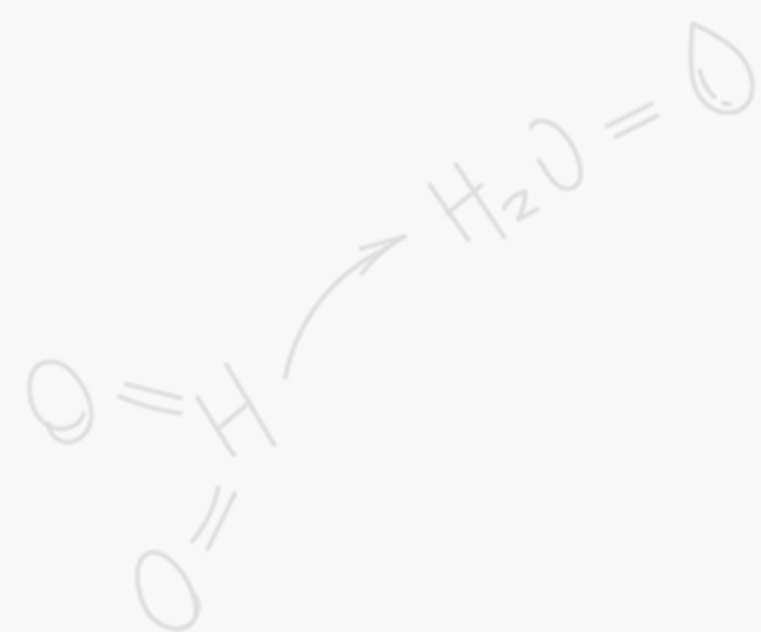




VISUAL
PHYSICS



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

SHORT NOTES



C H A P T E R

Work, Power & Energy

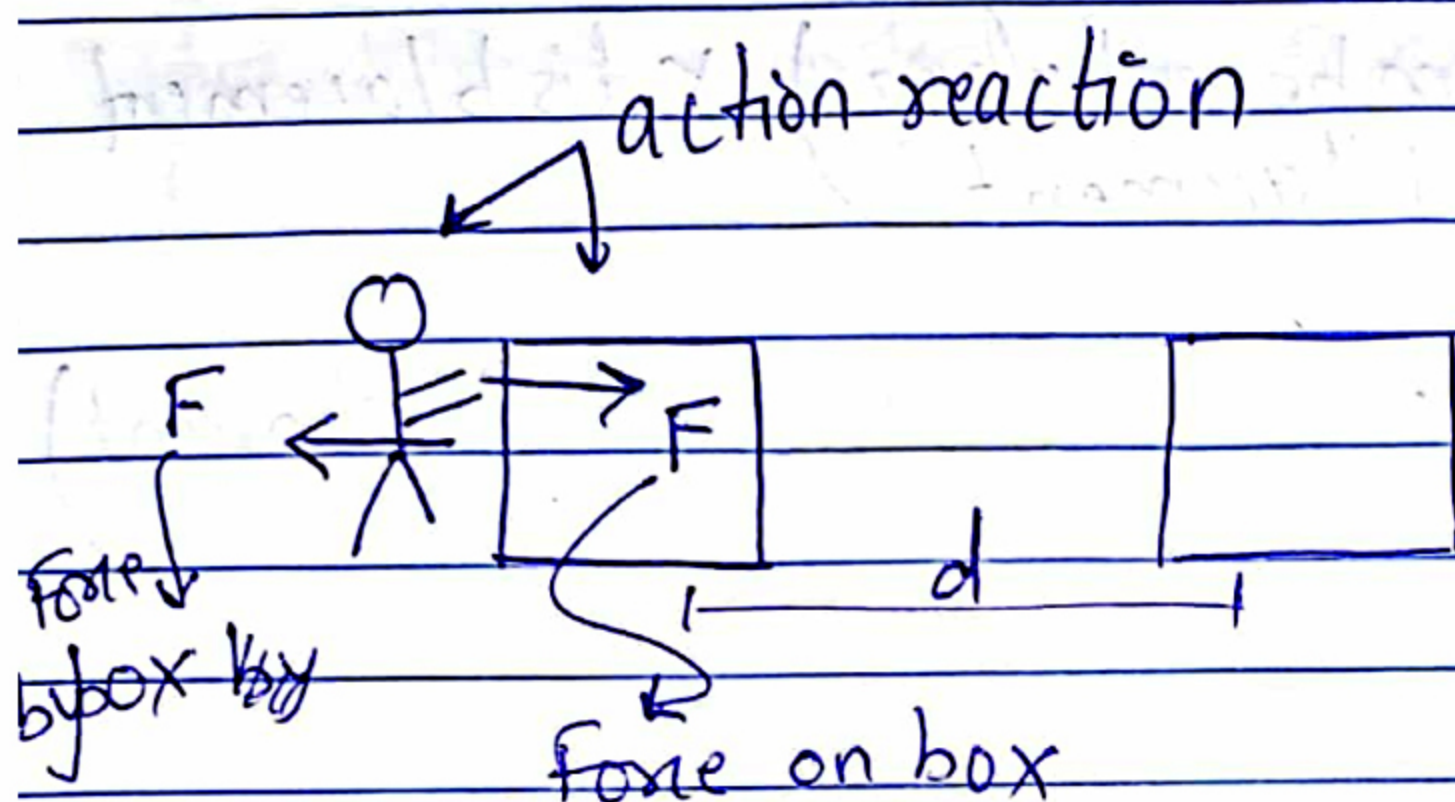


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'F' force needed to displace the box by d .



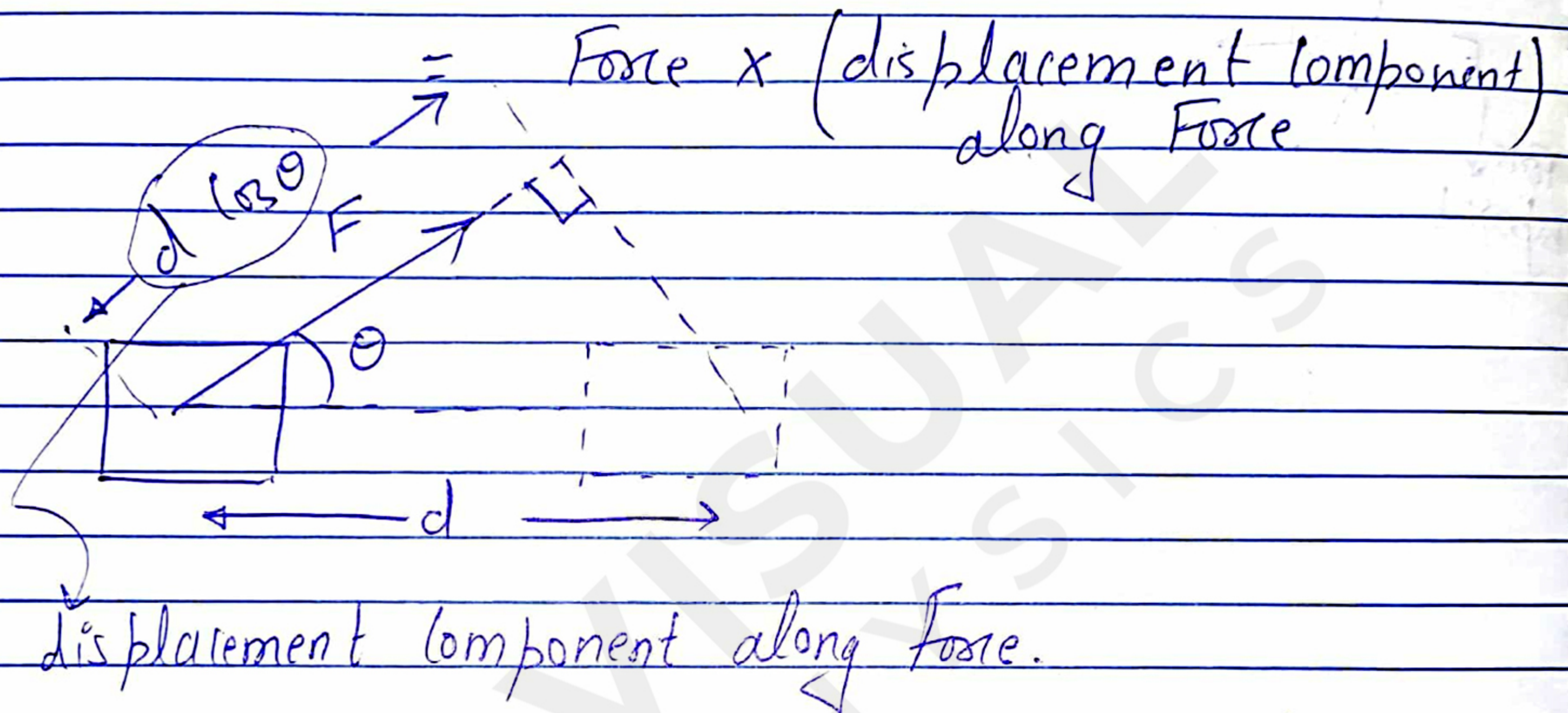
Here $F \cos \theta$ amount of force need to displace object by ' d '.

