Physics Knowledge Organiser
P10 - Force and motion

Momentum – *whole page is HT only*

Momentum is a property that any moving object has. It is defined as the product of mass and velocity of the object, so if the velocity is 0 m/s (stationary), the momentum is also 0.

Since momentum is calculated using **velocity**, which has a direction, momentum is a vector quantity. Just like with velocity, you can show the momenta (the plural of momentum) of objects moving in opposite directions by using a + sign for one of them and a – sign for the other.

Conservation of Momentum

Momentum is a property that is conserved in closed systems. This means the total momentum before an event is exactly equal to the total momentum after the event. This is called **conservation of momentum**. You can see conservation of momentum in action when objects collide (like snooker balls or cars in a crash) or when something stationary separates (e.g. firing a bullet from a gun or jumping off a stationary skateboard – it also explains why you should be very careful when jumping from a small boat onto the bank).

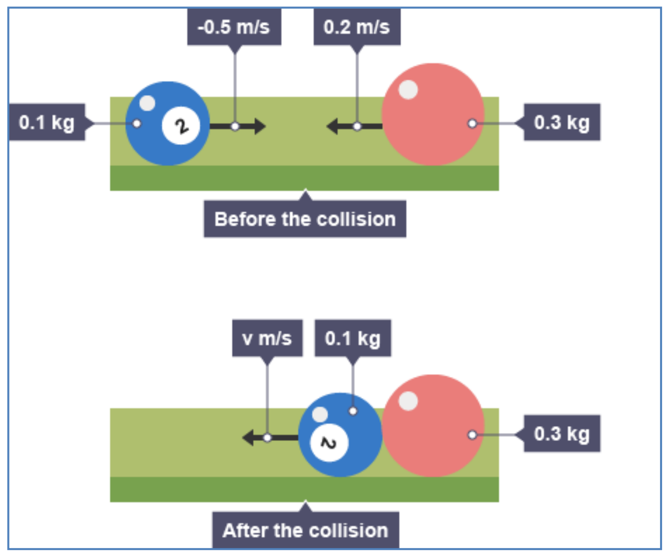
In this example: the boat is stationary at the bank, meaning its momentum is 0 kg m/s. When the person jumps out, they have a velocity and therefore a momentum. The boat **must** move away from the bank, since momentum is conserved (so must add up to 0 **after** the event too) so the boat has momentum in the opposite direction to the person – the boat moves away from the bank.

Conservation of Momentum in a Collision

Look at the diagram far right. The '2' ball has a negative velocity because it is moving in the opposite direction of the other ball. The total momentum before they collide = (0.1 x -0.5) + (0.2 x 0.3) = 0.01 kg m/s. According to the rule of conservation of momentum, the total momentum after the collision is also 0.01 kg m/s. Also, by looking at the diagram, you can see that both balls are now moving to the left, together. The total mass is 0.1 + 0.3 = 0.4 kg.

Rearranging to make velocity the subject, $v = \frac{p}{m}$
v = 0.01/0.4 = 0.025 m/s is the velocity after the collision.

Key Terms	Definitions
Momentum	A property of any moving object, calculated as the product of mass and velocity. Measured in kg m/s.
System	Systems are how physicists divide up the universe. Systems involve an object or objects and their interactions. They can be very simple (e.g. a falling object) or very complicated (e.g. our whole galaxy).
Closed system	A system where objects are not thought to be affected by external forces or other objects outside the system. We only think about the objects inside the system, which means the quantities *momentum* and *energy* are **conserved**.
Conservation	Simply means 'keeping the same.' To add detail, conservation of a quantity means that the total amount of it is the same before and after an event. In any closed system, the total amount of energy and momentum before and after an event is equal.
Equation	**Meanings of terms in equation and units**
$p = m\,v$ * HT only	*p = momentum (kilogram metres per second, kg m/s)* *m = mass (kg)* *v = velocity (m/s)*



