

## Newton's first law of motion

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Sir Isaac Newton aimed to describe and predict the movement of every object in the Universe using his three laws of motion. Like many other 'laws' they give the right answers for the majority of the time. For example, the paths of planets, moons and satellites are all calculated using Newton's laws.

### Newton's first law of motion

Newton's first law of motion states that a body will stay at rest or move with constant velocity unless a resultant external force acts on it.

Note: Moving in a straight line at a constant speed, in other words, moving at a constant velocity is commonly referred to as uniform motion.

There are two consequences of this law:

1. If a body has an acceleration, then there must be a resultant force acting on it.
2. If a body has no acceleration, then the forces acting on it must be in equilibrium (have zero resultant force).

At first glance this law would appear contrary to everyday experience: give an object a push to set it in motion - then, it will slow down and come to rest - it does not 'continue in a state of uniform motion'. This is due to unseen resistive forces of *friction* and *air resistance* opposing the motion. (Figure 1).

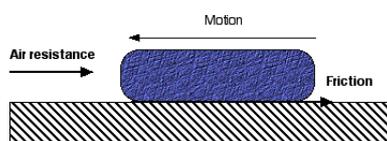


Figure 1: Resistive forces acting together to oppose motion

Bodies resist changes to their motion. In mechanics, *inertia* is the resistance of a body to a change in its velocity. It is the property discussed in Newton's first law, sometimes known as *the principle of inertia*. Put simply, if a body having constant mass is not acted upon by an external force, its velocity will not change. Since acceleration is change in velocity, inertia is effectively a body's resistance to acceleration. Inertia depends upon both a body's mass and its velocity. the greater the body's mass the greater an external force will be needed to change its velocity by the same amount, i.e. produce the same acceleration.

### Example 1

Consider a parachutist who jumps from an aeroplane that is travelling horizontally. The initial vertical speed of the parachutist is zero. However he will immediately be acted upon by his weight acting vertically downwards and since the external resultant force is not zero he will accelerate downwards.

As the parachutist's speed increases so does the air resistance. This opposes the downwards force of his weight and means that he will not increase in speed indefinitely. Eventually the air resistance will increase until it equals his weight. At this point the resultant force on the parachutist will be zero and he will stop accelerating; instead he will continue to fall at a constant or *terminal* velocity. For the human body this is about  $45\text{-}55\text{ m s}^{-1}$  (or 100-120 mph).

When the parachutist pulls the rip-cord and the parachute is opened the air resistance is suddenly increased such that it is greater than his weight. The resultant force is upwards meaning that the parachutist will start to decelerate. This will continue with the air resistance reducing until the forces are again equal and the speed of fall is constant. At this point the terminal velocity should be only a few  $\text{m s}^{-1}$ .

### Example 2

For a car parked at rest on a hill (Figure 2), the three forces (friction, weight and normal reaction force) have zero resultant force.

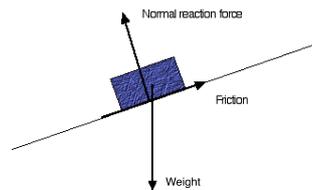


Figure 2: Friction balancing the component of weight down a slope.

If the vehicle moves with constant velocity, the driving force and resistive forces (air resistance and friction) must be equal in magnitude and opposite in direction.

### Exercise

A puck is sliding along a smooth horizontal surface, will the motion remain uniform?

### Solution

From the definition of smooth (see mechanics sheet 1.4.) we note that we assume the surface is frictionless. Then the only forces acting on the puck will be *weight* and the *normal reaction force* from the surface. These two forces are equal and opposite so there will be no resultant force, and therefore the motion will remain uniform.

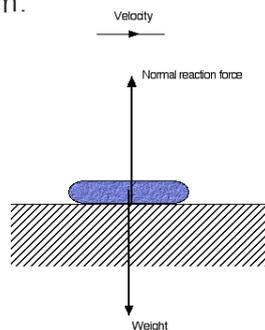


Figure 3: A puck sliding on a smooth surface.