$$\text{Work} = \overset{\substack{\text{(N)} \\ \nearrow}}{F} \cdot \overset{\substack{\text{(m)} \\ \nearrow}}{d} = F \cos \theta d \quad \text{so SI unit (N-m)}$$

Force on object displacement

Now $F \cos \theta$ is component along ' d '
 & $d \cos \theta$ is component along ' F '

So, $W = (\text{Force component along displacement}) \times \text{displacement}$



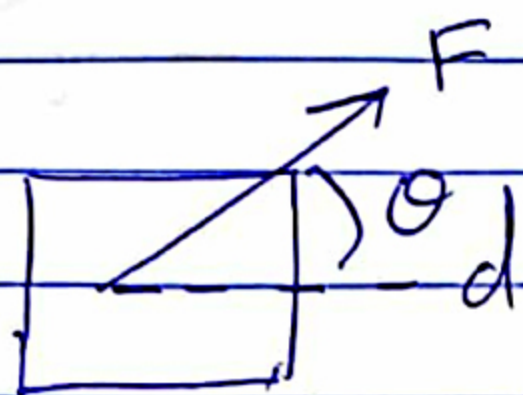
If in terms of Vector

$$W = (F_x \hat{i} + F_y \hat{j} + F_z \hat{k}) \cdot (x \hat{i} + y \hat{j} + z \hat{k})$$

$$W = F_x x + F_y y + F_z z$$

Scalar
no direction

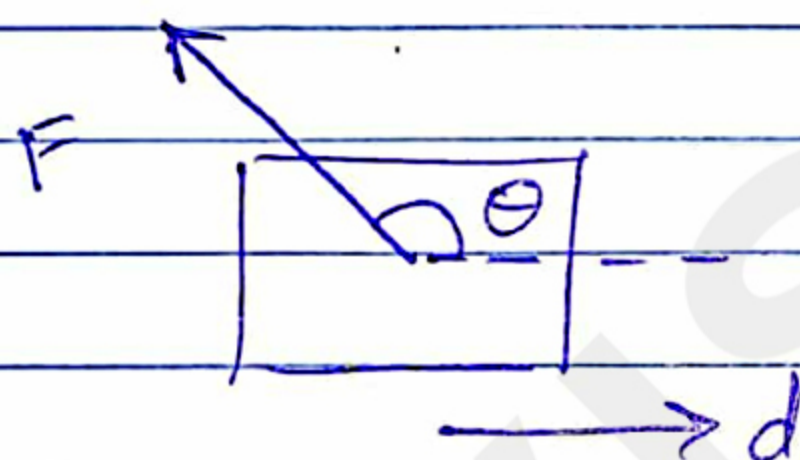
positive work ($0 < \theta < 90$)



$$W = Fd \cos \theta$$

Work is done on the object

negative work ($90 < \theta < 180$)

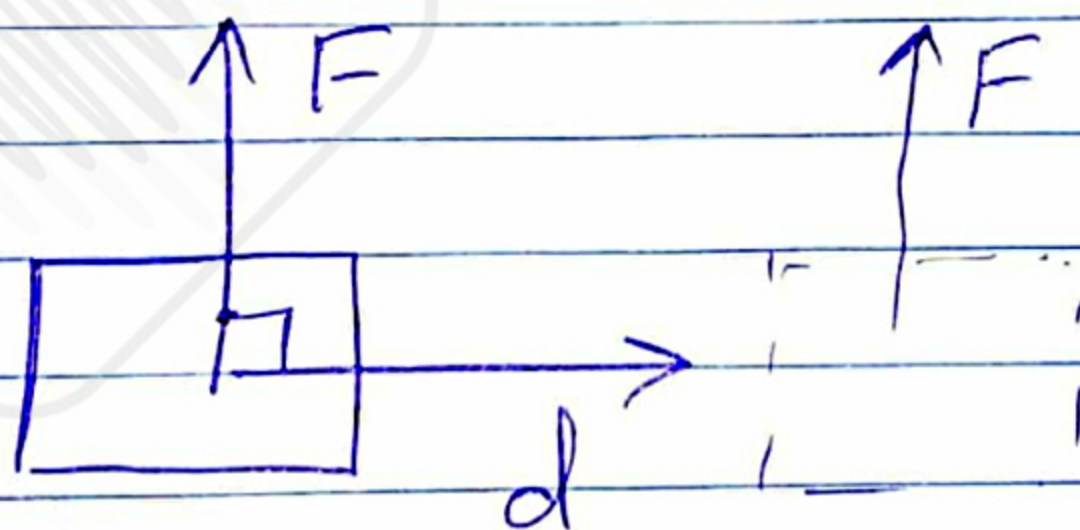


$$W = Fd \cos \theta$$

negative as
 $\cos \rightarrow -ve$
when $90 < \theta < 180$

Here work is done against the object

Zero work:

