WJEC (Eduqas) Physics GCSE

4.2: Forces and Newton's Laws of Motion

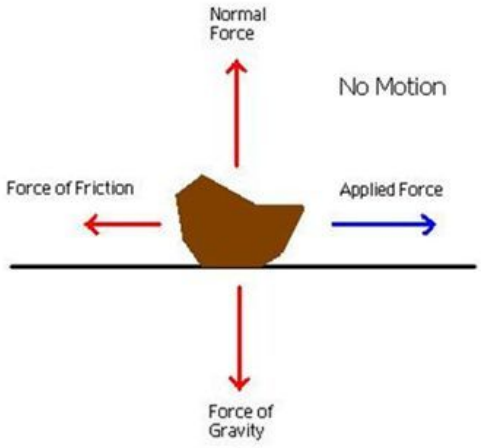
Detailed Notes

(Content in **bold** is for higher tier **only**)

Newton's First Law

A body will travel with uniform motion along a straight line or remain at rest unless acted upon by a resultant force

Essentially this means that if forces are **balanced**, they will have **no overall effect** on the motion of an object as there is **no resultant force**. The object would remain **still**, continue at a **constant velocity** or **float** when the forces are in balance.



Newton's first law: when forces are balanced the object remains stationary (slideplayer.com).

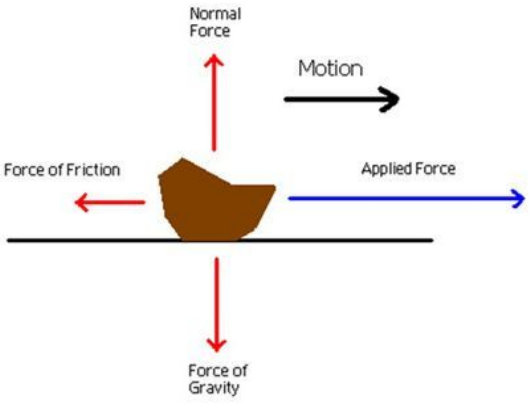
Newton's Second Law

A resultant force acting on a body will cause a change to its velocity.

The **resultant force** causes **acceleration** of the object, which depends on the object's **mass**.

$$F = ma$$

F is the resultant force (N), m is mass (kg) and a is acceleration (m/s^2).



Newton's second law: when forces are imbalanced the object accelerates (slideplayer.com).

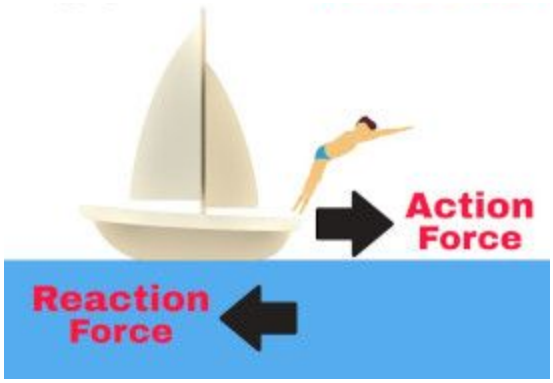
Inertia

The forces that resist a change in motion are inertia forces. The inertia of an object depends on its mass, so the greater the mass, the greater the inertia. This means a greater force is required to change the motion of a heavier object as inertia has to be overcome.

Newton's Third Law

When two objects interact, they exert equal and opposite forces on each other.

For example, if a person jumps from a boat, the person will move **forward** (the **action**) and the boat will move **backwards** (the **reaction**).



Newton's third law: every action has an equal and opposite reaction (thenewtonslaw.com).

Momentum

Moving objects have momentum, which means it is likely to continue travelling in the direction it is current heading in. The greater an object's momentum, the harder it is to change its direction. Momentum depends on velocity and mass.

$$p = mv$$

p is momentum (kg m/s), m is mass (kg) and v is velocity (m/s).

Newton's Second Law

In Newton's second law, resultant forces and acceleration of an object are related ($F=ma$). This law can also be used with the concept of momentum. The force experienced is related to the change in momentum over time.

$$F = \Delta p / t$$

F is force (N), Δp is the change in momentum (kg m/s) and t is time (s).

The faster the momentum is changed, the greater the force experienced as time is reduced.

Conservation of Momentum

In closed systems where no external forces act, the total momentum before and after an event remains the same. This includes explosions and collisions. Momentum is conserved.

$$momentum\ before = momentum\ after$$
$$m_1v_1 = m_2v_2$$

This concept can be used in calculations to find the velocity of objects after a collision or explosion.

Example:

Two railway carriages collide and join to move off together afterwards. Carriage A has a mass of 12,000 kg and moves at 5 m/s before the collision. Carriage B has a mass of 8,000 kg and is stationary before the collision. What is the velocity of the two carriages together after the collision?

$$momentum\ before = momentum\ after$$
$$m_1v_1 = m_2v_2$$
$$(12000 \times 5) + (8000 \times 0) = (12000 \times v) + (8000 \times v)$$
$$60000 = 20000v$$

$$\Rightarrow v = 60000 / 20000$$
$$v = 3\ m/s$$

Example 2:

A 5kg cannonball sits stationary inside a 100 kg cannon. When fired, the cannonball moves forwards with a velocity of 40 m/s. What is the recoil velocity of the cannon?

$$momentum\ before = momentum\ after$$
$$m_1v_1 = m_2v_2$$
$$(5 \times 0) + (100 \times 0) = (5 \times 40) + (100 \times v)$$
$$0 = 200 + 100v$$
$$-200 = 100v$$

$$\Rightarrow v = -200 / 100$$
$$v = -2\ m/s$$

The negative sign indicates that the canon moves in the opposite direction to the fired cannonball.