KINEMATICS.

- Mechanics can be classified into Kinematics, Statics and Dynamics.
- Kinematics is the study of motion without considering the cause of the motion.
- Dynamics is the study of motion by considering the cause of motion.
- Statics is the study of objects at rest under the action of forces.

- A body is said to be at rest if it does not change its position with respect to the surrounding/observer, time etc.
- A body is said to be in motion if it changes its position with respect to observer/surrounding.
- Rest and motion are relative terms.
- Everything in this universe are in motion.

- Distance is the length of paths from initial point to final point, which are infinite in number.
- Displacement is the length of the shortest path from initial point to final point.
- Distance is a scalar while displacement is a vector.
- If a body travels along a straight line, magnitude of distance & displacement is the same.

- Speed is the distance travelled per unit time.
- It is rate of change of distance.
- Speed = Distance covered / Time taken.
- Average speed = Total distance / Total time
- It is a scalar quantity.

- Velocity is displacement per unit time.
- Rate of change of displacement.
- Velocity = Displacement / Time taken
- Average velocity = Total displacement / Total time
- It is a vector quantity.

- A body is said to move with uniform velocity if it travels equal distance in the same direction in equal time interval whatever small the time interval is. Simply it is velocity which dosen't change with respect to time.
- Non-uniform velocity is when magnitude and/or direction of a velocity changes with respect to time not necesarily at an uniform rate.

- Acceleration is the rate of change of velocity of a body.
- It is a vector quantity with unit ms^{-2}.
- Average acceleration is given by $v-u/t$.
- When $v<u$, we say deceleration/negative acceleration/ retardation.

Instantaneous velocity and acceleration.

- Instantaneous velocity is the velocity of a body at a particular instant of time or at a particular position of its path.
- Equal to the limiting value of avg. velocity when time interval tends to zero.

$$v = \lim_{\Delta t \to 0} \frac{\Delta s}{\Delta t} = \frac{ds}{dt}$$

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$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt} = \frac{d^2 s}{dt^2}$$

Equations of motion with uniform acceleration.

$$u \xrightarrow[t]{a} v$$

This is rectilinear motion
u - initial velocity
V - final velocity
a - acceleration (constant)
s - distance travelled
t - time taken
from the definition of acceleration

$$a = \frac{\text{change in velocity}}{\text{time}}$$

$$a = \frac{v-u}{t} \quad \therefore \quad v = u + at$$

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From definition of avg velocity

$v_{avg} = \frac{s}{t}$ --- (i) $\qquad v_{avg} = \frac{v+u}{2}$ --- (ii)

[for constant a]

$v+u/2 = s/t$ $\qquad s = v+u/2 \times t$

$\therefore s = 1/2(u+v).t$ $\qquad$ or $s = v+u/2 \times v-u/a$

or $s = v^2-u^2/2a$

$s = 1/2(u+u+at).t$ $\qquad$ or, $v^2 - u^2 = 2as$

or, $s = 1/2(2u+at).t$ $\qquad \therefore v^2 = u^2+2as$,,

or, $s = 1/2 \times 2ut + 1/2 at^2$

$\therefore s = ut + 1/2 at^2$,,

Distance travelled in a particular second.

Distance in 8s and in 8^{th} s are different. To find that of 8^{th} s, we can do $S_{8s} - S_{7s}$. It means the distance covered in 1s of ~~that time~~. the 8 s interval.

$S_{nth} = S_n - S_{n-1}$

$= un + \frac{1}{2}an^2 - u(n-1) - \frac{1}{2}a(n-1)^2$

$= \cancel{un} + \frac{1}{2}an^2 - \cancel{un} + u - \frac{1}{\cancel{2}}a(n^2-\cancel{2}n+1)$

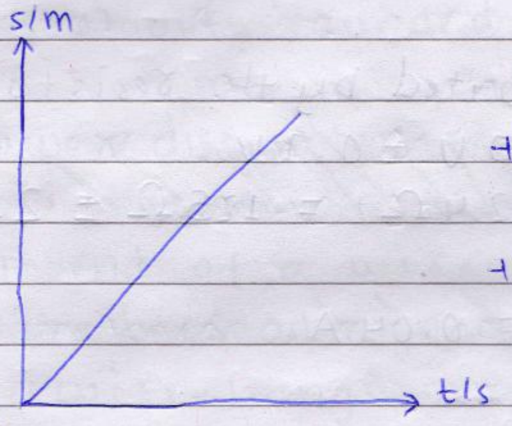
$= \frac{1}{2}\cancel{an^2} + u - \frac{1}{2}\cancel{an^2} + na - \frac{1}{2}a$