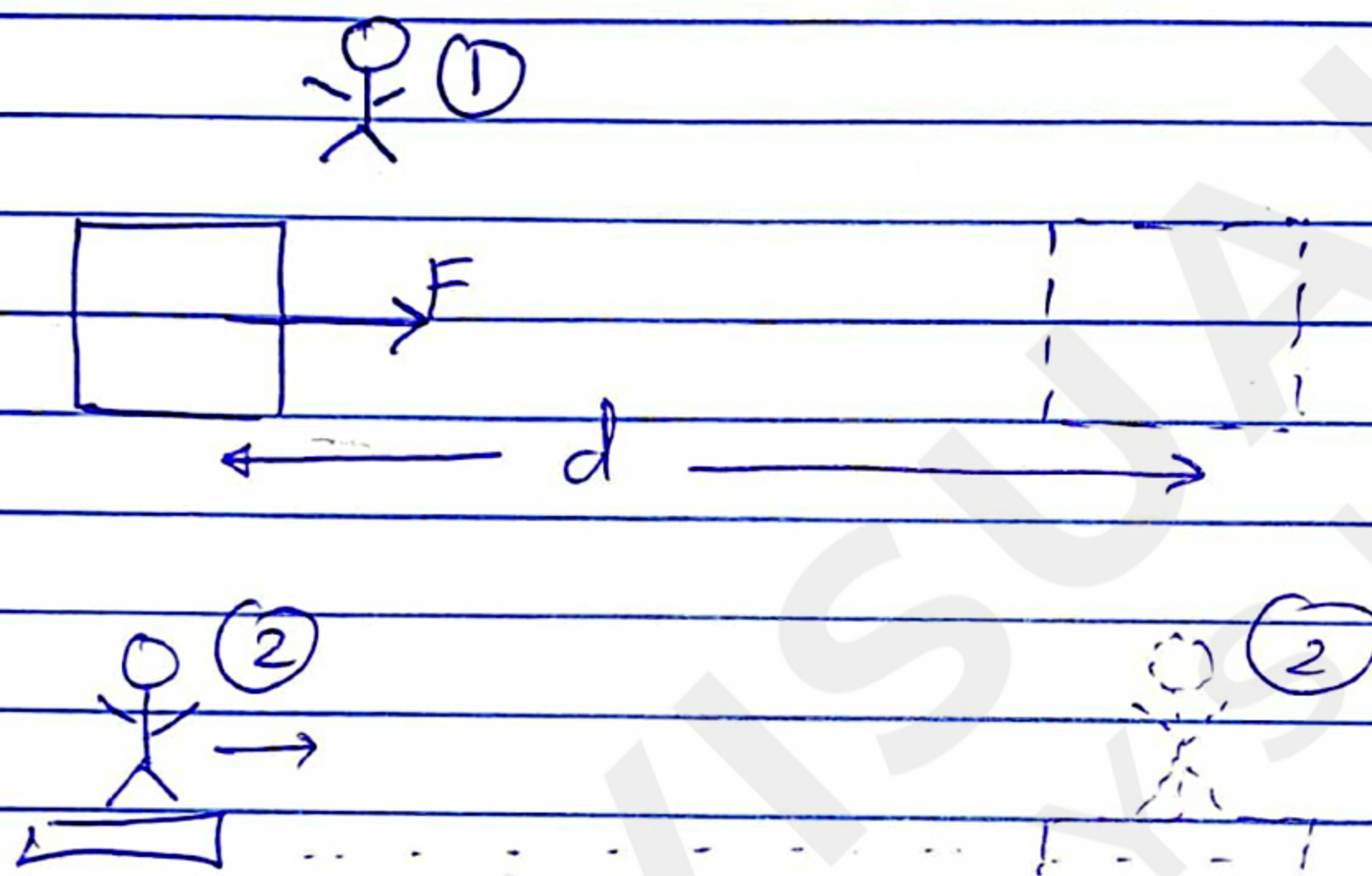


As here force is not responsible in displacing the object and also not restricting the object displacement.

Hence no work done

$$W = Fd \cos 90 = 0$$

Work Depends on frame of reference:-



for (1), block move by d

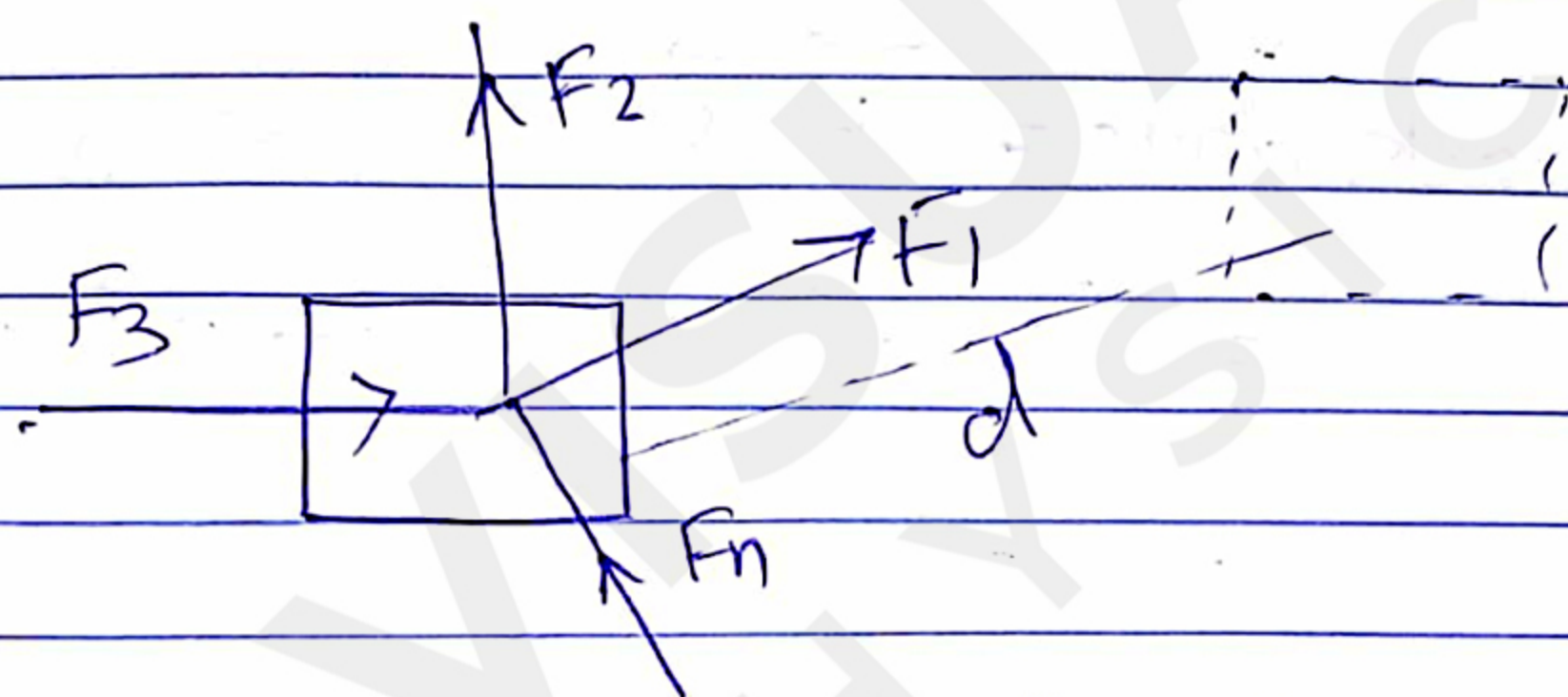
$$\text{so } W_1 = Fd$$

for observer (2), block did not move

so

$$W_2 = F(0) = \underline{0}$$

so work depends on frame of reference.



In this case $Work = \vec{F}_{net} \cdot \vec{d}$

$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \dots + \vec{F}_n$$

Now

$$W = \vec{F} \cdot \vec{d}$$

↙
when the force is constant throughout
'd'

Now, what if, F is not constant
throughout?

We calculate small work ' dW '.

