Momentum and Newton’s Law of motion

Newton’s Laws of Motion

First law

Every object continues in a state of rest, or in uniform velocity unless acted on by a resultant force.

The property of an object to stay in rest or in uniform velocity is called inertia.

Second law

For an object of constant mass, its force is directly proportional to its acceleration.

Force = mass $\times$ acceleration

$F = ma$

The unit of Force is a “Newton” or N. A Newton is defined as the force which will give a $1\,kg$ mass an acceleration of $1\,ms^{-2}$.

Third law

Whenever one object exerts a force on another, the second object exerts an equal and opposite amount of force onto the first.

When you exert a forward force on a box, the box will exert an equal force back onto you. A rocket will exert force on the exhaust gas which exerts an opposite force on the rocket, propelling it upwards.

Momentum

The momentum of a particle is defined as the product of the mass and velocity.

momentum = mass $\times$ velocity

$$p = mv$$

So the unit of momentum is $kg\,ms^{-1}$ or Ns ($N = kg\,ms^{-2}$)

Referring to the first law, if an object is in rest or in uniform velocity, the momentum is constant/unchanged.

The resultant force of an object is directly proportional to to the rate of change of its momentum.

$$F = \frac{\Delta p}{\Delta t}$$

$$F = \frac{\Delta (mv)}{\Delta t} = \frac{m\Delta v}{\Delta t} = ma$$

Weight

Weight is the force of gravity which acts upon an object

$$W = mg$$

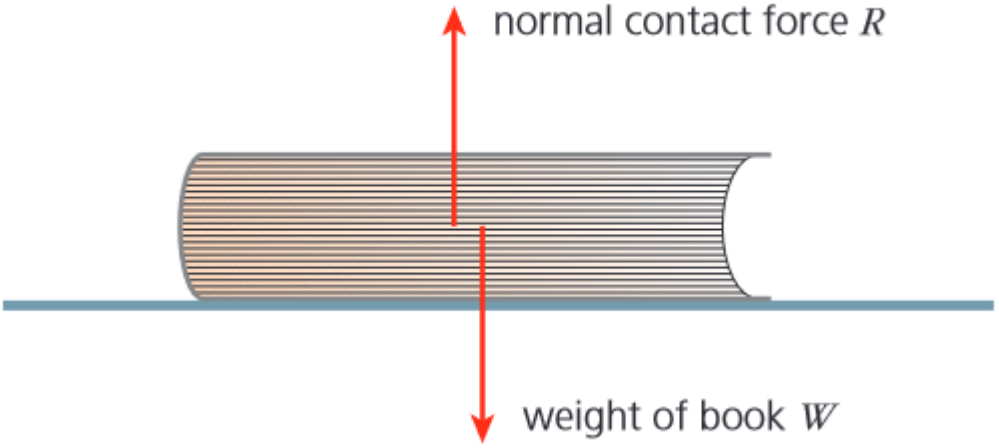
$g = 9.81\ ms^{-2}$ for Earth

Therefore, 1 kg of mass on Earth has a weight of 9.81 N.

A falling object and an object at rest have the same weight. Since an object at rest exerts a force downwards, there is another force acting upon the object to have a resultant force

of 0(Newton’s first law). This force is called the **normal contact force**.

For example, a book on a table has a normal contact force. “contact” because this happens due to the contact between the table and the book. “normal” because it happens perpendicularly to the point of contact. Therefore, the book remains at rest on the table.



A common mistake is to think that “The weight W is equal to the normal contact force R due to Newton’s third law”, but this is incorrect. The third law only applies to forces acting on different bodies, while here both the gravitational force and the normal contact force act on ***the book only***.

For Newton’s third law, the book exerts its weight on the table, and the table exerts an equal force back on the book. Only then is the third law related. Even when the book is not on the table, the book exerts its gravitational force on the Earth and vice versa, so the third law is satisfied.