WJEC (Wales) Physics GCSE

2.2: Newton's Laws

Detailed Notes

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

Mass & Weight

Mass is a measure of the **amount of matter** something is made up of. It is a **scalar** measurement, measured in kilograms (kg).

Weight is the **force** experienced by all mass because of **gravity**. Gravity is an acceleration that causes a force of **attraction** between any two objects that have **mass**. Objects of relatively small mass, such as those on the Earth's surface, only experience significant attraction to their **most proximal massive body**: the Earth. At different points on the Earth's surface, objects experience slight variations in the gravitational attraction to the Earth. However, at GCSE, the approximation that all objects on the **Earth's surface** experience a **gravitational pull** of ~=**10N/kg** is reasonable.

Note that the units N/kg are the same as those of acceleration: m/s^2 (see 'Newton's Second Law').

Mass and weight are **directly proportional** and related via the **gravitational field strength** (g).

$$W = mg$$

W is weight (N/), m is mass (kg) and g is gravitational field strength (N/kg).

Since different planets/solar bodies have different masses, the gravitational acceleration (g) imposed by each planet/solar body on surface objects varies. Consequently an object may possess a **different weight**, even though its **mass remains unchanged**. On the moon, g = 1.6 N/kg, therefore my tea mug, which has a mass of 0.2kg would weigh 2N (0.2 x 10 = 2) on Earth but only 0.32N (0.2 x 1.6 = 0.32) on the moon.

In distant space where the **gravitational field strength** is weak, small (non-massive) objects will appear to be **'weightless'** despite still having mass.

Inertia

Inertial forces are those that **resist** any change to the velocity or state of motion of an object. The inertia of an object depends on its **mass**. 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 Laws of Motion

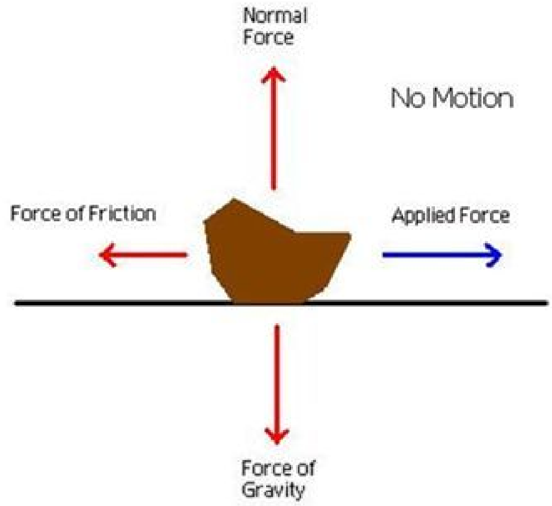
For higher tier exams, you must be able to state the laws.

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**, the motion of an object will **remain unaffected** since there is **no resultant force**. An object remaining **still**, continuing at a

constant velocity, or **floating** in still water would all be examples of **balanced forces** (i.e. there is no resultant force).



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

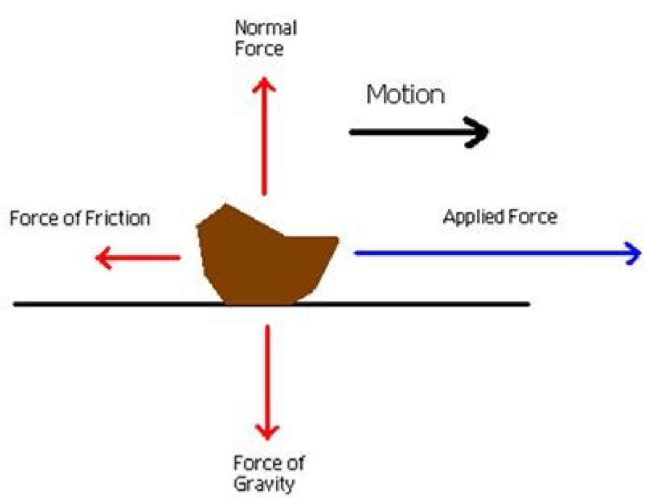
Newton's Second Law

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

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

$$F = ma$$

F is the resultant force (N), m is mass (kg) and a is acceleration (m/s²).

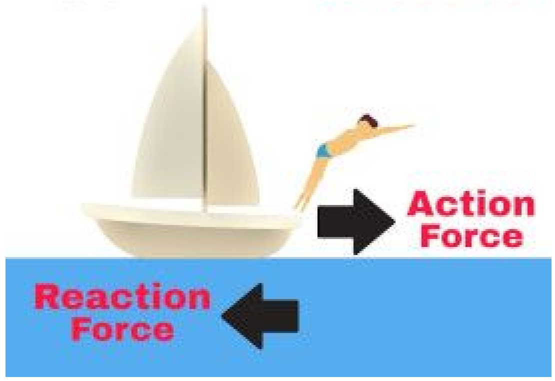


Newton's second law: when forces are imbalanced the object accelerates (slideplayer.com).