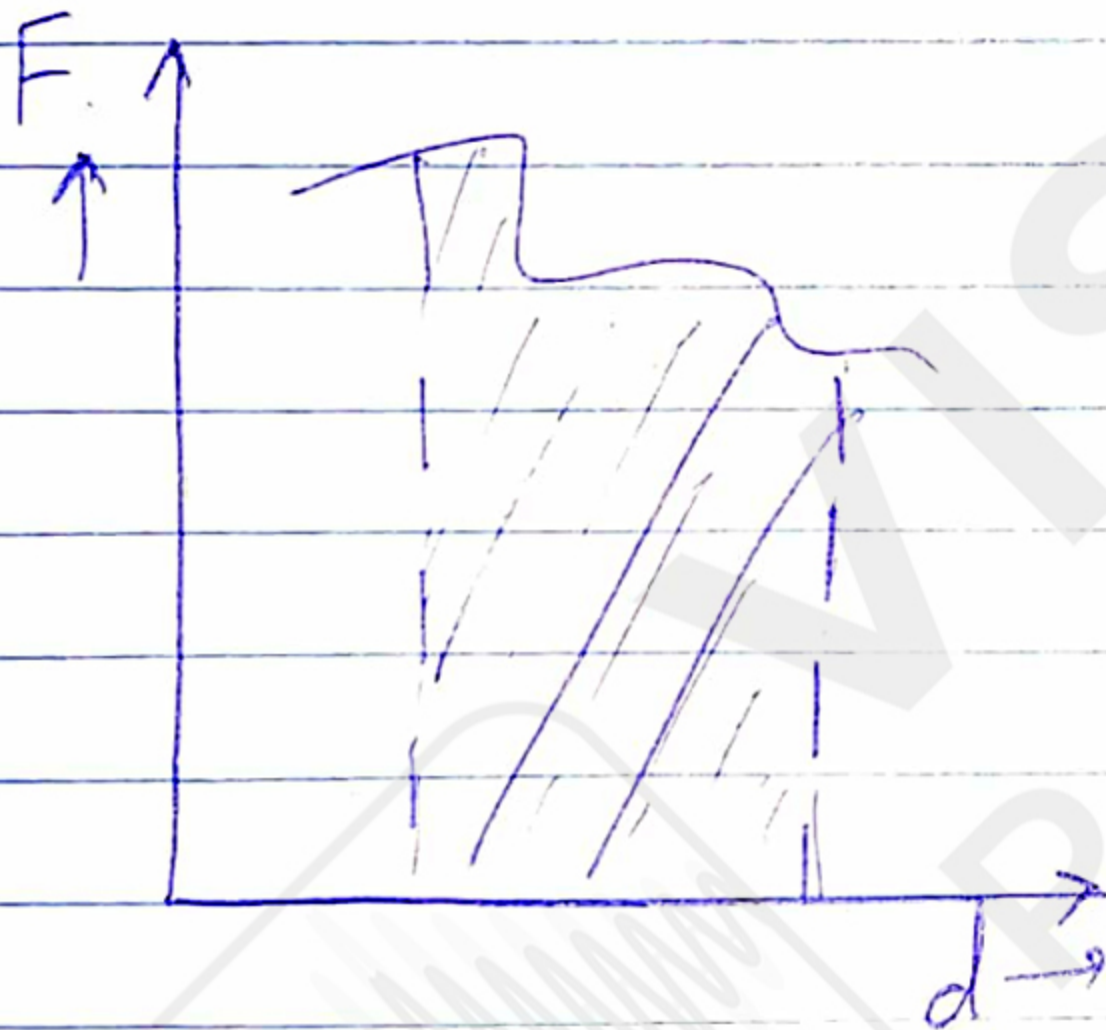
for small displacement ' ds '

for which F is constant. ↳ displacement

$$\text{so, } dW = \vec{F} \cdot d\vec{s}$$

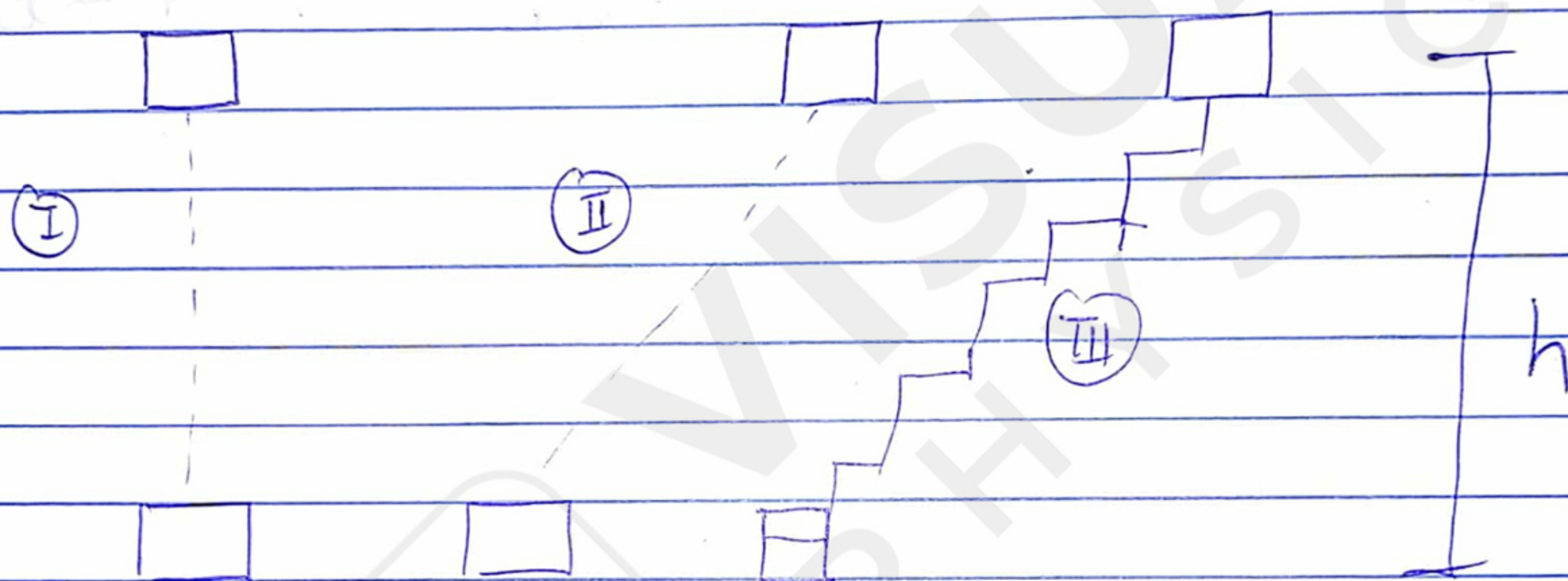
$$\text{so net work} \Rightarrow \int dW = \int \vec{F} \cdot d\vec{s}$$

Graphical Interpretation of Work:



Area under $F-d$ graph
gives work done!

Work done by gravity:



In all three cases work is same $(mg)(h)$

Work done by friction

Static friction:

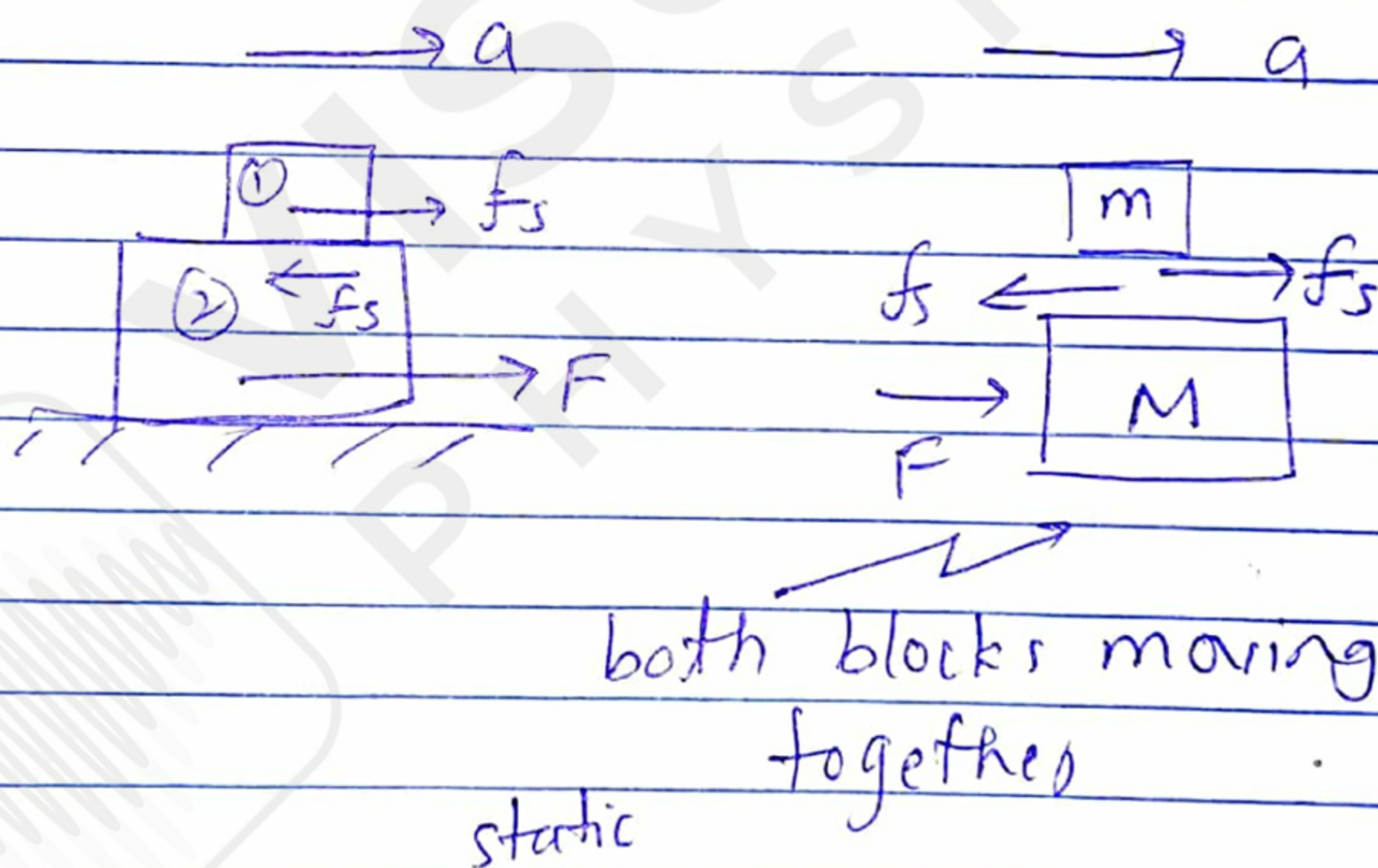
Case I:



