9 Force and Momentum

9.1 Momentum and Impulse

The effect of a force on an object (change in velocity) depends on its

- **Mass**, and
- The **amount of force**

The **momentum** of an object is defined as its mass × velocity.

- **Newton's first law** tells us that a force is needed to change the momentum of an object.
  - If a moving object **gains or loses mass**, the velocity would change to keep its momentum constant.
- **Newton's second law** can be status as

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

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

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

Force-time Graphs

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

The unit of impulse is therefore the **newton second**.

9.3 Conservation of Momentum

Newton's third law states when two object interact, they exert equal and opposite forces on each other.

For a force to be considered a **force pair**.

- The two forces must be **of the same type**, and
- Acting on different objects.

The **principle of conservation of momentum** states that for a system of interacting objects, the total momentum remains constant, provided no external resultant force acts on the system.

In a collision

$$\text{total final momentum} = \text{total initial momentum}$$

9.4 Elastic and Inelastic Collisions

- An **elastic collision** is one where there is no loss of kinetic energy.
- An **inelastic collision** occurs where the colliding objects have less kinetic energy after the collision than before the collision.
  - Some of the initial kinetic energy is **transferred to the surroundings**.

9.5 Explosions

An explosion is where two objects **fly apart** after being **initially at rest** - they recoil from each other with equal and opposite amounts of momentum.

By the principle of conservation of momentum, two objects

$$\begin{aligned} m_A v_A + m_B v_B &= 0 \\ m_A v_A &= -m_B v_B \end{aligned}$$