9 Force and Momentum

9.1 Momentum and Impulse

Force is needed to change the velocity of an object.

The **effect of a force** on an object depends on.

- The **mass** of the object.
- The amount of force.

Newton's laws of motion only apply where

- **Gravity is weak**, and
- The speed of objects is **much less than the speed of light**.

The **momentum** of an object is defined as its mass $\times$ velocity. $p = mv$

- The unit of momentum is kgms^{-1}.
- Momentum is a **vector quantity** with the same direction as the object's velocity.

Momentum and Newton's Laws of Motion

Newton's first law tells us that a force is needed to change the momentum of an object.

- If the momentum is constant, there is no resultant force acting on it.
- If a moving object with constant momentum **gains or loses mass**, its **velocity would change** to keep its momentum constant.
  - E.g. a cyclist speeding past a service point collects a water bottle and **gains mass** therefore **loses velocity**.

Newton's second law states the force is proportional to the **change in momentum per second**.

$$\begin{aligned} F \propto \frac{\text{change of momentum}}{\text{time taken}} &= \frac{mv - mu}{t} \\ &= \frac{m(v-u)}{t} \\ &= ma \end{aligned}$$

The change of momentum of an object can be written as $\Delta(mv)$.

$$F = \frac{m\Delta v}{\Delta t} \qquad \text{for constant } m$$
$$F = \frac{v\Delta m}{\Delta t} \qquad \text{for constant } v$$

The **impulse of a force** is defined as force × time for which the force acts.

$$I = F\Delta t = \Delta(mv)$$

The impulse of a force is equal to the **change of momentum** of the object.

The unit of momentum can be given in the **newton second** (Ns) or kgms^{-1}

Force-time Graphs

The area under the line of a force-time graph represents the change of momentum or the impulse of the force.