body is not moving

$$\text{Work} = f_s (0) = 0$$

Case II:



both blocks moving
together

static

So work done by friction of small block

$$= (f_s)(d) = + f_s d$$

f_s is opposite
to d

$$\text{on } M \text{ (big block)} = (f_s) \cdot (d)$$

$$= -f_s d = f_s d / 0.5180$$

so, static friction work can be positive, negative and zero depending on condition

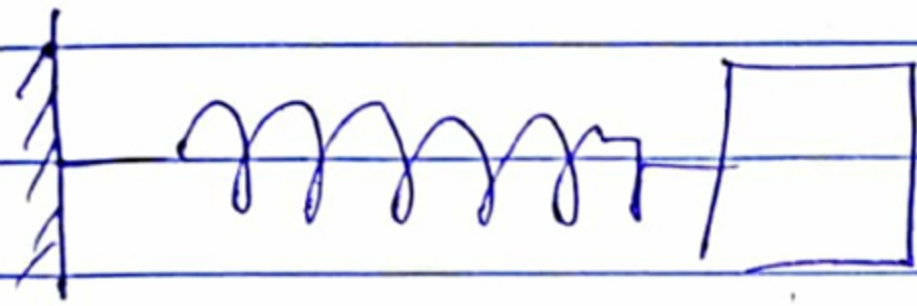
Kinetic friction:

occurs Kinetic friction is there when slipping

so

$$\boxed{W = (\vec{f}_k) \cdot \vec{d}}$$

Work done by spring



So spring force is always opposite to displacement.

Hence spring always do negative work

$$W = -\frac{1}{2} k x^2$$

Spring Constant.

displacement

magnitude

Kinetic energy

$$K.E = \frac{1}{2} m v^2$$

Energy
possessed because
of motion

velocity
mass of body

Also $K.E = \frac{1}{2} m v^2 \times \frac{m}{m}$

$$K.E = \frac{1}{2} \frac{p^2}{m}$$

momentum

Work - Energy theorem

Net work done on body = change in K.E

All types of work
i.e. gravitational, Spring,
friction etc.

$$= \frac{1}{2} m [v_f^2 - v_i^2]$$

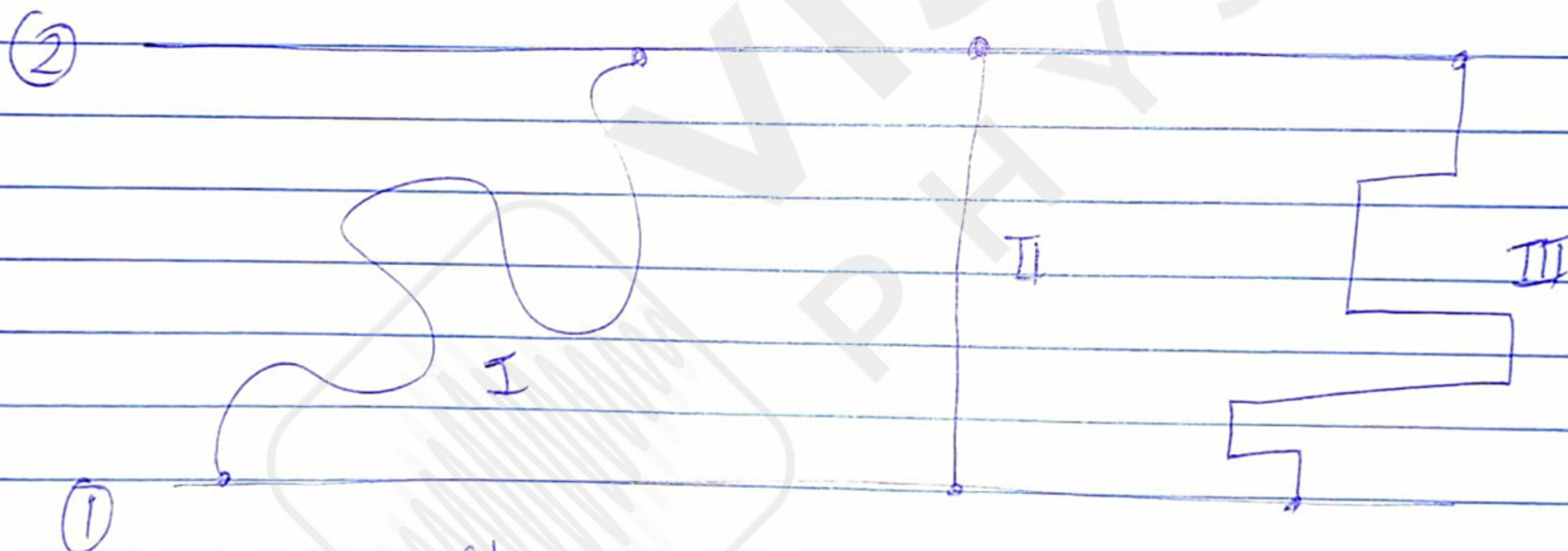
final
velocity

initial
velocity

$$\sum W = \Delta K$$

Conservative And non-conservative forces

Conservative force :- work does not depend on path taken. only depends on final and initial point