$= \cancel{u+na-\frac{1}{2}}a \qquad u + na - \frac{1}{2}a$,,

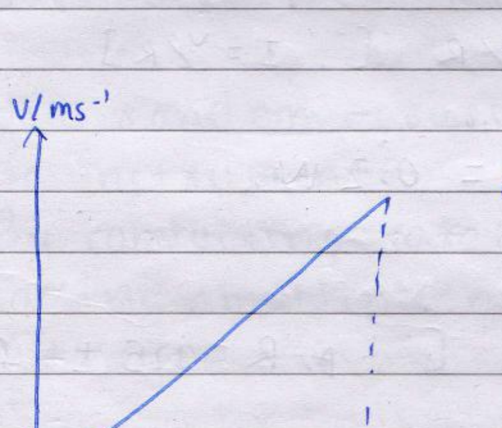
$= u + \frac{1}{2}a(2n-1)$,,

Graphical representation of motion.

Displacement - time (s - t) graph.
- Time is plotted along x - axis.
- Displacement is plotted along y - axis.



It is applicable to :
- find displacement or position of body at any time.
- find velocity of body at any instant of time as the slope of the line.
- Velocity at origin is also same as velocity everywhere.
- But a curve indicates presence of acceleration.
- For this we need to make tangent & find instantaneous velocity.
- Initial velocity of curves is 0.



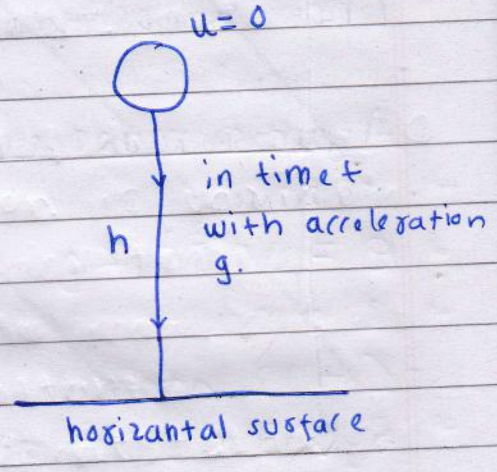
Area under (v - t) graph gives displacement.

Experiment to determine acceleration of free fall using falling object.

