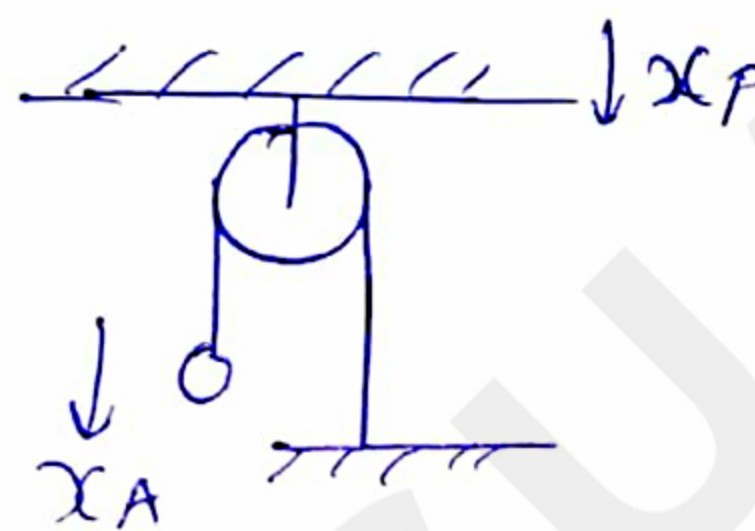
Shortcut methods:



$$x_p = \frac{x_A + x_B}{2}$$

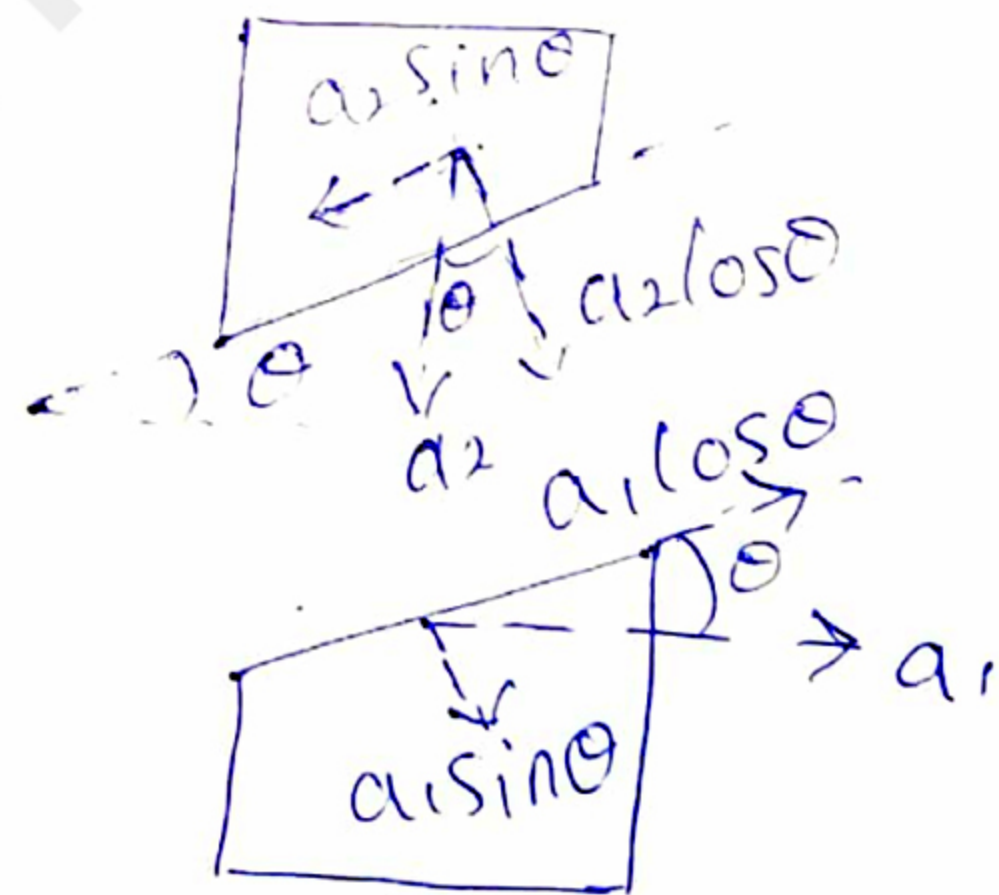
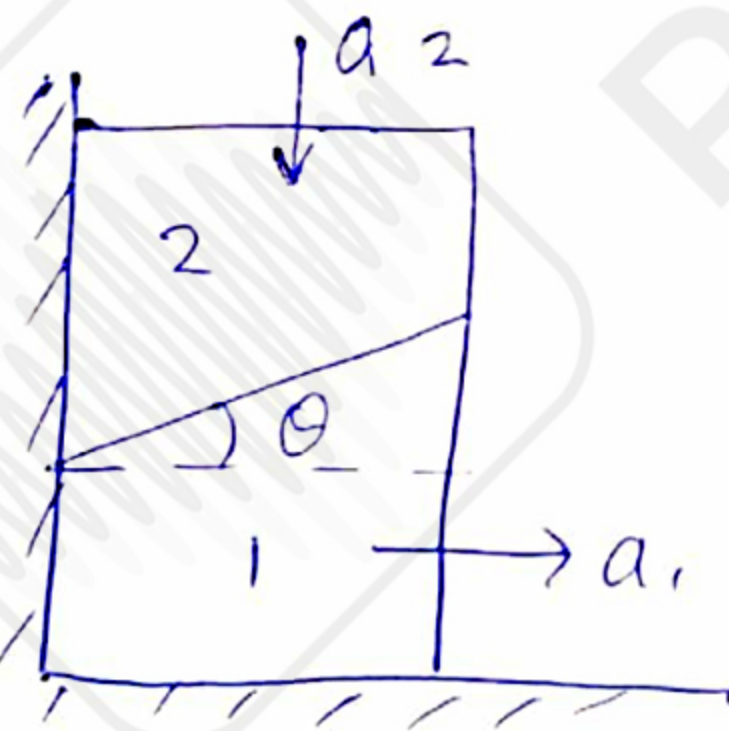