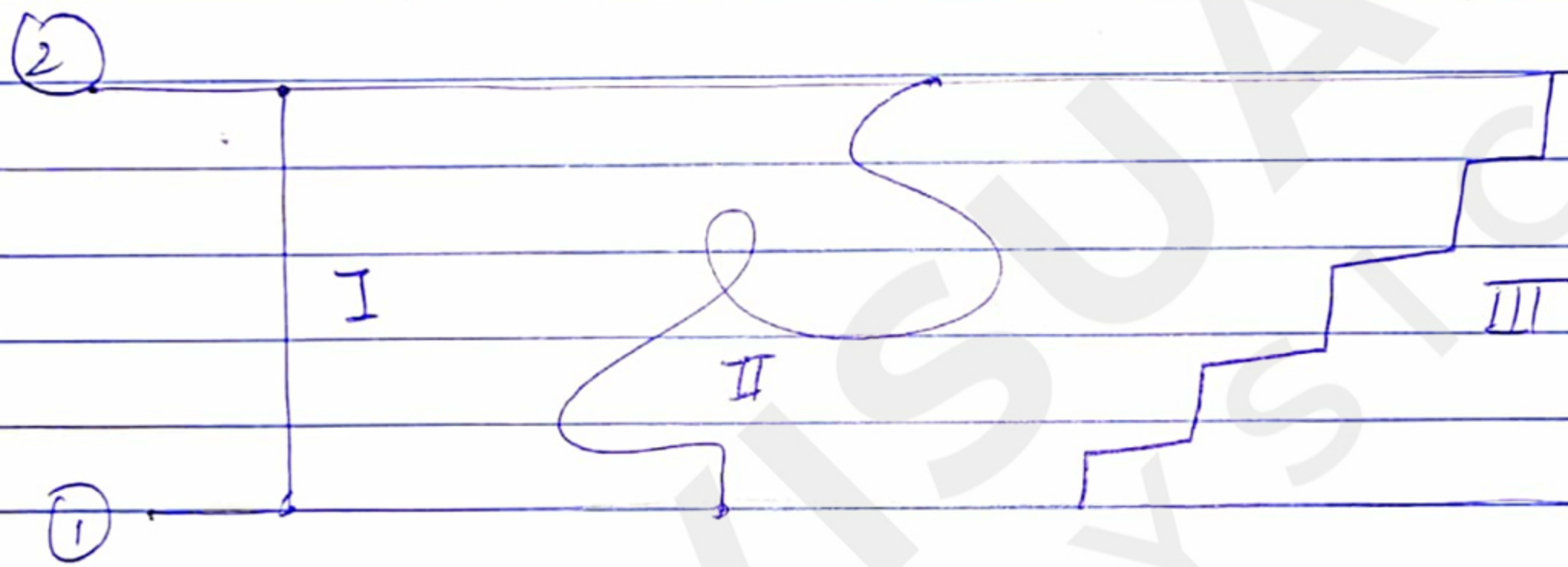


In all cases work is same

e.g. gravity force, spring force.

Non - Conservative force:

Work depends on path taken by the body.



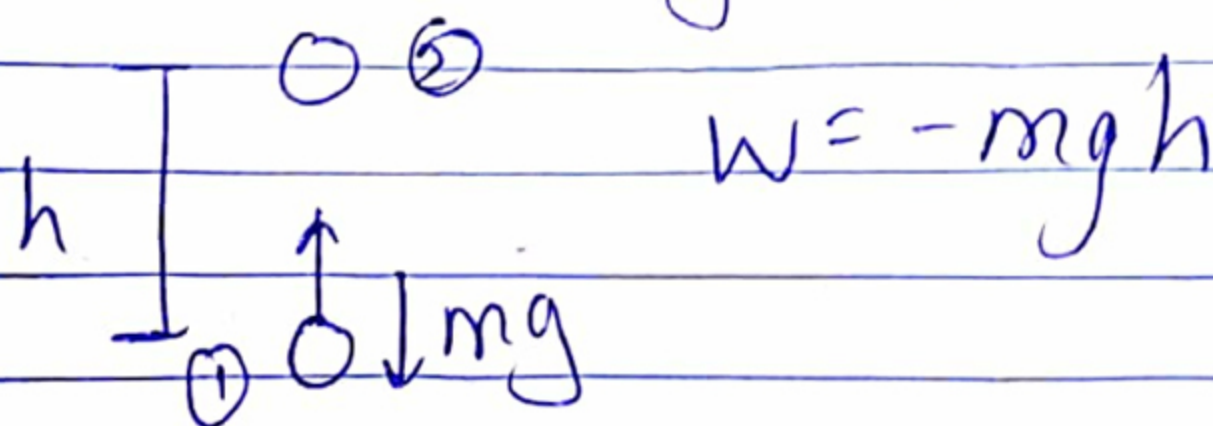
In all three cases work are different.

→ Work depend on path

e.g. friction, drag force.

Theory section Q8

Work in taking object from ground to height h



Potential Energy:

Energy associated because of the configuration of one body with respect to other body.

In simple term object will have different potential energy with different frame of point of observation because of the change in configuration.

We can always find change in potential energy

$$W_{\text{conc}} = -\Delta U$$

Work by conservative force $\rightarrow$ change in p.E

OR

$$F_c dx = -du$$

$$F_c = -\frac{du}{dx}$$

Spring P.E

So, taking ground as reference:

$$\Delta U_g = -W$$

$$g = -(-mgh)$$

$$U = mgh$$

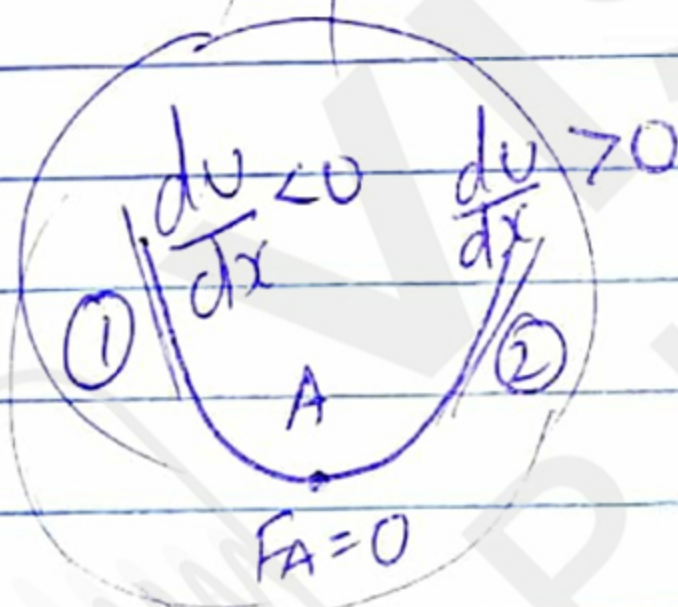
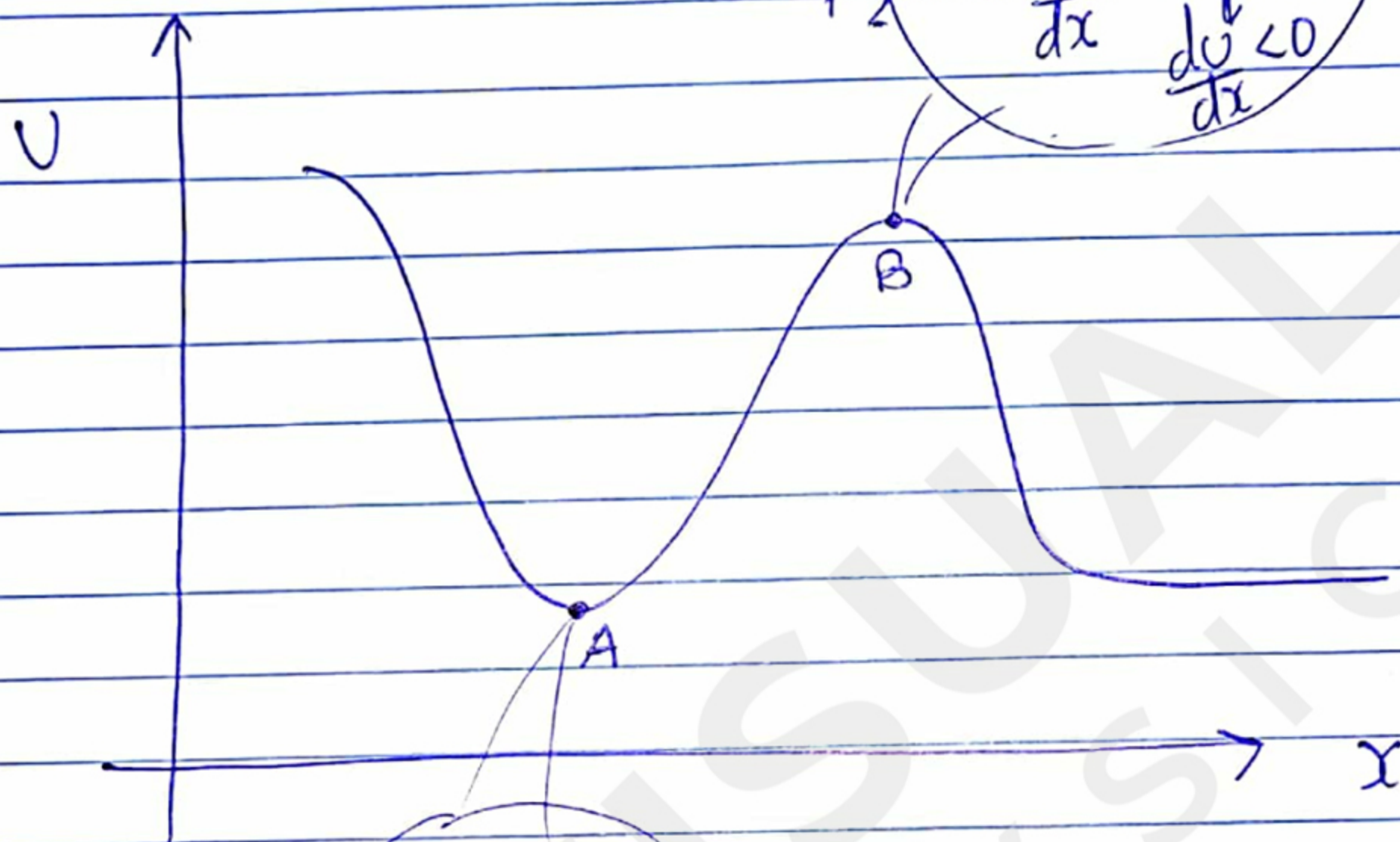
$$\Delta U = -\left(-\frac{1}{2}kx^2\right)$$