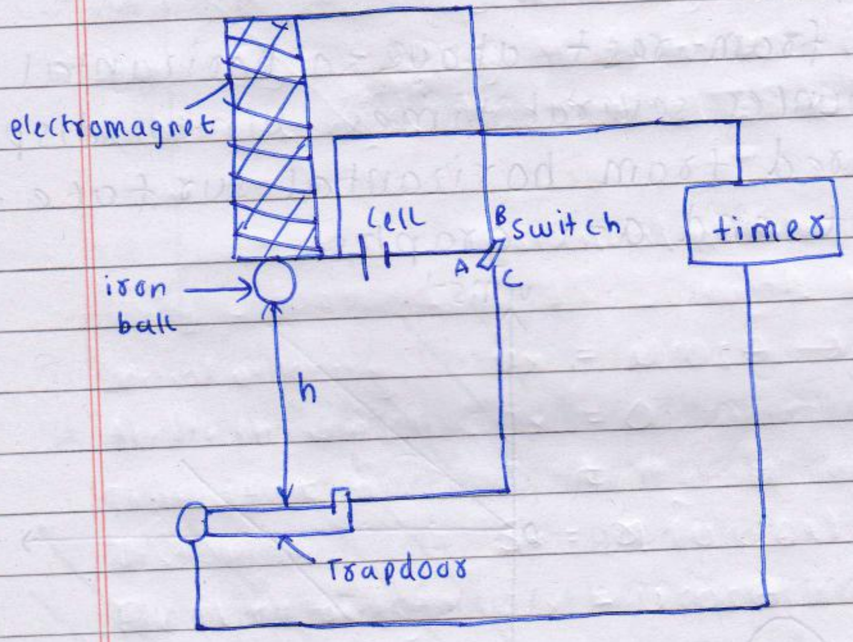
$$s = ut + \frac{1}{2}at^2$$

$$h = \frac{1}{2}gt^2$$

$$\therefore g = \frac{2h}{t^2}$$



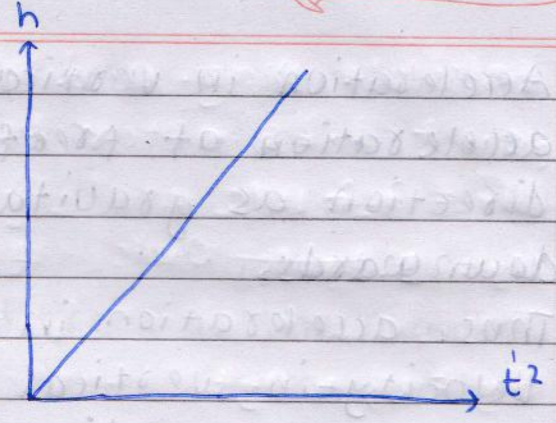
Experimental set-up



when switch is ~~to~~ turned the other way, A connects with C but disconnects with B. thus current stops to electromagnet but starts to the timer thus timer starts, when ball falls.

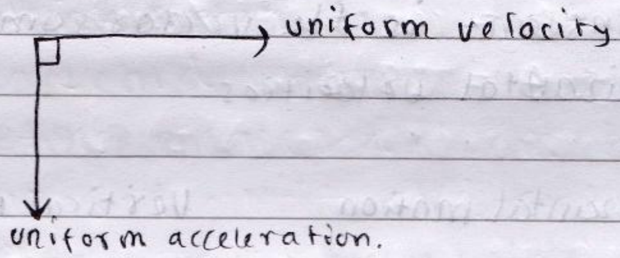
$h = \frac{1}{2} g t^2$

Gradiest of this graph gives us $g/2$
Thus, twice the gradient gives g.



Projectile motion

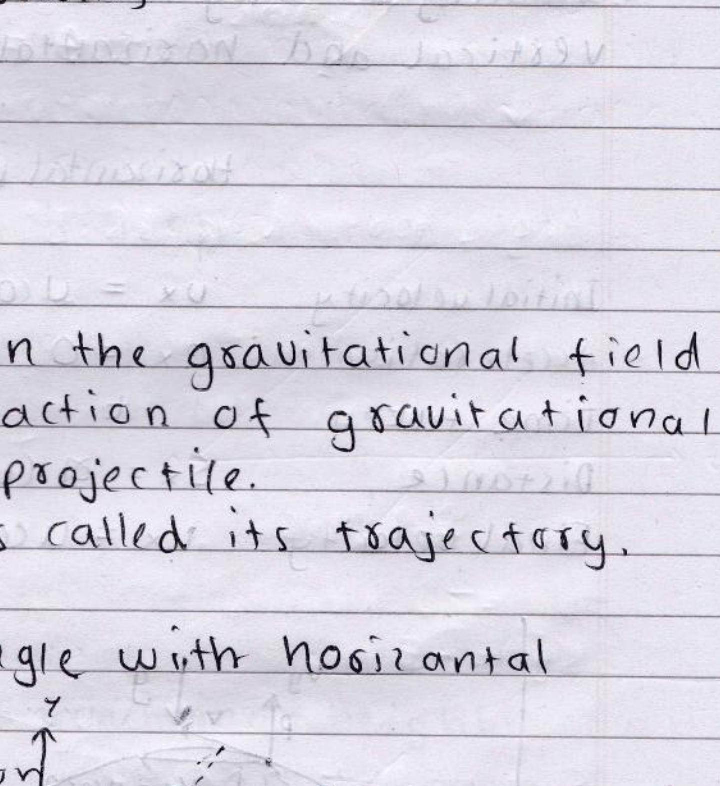
→ Motion due to a uniform velocity in one direction and uniform acceleration in perp. direction



→ An object projected in the gravitational field so that it moves under action of gravitational force alone is called projectile.
→ Path of projectile is called its trajectory.

