Newton's Three Laws of Motion

1st Law	An object will remain at rest or will continue to move in a straight line at a constant velocity unless it is acted upon by a resultant force.
2nd Law	$F = m\,a$ (An unbalanced force = Mass × Acceleration)
3rd Law	Every action has an equal and opposite reaction.

2.1 Newton's Second Law

In the second law, m is the mass of an object, modelled as a particle, and a is the acceleration of that object when it is acted upon by a resultant force, F. In lesson 1 we looked at techniques to find a single resultant force replacement for several forces acting on a particle. It is helpful to think of the F in $F = ma$ as the force left over after as much balancing of forces has been done as possible. This left over force, the resultant, is what causes acceleration in $F = ma$.

If the forces on an object all balance, then, because the resultant, F, is zero, the acceleration, a, is also zero.

2.2 Example

Close to Earth's surface, the acceleration due to gravity is about 9.8 m s^{-2} in magnitude. The letter g is often used to denote this special acceleration. The formula $F = ma$ is often written as $W = mg$ for this special situation.

(i) By Newton's 2nd Law, what force will act on a mass of 8 kg ?

(ii) What are the SI units of force ?

(iii) What special word is used to describe this force ?

(iv) When one person incorrectly asks another person, “What is your weight ?”, what should they more correctly (accurately) say ?

2.3 Exercise

Question 1
A large crate of mass 87 kg sits on a lake of ice.
Find the resultant force required to accelerate the crate at 2.5 m s^{-2}

Question 2
A particle of mass 280 kg is acted on by a resultant force of 120 Newtons
Find the acceleration of the particle.

Question 3
How many Newtons does an apple of mass 0.22 kg weigh ?

Question 4
Find the mass of a particle whose weight is 388 N.

Question 5
On the surface of the Earth, an astronaut has a weight of 735 N.
On the surface of the Moon the acceleration due to gravity is about 1.6 m s^{-2}.
Find the weight of the astronaut when he is walking on, walking on, the Moon.

Question 6

I'm designing a sports car that has a mass of 850 kg.

I'd like it to accelerate from 0 to 90 km h^{-1} in 5 seconds.

Assuming no friction, what driving force does the engine need to produce ?

Question 7

A car of mass 640 kg travels a distance of 40 m along a straight horizontal road while uniformly accelerating from rest to 26 m s^{-1}.

(i) Find the car's acceleration.

(ii) What is the magnitude of the accelerating force ?

Question 8

A 800 kg car is travelling at 25 m s^{-1}.

When a traffic light changes to red, it stops in 6 seconds.

Find the constant breaking force applied.

Question 9

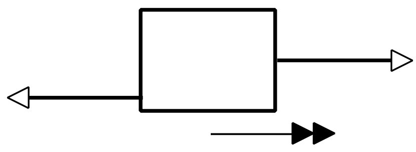
An Eddie Stobart lorry of mass 8 tonnes experiences resistance totalling 900 N as it travels along a horizontal road.

The engine's driving force is 3500 N.

(i) Add the forces 900 N, 3500 N, and a mass in kg to the diagram below.

(ii) What is the force available to cause acceleration ?

(iii) Find the constant acceleration of the lorry.



Question 10

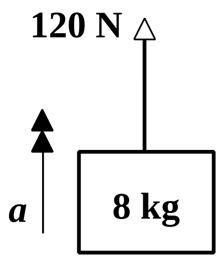
An 8 kg crate is being raised with a rope such that it accelerates upwards.

The tension in the rope is 120 N.

(i) On the diagram add on (as a force) the weight of the crate.

(ii) What is the force available to cause acceleration ?

(iii) Calculate the acceleration of the crate, *a*.

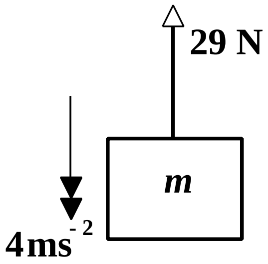


Question 11

A crate is being lowered with a rope such that it accelerates downwards at 4 m s^{-2}.
The tension in the rope is 29 N.

(i) On the diagram add on (as a force) the weight of the crate in terms of *m*.

(ii) Calculate the mass of the crate, *m*, in kg.

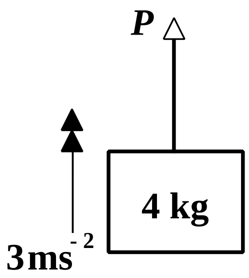


Question 12

A 4 kg crate is being raised with a rope such that it accelerates upwards at 3 m s^{-2}.

(i) On the diagram add on (as a force) the weight of the crate.

(ii) Calculate the tension in the rope, *P*.



Question 13

A 7 kg crate is being lowered with a rope such that it accelerates downwards at 6 m s^{-2}.

(i) On the diagram add on (as a force) the weight of the crate.

(ii) Calculate the tension in the rope, *P*.