$$\Delta U_s = \frac{1}{2}kx^2$$

We take $U_{\text{ground}} = 0$ (for reference) so at height 'h'

$$\Delta U = U - 0 = mgh$$

stability:



A → stable
B → unstable

for A, when we move along x "lowest potential"
Stable point

at ① $\frac{du}{dx} < 0$, $F_1 = -\frac{du}{dx}$

& ② $\frac{du}{dx} > 0$, $F_2 = -\frac{du}{dx}$

F_1 & F_2 always toward A.

but for (B), case is opposite, always opposite to B.

Mechanical Energy & ITS Conservation

$$E = K + U$$

↓ ↗ potential energy

Mechanical energy ↘ kinetic energy

if only conservative forces acts while changing state from one state to other state.

$$E_f = E_i$$

↓ ↗ Mechanical energy initial

Mechanical energy Final

$$K_f + U_f = K_i + U_i$$

But for work energy theorem

$$W_{\text{conservative}} + W_{\text{non-conservative}} = \Delta K$$

Power:

→ rate of doing work

$$P = \frac{dw}{dt}$$

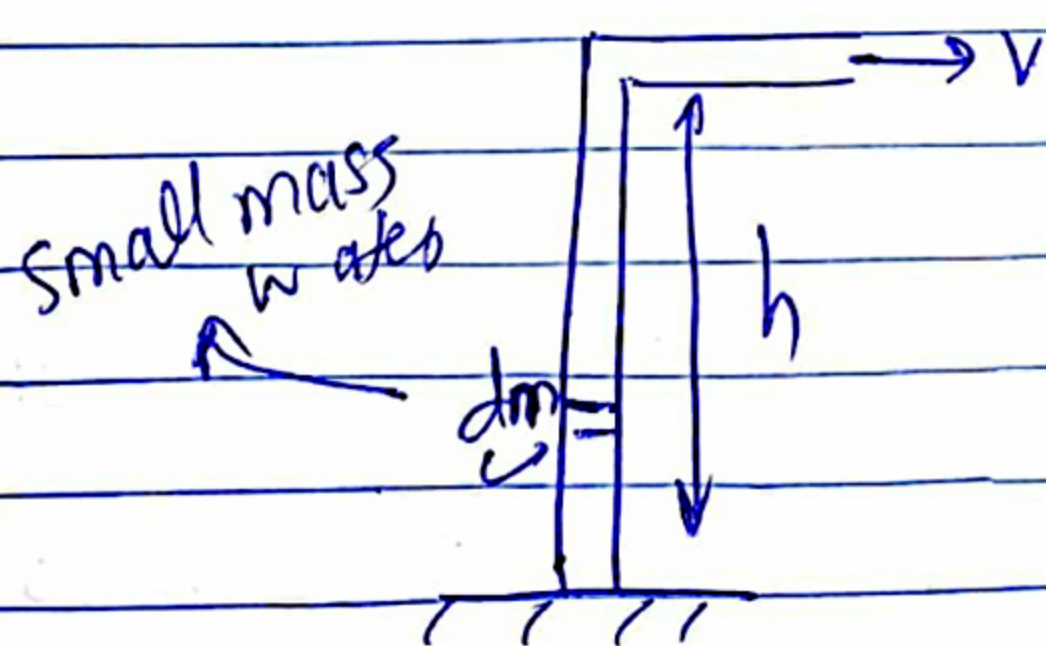
$$P = \frac{d(\vec{F} \cdot \vec{s})}{dt}$$

= if force is constant

$$= \vec{F} \cdot \frac{d\vec{s}}{dt}$$

$$\boxed{P = \vec{F} \cdot \vec{v}}$$

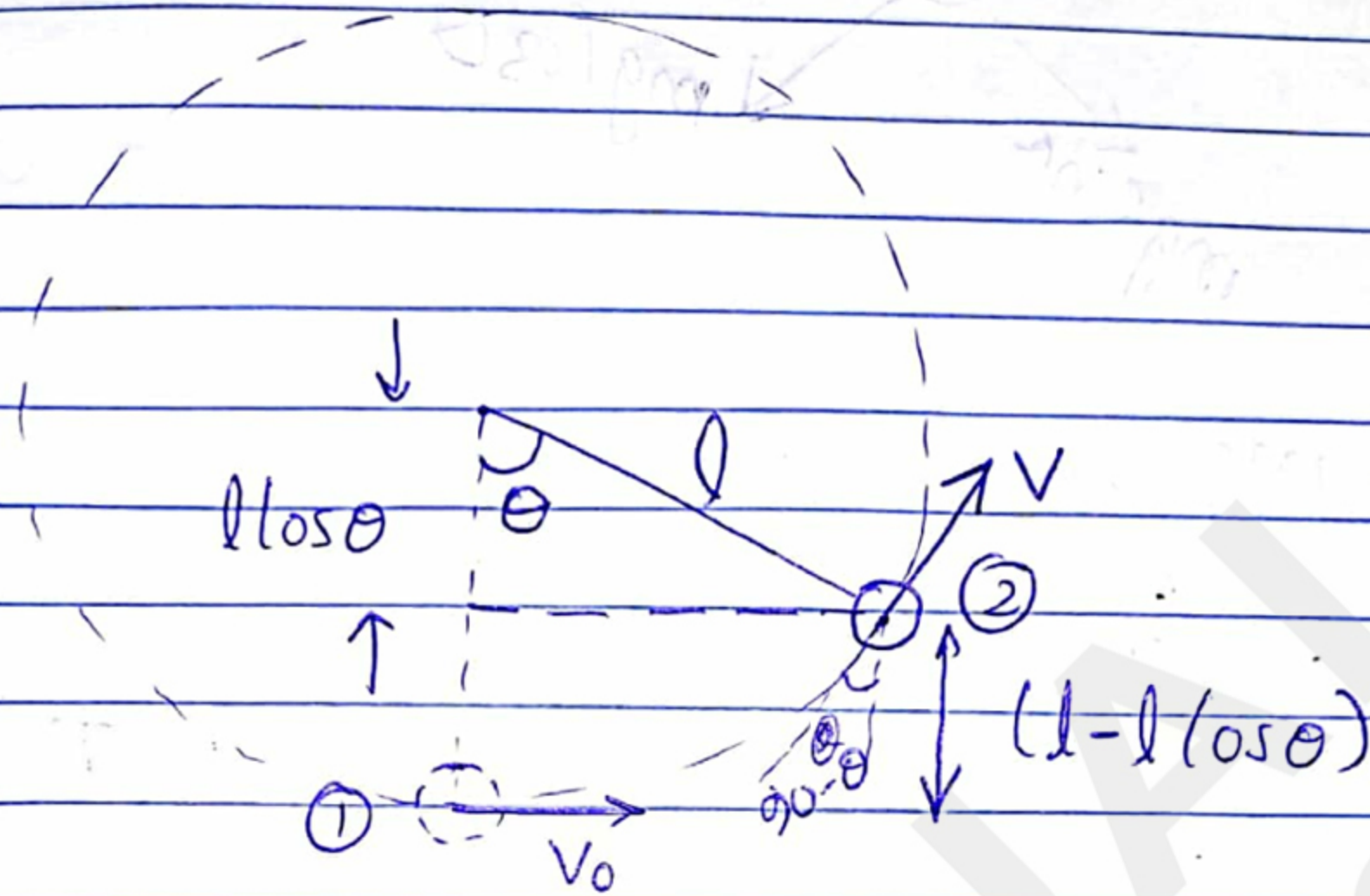
Power of water-drawing pump.



