7 On the Move

7.1 Speed and Velocity

- **Displacement** is distance in a given direction.
- **Speed** is defined as change of distance per unit time.
- **Velocity** is defined as change of displacement per unit time - velocity is speed in a given direction.

The unit of speed and velocity is the metre per second ms^{-1}.

Distance-time Graph

A **distance-time graph** is a graph of distance against time.

For motion at constant speed, its distance-time graph is a straight line with a constant gradient.

$$\text{speed } v = \frac{s}{t} = \text{gradient of line}$$

For motion at changing speed that travels a distance s in time t

$$\text{average speed} = \frac{\Delta s}{\Delta t}$$

The gradient of the line at any point can be found by drawing a **tangent to the line** and then measuring the gradient of the tangent.

The delta Δ notation means **a change of something**.

An object moving at **constant velocity** moves at the same speed without changing its direction of motion.

- If an object changes its direction of motion or its speed or both, its velocity changes.

7.2 Acceleration

Acceleration is defined as change of velocity per unit time.

- The unit of acceleration is the metre per second per second

$$\text{ms}^{-2}$$

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- **Deceleration** values are negative and signify that velocity **decreases with respect to time**.

Uniform acceleration is where the velocity of an object moving along a straight line changes at a constant rate - the acceleration is constant.

Non-uniform acceleration is where the direction of motion of an object changes, or its speed changes.

Acceleration = gradient of the line on the velocity-time graph

7.3 Motion Along a Straight Line at Constant Acceleration

1. From $a = \dfrac{v-u}{t}$
$$v = u + at$$
2. From $s = \bar{v}t$
$$s = \frac{(u+v)t}{2}$$
3. Substitute (1) to (2):
$$s = ut + \frac{1}{2}at^2$$
4. Multiply $a = \dfrac{v-u}{t}$ and $s = \frac{(u+v)t}{2}$
$$v^2 + u^2 + 2as$$

displacement = area under the line of a velocity-time graph

7.4 Free Fall

Investigate the free fall of a ball

1. Make a **video clip** of the ball's flight as it falls after being released from rest.
2. For each frame of the ball in the video, the **time of descent** of the ball and the **distance fallen** by the ball can be measured.
3. Use the equation $s = ut + \dfrac{1}{2}at^2$, plot a graph of s against t^2. Then the acceleration is $2 \times$ gradient.

The **acceleration of free fall** is the value of acceleration when there are no external forces acting on the object apart from the force of gravity, and is represented by the symbol g.

$$g \approx 9.8\text{ms}^{-2}$$

7.5 Motion Graphs

- **Displacement-time graph**: the gradient of the line represents the **velocity** of the object.
- **Velocity-time graph**: the gradient of the line represents the object's **Acceleration**.
  - The area under the line represents the **displacement** of the object from its starting position.

7.6 Projectile Motion 1

A **projectile** is any object acted upon only be the force of gravity.

- The acceleration of the object is **always downwards** and **equal to g** because the force of gravity acts downwards.
- Horizontal velocity of the object is constant because the acceleration of the object **does not have a horizontal component**.
- The motion in the horizontal and vertical direction are **independent** of each other.

$$v = u - gt$$
$$y = ut - \frac{1}{2}gt^2$$

Horizontal Projection

If the initial project of a stone off a cliff is horizontal.

- Its path through air **becomes steeper** as it drops.
- The faster it is projected, the further away it will fall into the sea.
- The time taken for it to fall into the sea **does not depend on how fast it is projected**.
  - The downward acceleration for each speed is g.

A camera can be used to record the motion of projectiles. Where A is released from rest and B was given an initial horizontal projection.

- The **horizontal position** of B change by equal distance per unit time.
  - The horizontal component of B is constant.
- At any instant, A is at the **same level** as B.
  - A and B have the same vertical component of velocity at any instant.

7.7 Projectile Motion 2

Any form of motion where an object **experiences a constant acceleration in a different direction to its velocity** will be like projectile motion.

- A ball rolling across an **inclined board** will be a projectile path.
- A beam of electrons directed between two oppositely charged parallel plates.

The path of a projectile is **parabolic**.

Drag Force

A projectile moving in air experiences a **drag force** because of the resistance of air it passes through.

- Acts in the **opposite direction** to the direction of motion of the projectile.
- Increases as the projectile's speed increases.
- Has a **horizontal component** that reduces horizontal speed and the range.
- Has a **vertical component** that reduces maximum height and makes its descent **steeper than its ascent**.

The **shape of the projectile** affects the drag force and may cause a **lift force** on the projectile.