3 Mass and weight

Videos & questions on the CD ROM

Scientists use the words 'mass' and 'weight' with special meanings. By the 'mass' of an object we mean how much material is present in it.

Weight is the force on the object due to gravity. It is measured in **newtons**. The weight of an object depends on its **mass** and **gravitational field strength**. Any mass near the Earth has weight due to the Earth's gravitational pull.

Weight is calculated using the equation:

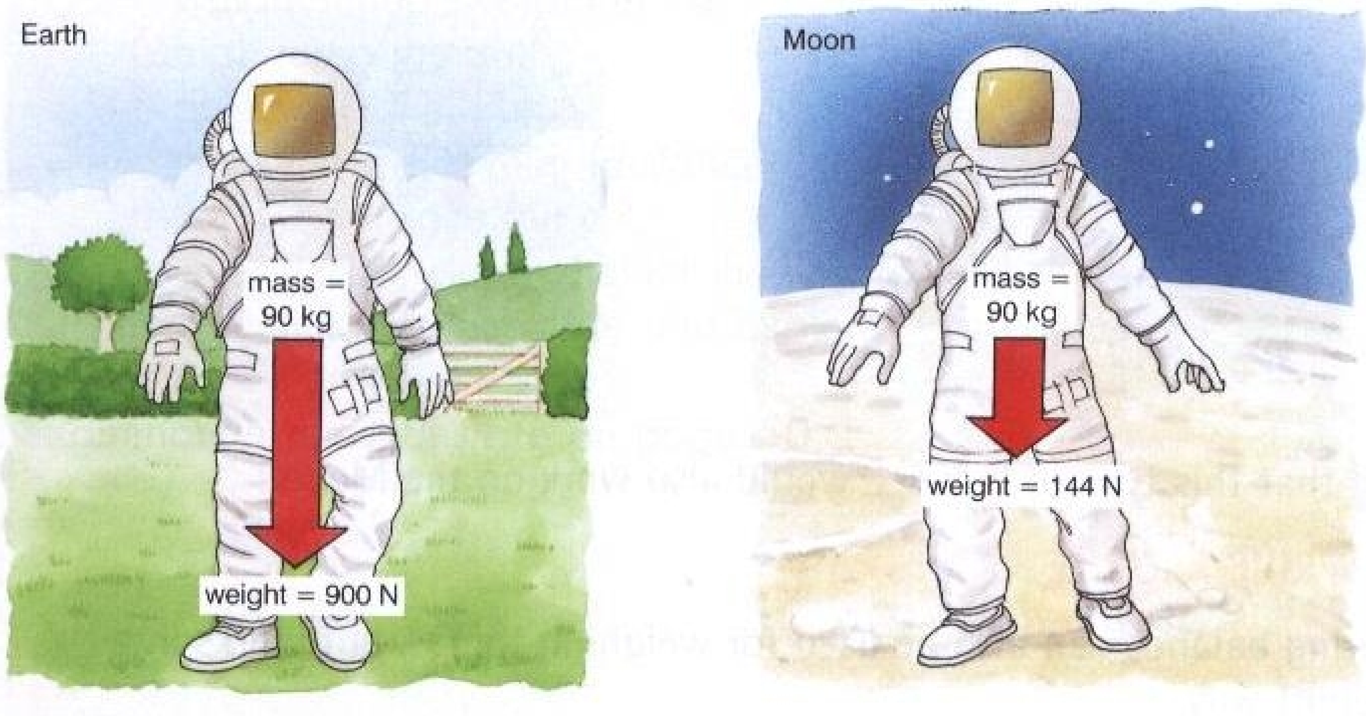
Weight (W) = mass (m) × gravitational field strength (g)

Scientists often use the word 'field'. We say that there is a 'gravitational field' around the Earth, and that any object that enters this field will be attracted to the Earth.

The value of the gravitational field strength on Earth is 9.8 N/kg, though we usually round it up to 10 N/kg to make the calculations easier. A gravitational force of 10 N acts on an object of mass 1 kg on the Earth's surface.

Note that gravity does not stop suddenly as you leave the Earth. Satellites go round the Earth and do not escape, because the Earth is still pulling them, even if less strongly than before the satellites were launched. The Earth is even pulling the Moon gently, and this is why it orbits the Earth once per month. And the Earth goes round the Sun because the Sun's gravity is pulling the Earth.

