Module 3 Section 1: Motion

Definitions

The **displacement** of a point B from a point A is the shortest distance from A to B, together with the direction as it is a vector.

Mean speed = $\frac{\textit{total distance travelled}}{\textit{total time taken}} = \frac{\Delta x}{\Delta t}$

Instantaneous speed = rate of change of distance.

Mean velocity = $\frac{\textit{total displacement}}{\textit{total time taken}}$

Instantaneous velocity = rate of change of displacement.

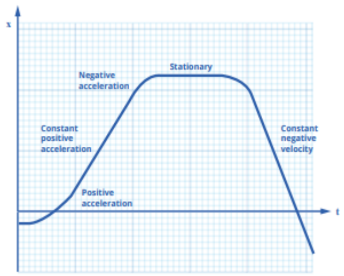
Mean acceleration = $\frac{\textit{change in velocity}}{\textit{time taken}} = \frac{\Delta v}{\Delta t}$

Instantaneous acceleration = rate of change of velocity.

Note; displacement, velocity and acceleration are vectors.

Displacement-time graphs

x-t graphs:



The **gradient of the graph represents the velocity**, steeper lines mean a higher velocity. Using **tangents** to the curve and calculating their gradient allows you to calculate the velocity at any point.

Suvat equations

1. $v = u + at$
2. $s = ½(u + v)t$
3. $s = ut + ½at^2$
4. $v^2 = u^2 + 2as$

Acceleration Due to Gravity

You need to be able to work out speeds, distances and times for objects moving vertically in a uniform gravitational field with an acceleration of g. As g is a constant acceleration you can use the equations of motion. But because g acts downwards, you need to be careful about directions. To make it clear, there's a sign convention: upwards is positive, downwards is negative.

- g is always downwards, so it's usually negative.
- t is always positive.
- u and v can be either positive or negative.
- s can be either positive or negative.

Case 1: No initial velocity

This means an object is just falling — initial velocity $u = 0$.
Acceleration $a = g = -9.81\ ms^{-2}$. Hence the equations of motion become:

$$v = gt \qquad v^2 = 2gs$$
$$s = \frac{1}{2}gt^2 \qquad s = \frac{1}{2}vt$$

Case 2: An initial velocity upwards

This means it's projected up into the air. The equations of motion are just as normal, but with $a = g = -9.81\ ms^{-2}$.

Case 3: An initial velocity downwards

This is like case 2 — the equations of motion are as normal with $a = g = -9.81\ ms^{-2}$.

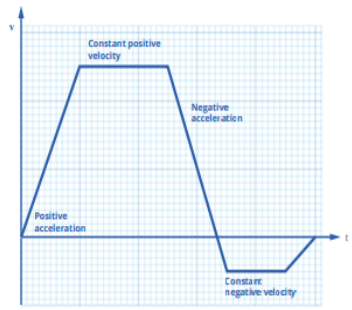
Free Fall

When there is gravity acting on an object and nothing else. Defined as the motion if an object undergoing an acceleration of 'g'

- Acceleration is a vector 'g' acts vertically down
- Magnitude of 'g' is $9.81ms^{-2}$
- The only force acting on an object in free fall is its weight
- Objects can have an initial velocity in any direction and still undergo free fall as long as the force providing the initial velocity is no longer acting

Displacement-time graphs

v-t graphs:



The **gradient of the line is the acceleration** and the **area under the line is the displacement**. Note that the displacement may be negative.

Projectile Motion

Any object given an initial velocity and then left to move freely under gravity is a projectile

Horizontal and vertical components of the objects motion are completely independent

Follow a curved path because the horizontal velocity remains constant, while the vertical velocity is affected by the acceleration due to gravity, g

Projectile motion at an angle

Resolve the initial velocity into horizontal and vertical components

Use the vertical component to work out how long its in the air and/or how high it goes

Use the horizontal component to work out how far it