2 Kinematics

Rectilinear Motion

Definitions

Distance **d**	The total length of path travelled by a moving object, irrespective of the direction of motion.
Displacement **s** (Area under **v-t** graph between any two points)	The linear distance of the position of an object with reference to a given position (origin). Distance and direction have to be specified.
Instantaneous velocity **v** (Gradient of **s-t** graph)	Rate of change of displacement $v = \frac{ds}{dt}$
Average velocity **<v>**	$\langle v \rangle = \frac{\text{total displacement}}{\text{total time taken}} = \frac{\Delta s}{\Delta t}$
Instantaneous acceleration **a** (Gradient of **v-t** graph)	Rate of change of velocity $a = \frac{dv}{dt}$
Average acceleration **<a>**	$\langle a \rangle = \frac{\text{change in velocity}}{\text{total time taken}} = \frac{\Delta v}{\Delta t}$

Equations of motion*

*Can only be used when acceleration is **constant**.

❶: $v = u + at$

❷: $s = ut + \frac{1}{2}at^2$

❸: $v^2 = u^2 + 2as$

❹: $s = \frac{1}{2}(u + v)t$

u: initial velocity
v: final velocity
t: time taken
a: acceleration
s: displacement

Effects of air resistance on acceleration

Free-fall acceleration with **no** air resistance is 9.81 ms^{-2} downwards. A **moving** object experiences air resistance (air drag/viscous force) which acts opposite to its velocity and depends on the density of air and on the speed of the body.

Object falling with air resistance R

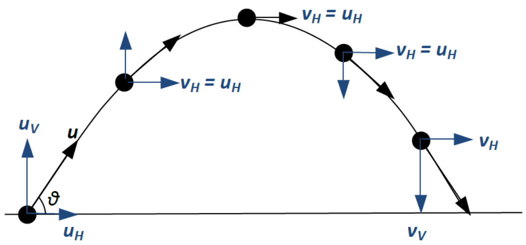
- Initial: velocity ***v***, R = 0, so a = 9.81 m s^{-2}
- As downwards ***v*** ↑, upward R ↑
- Since W > R, net downward force present. Object continues accelerating downwards and ***v*** increases at a decreasing rate
- Upward R ↑ until R = W, thus no net force and acceleration. Object reaches terminal ***v***.

Object thrown up with air resistance

- Initially, W and R downwards, thus acc downwards more than 9.81 m s^{-2}
- at max height, ***v*** and R = 0. Acc = 9.81 ms^{-2}.
- On way down, W and R in opposite directions. ***v*** ↑ with decreasing rate until terminal ***v***.

Projectile Motion

For non-linear motion, W does not affect horizontal motion. Therefore, horizontal and vertical motions are treated separately.



$u_H = u\cos\theta \qquad u_V = u\sin\theta$

Horizontal: $v_H = u_H$ and displacement $s_H = v_H t$ since there is no resultant force horizontally.

Vertical: $v_v = u_v + a_v t$ or $v_v^2 = u_v^2 + 2a_v s_v$ and displacement s_v is $s_v = u_v t + \frac{1}{2}a_v t^2$ since there is constant acceleration.

Final: $v = \sqrt{(v_H^2 + v_V^2)}$, where the angle is determined through trigonometry.