$$x_p = \frac{x_A - x_B}{2}$$



$$x_p = \frac{x_A + 0}{2} = \frac{x_A}{2}$$

Wedge Constraint:



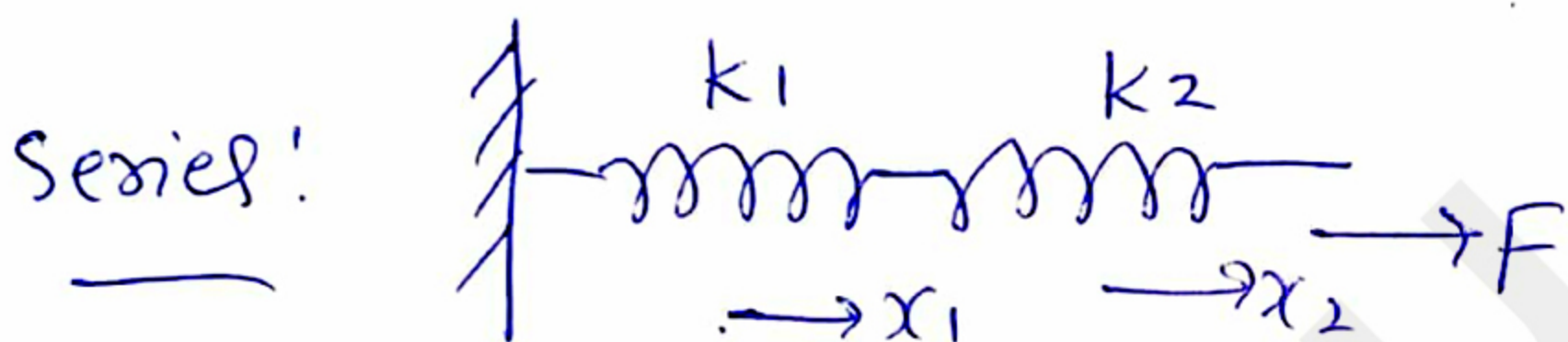
The two objects always remain in contact.

⇒ In order to maintain the component of velocity the vector perpendicular to contact surface will be same.

i.e. component of acceleration as well

$$\Rightarrow \boxed{a_1 \sin \theta = a_2 \cos \theta}$$

combination of springs

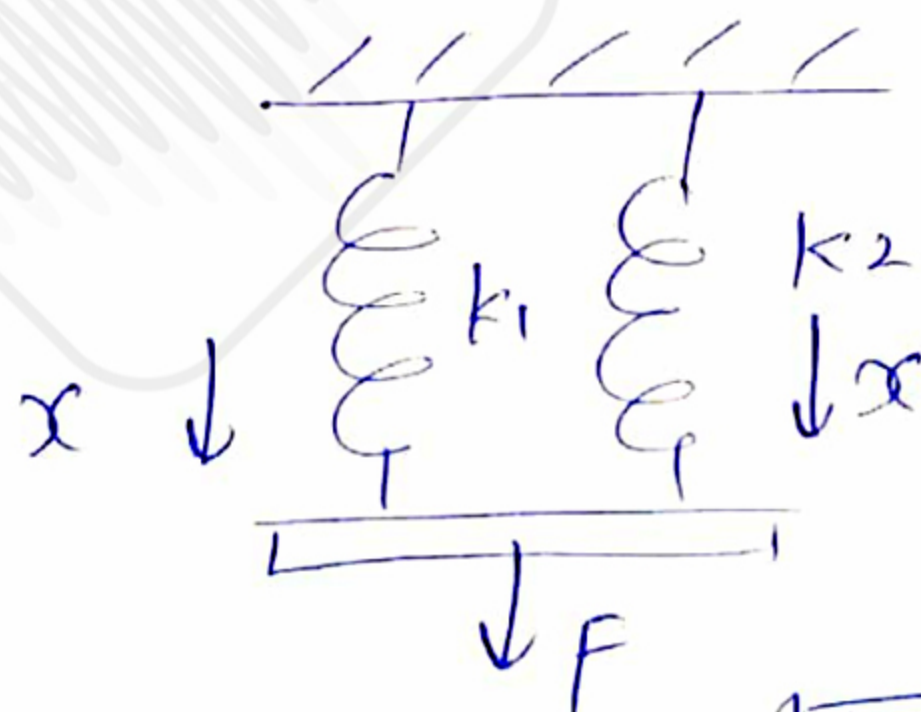


$$\boxed{F = k_1 x_1 = k_2 x_2}$$

$$\boxed{k_{\text{net}} = \frac{k_1 k_2}{k_1 + k_2}}$$

x = net displacement = $x_1 + x_2$

parallel:



$$\boxed{F = (k_1 + k_2) x}$$

$$\boxed{k_{\text{net}} = k_1 + k_2}$$