$$dw = \underbrace{(dm)gh}_{P.E} + \underbrace{\frac{1}{2}(dm)v^2}_{K.E}$$

$$P = \frac{dw}{dt} = \frac{dm}{dt} \left[gh + \frac{v^2}{2} \right]$$

motion in vertical circle:-

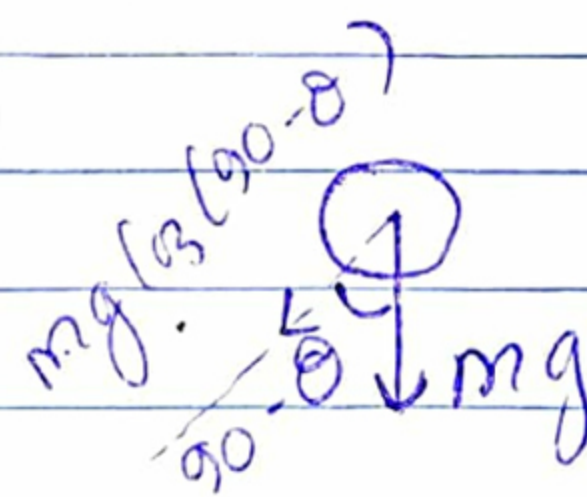


M.E Conservation.

$$\frac{1}{2} m v_0^2 = \frac{1}{2} m v^2 + m g (l - l \cos \theta)$$

$$\boxed{v = \sqrt{v_0^2 - 2gl(1 - \cos \theta)}} \quad - (i)$$

tangential acceleration :
or =



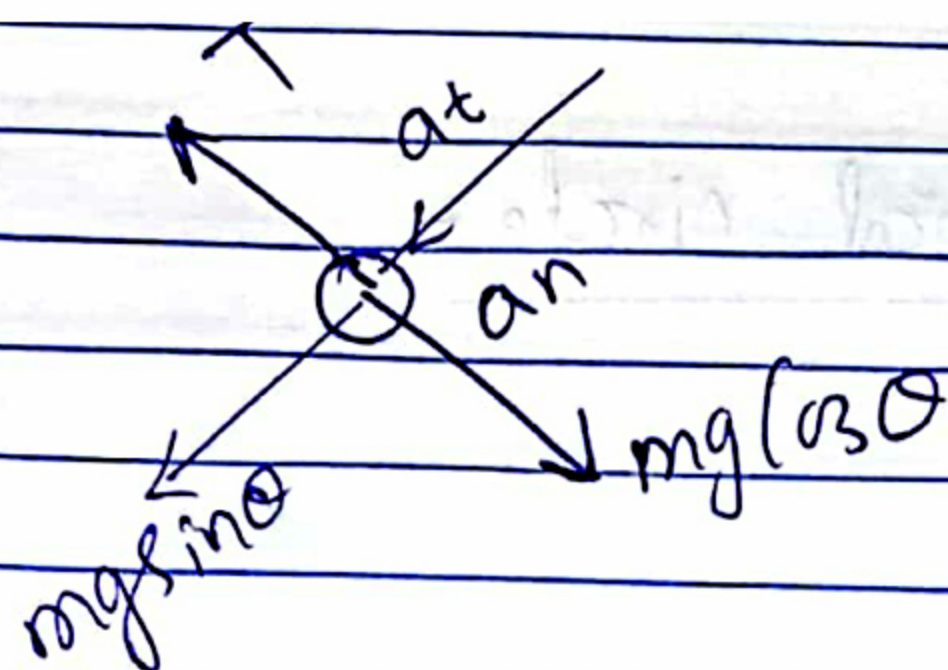
$$F = m g \sin(90 - \theta) = m a_t$$

$$\boxed{a_t = g \sin \theta}$$

↙ tangential

$$\text{and } \boxed{a_n = \frac{v^2}{l}}$$

↘ centripetal



$$T - mg \cos \theta = \text{max}$$

$$\Rightarrow \boxed{T = \frac{mv^2}{l} + mg \cos \theta} \quad \text{--- (II)}$$

from (I), $T \rightarrow T_{\min}$, at top as $\theta \rightarrow 180^\circ$

$$\text{So, } T_{\min} = \frac{mv^2}{l} + mg \cos 180^\circ$$

$$T_{\min} = \frac{mv^2}{l} - mg$$

if string sag at Top $T_{\min} = 0$

$$\Rightarrow \frac{mv^2}{l} = mg$$

$$\boxed{v = \sqrt{gl}}$$

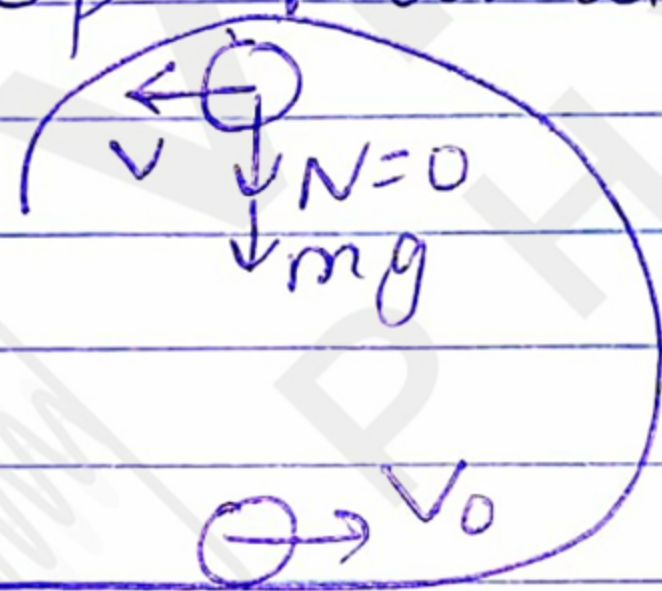
Now for $v_{\text{top}} = \sqrt{gl} = v_{\text{lowest}}$

from (i)

$$\sqrt{gl} = \sqrt{v_0^2 - 2gl(1 - \cos \theta)} \Rightarrow \boxed{v_0 \geq \sqrt{5gl}}$$

Just that is the minimum velocity for looping the loop for radius 'l' is $\sqrt{5gl}$.

$\Rightarrow$ Same condition applies for moving a car through a vertical circular track, in that case at top Normal = 0



$$v_0 = \sqrt{5gR}$$

$R \rightarrow$ radius

minimum speed to cover a loop.