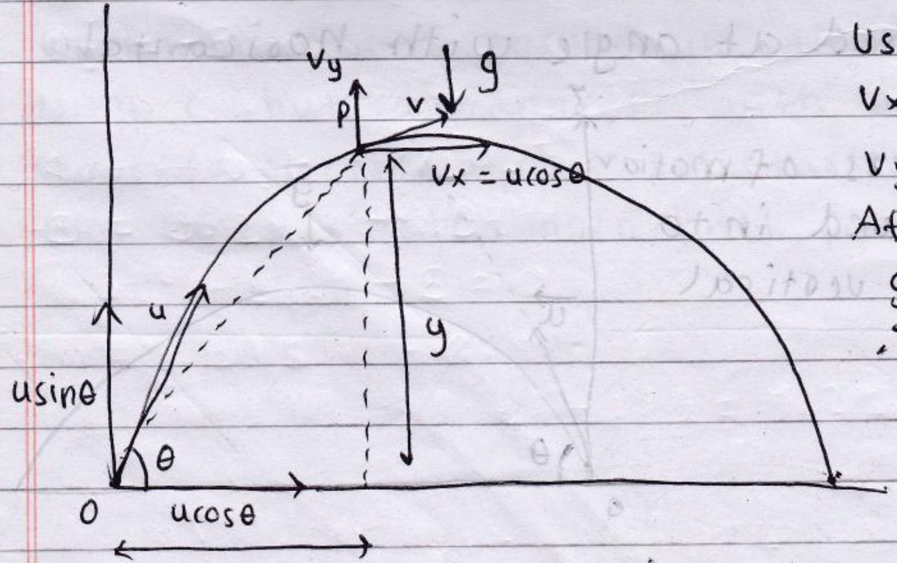
Projectile fired at angle with horizantal

→ The parameters of motion can be resolved into horizantal & vertical directions.



- Acceleration in vertical direction is equal to acceleration of freefall g. in down ward direction as gravitational force acts downwards.
- Thus, acceleration in horizantal direction is 0
- Velocity in vertical direction is variable but in horizantal distance is constant.
- vertical velocity decreases upto max. height then increases (Same for resultant).
- The resultant velocity is tangent to the curve of the trajectory.
- Vertical velocity at highest pt. of path is 0.
- Velocity at any instant is the vector sum of vertical and horizantal velocities.

	Horizantal motion	Vertical motion
Initial velocity	$u_x = u\cos\theta \rightarrow$	$u_y = u\sin\theta \uparrow$
Acceleration	$a_x = 0$	$a_y = g \downarrow$
Time taken	t	t
Distance	$S_x = x\ (u\cos\theta t)$	$S_y = y$
Final velocity	$V_x = u\cos\theta$	$V_y = u\sin\theta - gt$



Using $v = u + at$

$V_x = u\cos\theta$

$V_y = u\sin\theta - gt$

After highest pt,

$gt > u\sin\theta$

$\therefore V_y = -ve$

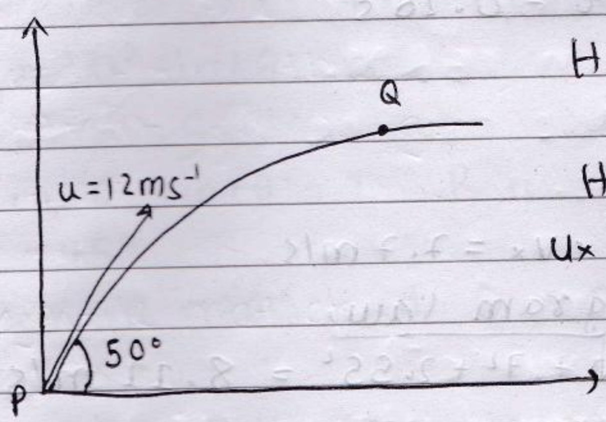
Right and up direction positive

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

$y = u\sin\theta \times t - \frac{1}{2}gt^2$

$= ut\sin\theta - \frac{1}{2}gt^2$,,

#



Here Q is the maximum height.