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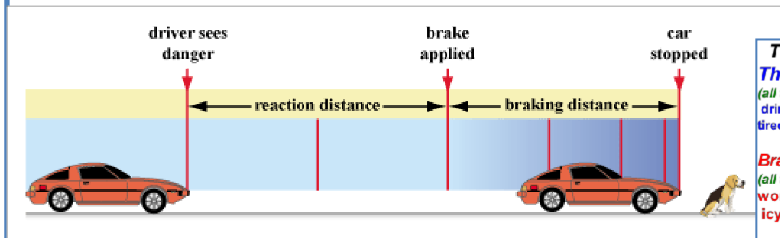
Forces and Braking

Stopping a vehicle requires a force to be applied, since the speed must change – the vehicle must decelerate to 0 m/s. The **stopping distance** of a vehicle depends on two factors, which add up to make the stopping distance. These are the **thinking distance** (distance travelled while the driver reacts) and the **braking distance** (distance travelled under the braking force).



Things which affect stopping distance

Thinking distance
(all these things are to with the drive)
drinking alcohol, taking drugs, tiredness, illness, not concentrating,

Braking distance
(all these things are to do with the car and road conditions)
worn tyres, poor brakes, wet roads, icy conditions, oil or grease on the road, etc.

For a particular braking force, the greater the speed of the vehicle, the greater the stopping distance. This is because going from a higher speed to 0 m/s is a bigger change in speed than going from a lower speed to 0 m/s. The thinking distance is longer at a higher speed, because reaction times won't change according to the speed – so you'd go further in the same time if you're going faster. Typical reaction times vary from 0.2 s to 0.9 s. Different factors affect the thinking and braking distances – see the box.

Braking Force and Work Done

When force is applied to the brakes, work is done by the friction force between the brake pads and the wheel. The **kinetic energy** of the vehicle is transferred to **thermal energy** – this is why brakes get hot.

To stop a vehicle in a certain distance, the faster the vehicle the larger the force needed, since a larger deceleration is needed (*F = ma* again). However, this can lead to overheating of the brakes and/or loss of control of the vehicle.

Forces cause a change in momentum

F = ma tells us a resultant force causes an acceleration. Substituting the equation for acceleration into *F = ma* gives you the equation above. It tells us that **reducing** the time taken to change momentum **increases** the force. This is why it hurts more to land on pavement than a trampoline. It also explains seatbelts, air bags, cycle helmets and cushioned tiles in playgrounds: all of these **increase** the time taken to slow to a stop, therefore **decreasing** the force acting on the object.

Key Terms	Definitions
Stopping distance	The distance a vehicle travels after the driver spots a danger and decides to stop. It is the sum of the thinking distance and braking distance.
Thinking distance	Distance travelled during a driver's reaction time.
Braking distance	Distance travelled while the driver is applying the brake (i.e. distance travelled under the braking force).
Kinetic energy	The form of energy of any moving object. Since the equation uses speed, not velocity, this is a scalar quantity.
Thermal energy	The form of energy associated with heat. The thermal energy of an object is proportional to its temperature.
System	An object or group of object, and its/their interactions.
Conservation of energy	A fundamental concept in physics. In a system, total energy is always conserved (it cannot be created or destroyed). However, it can be transferred from one store of energy to another.

Equation	Meanings of terms in equation and units
$E_p = m\,g\,h$	*E_p = gravitational potential energy (joules, J)* *m = mass (kg)* *g = gravitational field strength (newtons per kilogram, N/kg)* *h = height (metres, m)*
$E_k = 0.5\ mv^2$	*E_k = kinetic energy (joules, J)* *m = mass (kg)* *v = speed (m/s) – this is* ***squared*** *in this equation*
$F = \frac{m\Delta v}{t}$	*F = force* (N) *m = mass (kg)* *Δv = change in velocity (m/s)* *[and remember m Δv is change in momentum]* *t = time (s)* ***NOTE: This equation can be stated as: "force equals the rate of change of momentum"***