Further momentum

To be able to calculate force from change in momentum
To be able to explain and calculate impulse
To know the significance of the area under a force-time graph
To be able to explain the difference between elastic and inelastic collisions

Force

If we start at $F = ma$ we can derive an equation that links force and momentum.

$F = ma$ we can replace a in this equation with $a = \frac{(v-u)}{t}$

$F = m\frac{(v-u)}{t}$ multiplying out makes the equation

$$F = \frac{mv - mu}{t} \quad \text{or} \quad \boxed{F = \frac{\Delta(mv)}{\Delta t}}$$ where Δ means 'the change in'

This states that the force is a measure of change of momentum with respect to time. This is Newton's Second Law of Motion:

The rate of change of an object's linear momentum is directly proportional to the resultant external force. The change in the momentum takes place in the direction of the force.

If we have a trolley and we increase its velocity from rest to 3m/s in 10 seconds, we know that it takes a bigger force to do the same with a trolley that's full of shopping. Ever tried turning a trolley around a corner when empty and then when full?

Force is measured in Newtons, N

Car Safety

Many of the safety features of a car rely on the above equation. Airbags, seatbelts and the crumple zone increase the time taken for the car and the people inside to stop moving. Increasing the time taken to change the momentum to zero reduces the force experienced.

Catching

An Egg: If we held our hand out and didn't move it the egg would smash. The change in momentum happens in a short time, making the force large. If we cup the egg and move our hands down as we catch it we make it take longer to come to a complete stop. Increasing the time taken decreases the force and the egg remains intact.
Cricket Ball: If we didn't move our hands it would hurt when the ball stopped in our hands. If we make it take longer to stop we reduce the force on our hands from the ball.

Impulse

$$F = \frac{mv - mu}{t} \quad \text{multiply both sides by t} \rightarrow \quad Ft = mv - mu$$

$$F = \frac{\Delta(mv)}{\Delta t} \quad \text{multiply both sides by t} \rightarrow \quad \boxed{F\Delta t = \Delta(mv)}$$

We now have an equation for impulse. Impulse is the product of the force and the time it is applied for.
An impulse causes a change in momentum.

Impulse is measured in Newton seconds, Ns

Since $F\Delta t = \Delta(mv)$, the same impulse (same force applied for the same amount of time) can be applied to a small mass to cause a large velocity or to a large mass to cause a small velocity

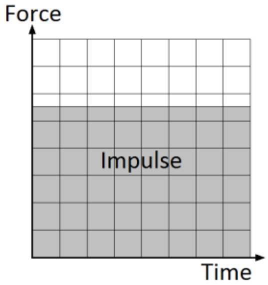
$$Ft = mv = mV$$

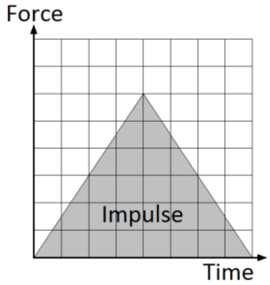
Force-Time Graphs

The impulse can be calculated from a force-time graph, it is the same as the area under the graph.

The area of the first graph is given by:

height x length = Force x time = Impulse





Collisions

There are two types of collisions; in both cases the momentum is conserved.

Elastic – *kinetic energy in conserved, no energy is transferred to the surroundings*

If a ball is dropped, hits the floor and bounces back to the same height it would be an elastic collision with the floor. The kinetic energy before the collision is the same as the kinetic energy after the collision.

Inelastic – *kinetic energy is not conserved, energy is transferred to the surroundings*

If a ball is dropped, hits the floor and bounces back to a lower height than released it would be an inelastic collision. The kinetic energy before the collision would be greater than the kinetic energy after the collision.