Horizonal component $= u_x$

$u_x = u\cos\theta$

or, $u_x = 12\cos 50°$

$\therefore u_x = 7.7\ ms^{-1}$

Vertical component $= u_y$

$u_y = u\sin\theta$

or, $u_y = 12\sin 50°$

$\therefore u_y = 9.2\ ms^{-1}$,,

+ Show that max height is 4.3 m

Max height $= S_y$

$u_y = 12\sin 50°$, $a_y = -9.81\ ms^{-2}$ $V_y = 0$

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

or, $0 = (12\sin 50)^2 - 2 \times 9.81 \times S_y$

$\therefore S_y = 4.3\ m$,,

+ Calculate time taken to reach max height,

$V = u + at$

or, $0 = 12\sin 50° - 9.81t$

$\therefore t = 0.937s \approx 0.94\ s$,,

+ Determine magnitude of PQ.

$PQ = \sqrt{4.3^2 + (7.7 \times 0.94)^2} = 8.4\ m$,,

+ Calculate mag. and direction of velocity at a point 1.2s after P. (At from Q),

$u_x = 7.7\ m/s$ $\quad a_y = -9.81\ m/s^2$

$u_y = \cancel{9.2\ m/s}\ 0\ m/s$ $\quad t = 0.26\ s$

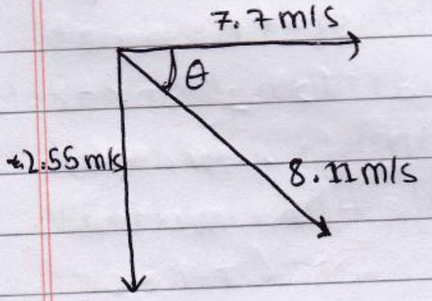
$V_y = u_y + a_y t$

or, $V_y = -9.81 \times 0.26$

$\therefore V_y = -2.55\ m/s$,, $\quad , V_x = 7.7\ m/s$

Now from parallelogram law,

$V = \sqrt{V_x^2 + V_y^2} = \sqrt{7.7^2 + 2.55^2} = 8.11\ m/s$



$7.7 = 8.11 \cos\theta$

or, $\theta = \cos^{-1}(7.7/8.11)$

$\therefore \theta = 18.3°$,,

$\therefore$ Angle formed is 18.3° with horizantal component.

+ Calculate time from point of projection to a point 5m vertically below surface

$u_y = 9.2\ m/s \uparrow$

$a_y = -9.81\ m/s^2 \downarrow$

$S_y = -5\ m \downarrow$

$S_y = \cancel{9.} u_y t + 1/2\, a_y t^2$

or, $-5 = 9.2t + -4.9t^2$

or, $4.9t^2 - 9.2t - 5 = 0$

$\therefore t = 2.31\ s\ ,\ -0.44\ s$

$\therefore$ ~~Total time = 2.31 + 1.9 = 4.2 s,,~~

\# Actual velocity of projectile goes from max. to min and again to max but not to 0.

For horizantal motion

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

$R = u\cos\theta \times \frac{2u\sin\theta}{g} - \frac{1}{2} gQ \frac{4u^2\sin^2\theta}{g^2 \times 0}$

$= \frac{u^2 \sin 2\theta}{g}$

when θ $\sin 2\theta = 1$, R is max

$\therefore \theta = 45°$

when $\theta = 30°$ and $\theta = 60°$, R is same.

DYNAMICS

- Study of motion by considering its cause.
- They are governed by Newton's law of motion.
- First law: Everybody in the universe continues to be at a state of rest or uniform motion along a straight line unless a resultant force acts on it.
- First law defines force as something (push or pull) that changes or tends to change the position of a body. Explains inertia as property of body by virtue of which a body tends to remain in its initial state of rest, motion, and direction and doesn't want to change its state.
- Falling of fruit when shaking branch.

- Mass of a body is a measure of its inertia, as large mass needs large force, small mass needs small force.
- Mass $\propto$ Inertia

- Every action has an equal and opposite reaction.
- During the interaction, if body A exerts a force on body B, then body B exerts an equal but opposite force of same nature on body A.

$F_{AB} = -F_{BA}$ [A due to B, B due to A]

- Forces exist in pair.
- Two forces, two bodies, equal in magnitude, opposite in direction, same in nature, Not cancelling each other.