Newton's Third Law

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

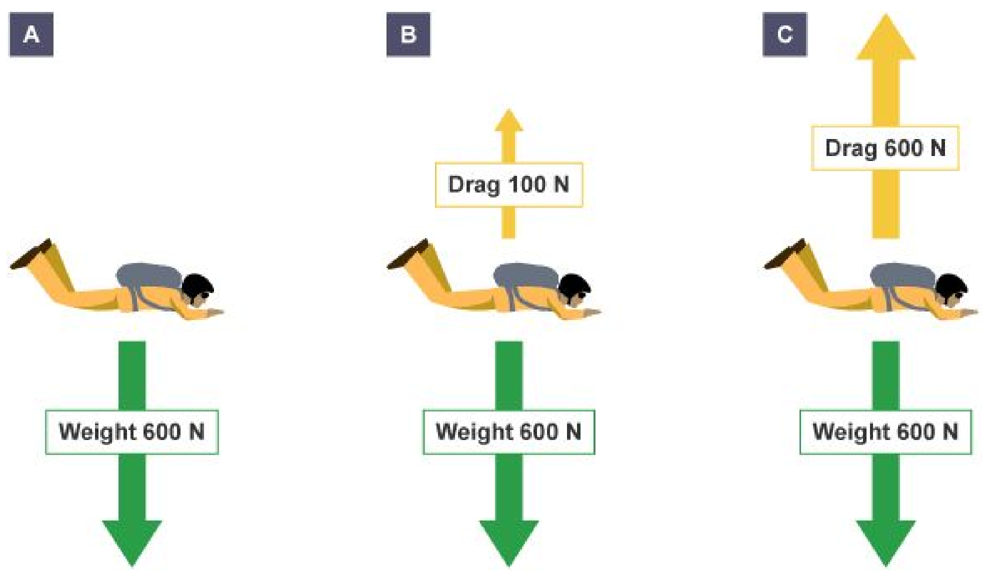
For example, if a person jumps from a boat, the person will move **forward** (the **action**) and the boat will move **backwards** (the **reaction**).



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

Terminal Speed

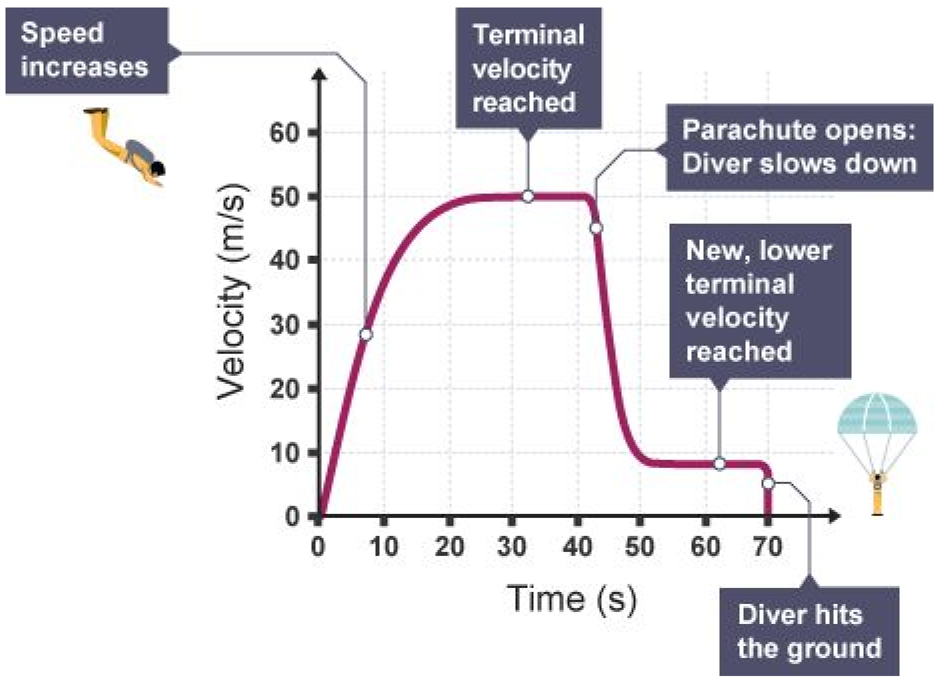
As an object starts to move through a **fluid** such as air or water, **resistance (drag) forces increase**, opposing the motion of the object. Eventually these drag forces will be **equal** to the **driving force** so the object moves at a **constant speed**. There is no longer a resultant force acting, so the object continues to move at a constant speed, known as its **terminal velocity**.



Free falling skydiver: A) driving forces increase. B) Resistance forces increase as a reaction force. C) Terminal velocity is achieved as the forces balance out (bbc.co.uk).

For a **free-falling** object such as a skydiver, the driving force is **weight** ($W = mg$). Therefore the terminal velocity varies depending on the **mass** of the diver; a greater mass means a greater weight so a greater terminal velocity. (It is important to note, however, that a more massive person is also likely to have a larger surface area, creating more drag. This would mitigate the correlation between the diver's mass and his/her terminal velocity to some extent.)

The diver's journey can be shown on a **velocity-time graph**. Their velocity **increases non-uniformly** as drag forces increase, until the terminal **constant** velocity is reached. When they open their parachute, the **drag forces** are significantly increased so they **slow down** to a safe speed and eventually land to a stop.



Velocity-time graph of a skydiver's journey (bbc.co.uk).