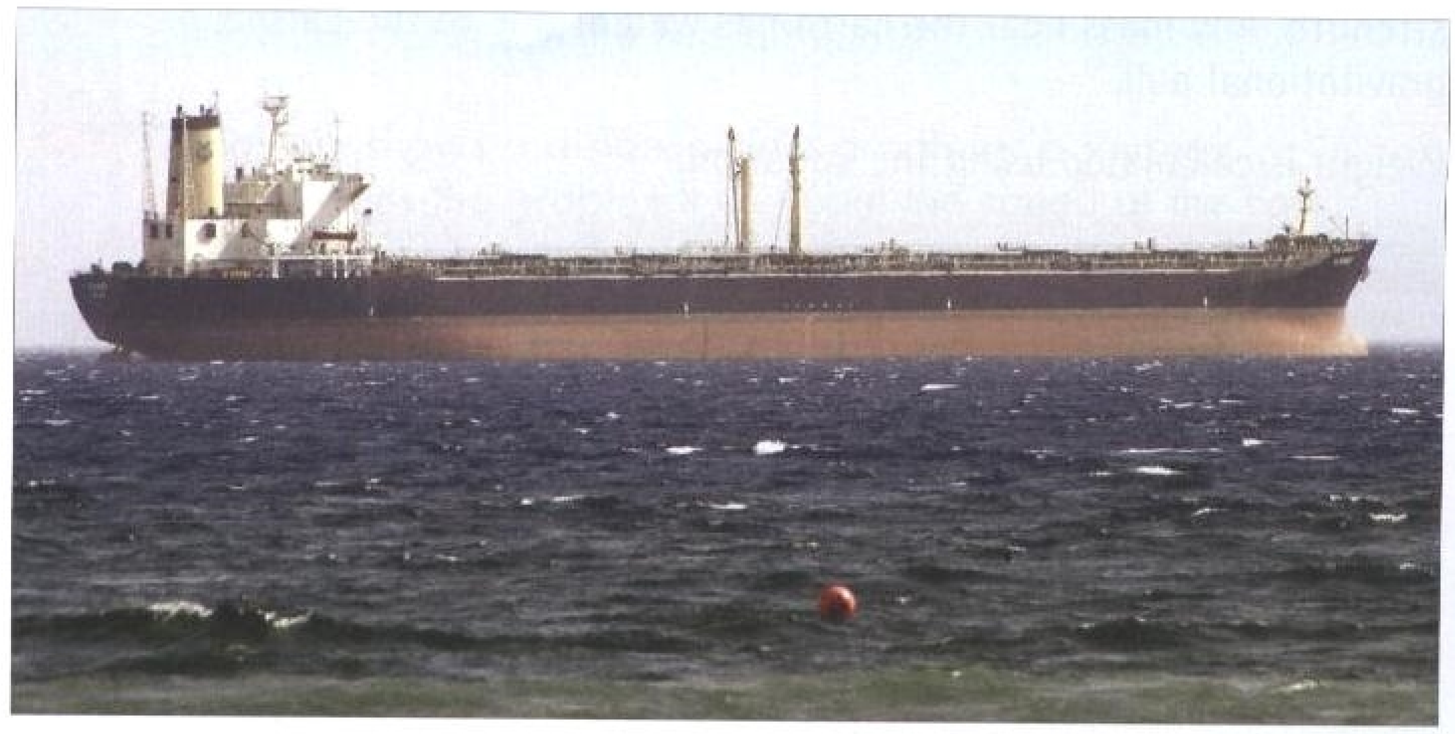
If you stand on the Moon you will feel the gravity of the Moon pulling you down. Your mass will be the same as on Earth, but your weight will be less. This is because the gravitational field strength on the Moon is about one-sixth of that on the Earth, and so the force of attraction of an object to the Moon is about one-sixth of that on the Earth. The gravitational field strength on the Moon is 1.6 N/kg.



Though your mass remains the same, your weight is greater on Earth than it would be on the Moon.

If two astronauts played American football, it would just as difficult to halt a rush by one of them on the Moon as it would be on the Earth, and any collision between them would hurt just as much. The reason is that it is the mass of an object that resists any change in the motion of the object, and the mass of each astronaut is the same in both places.

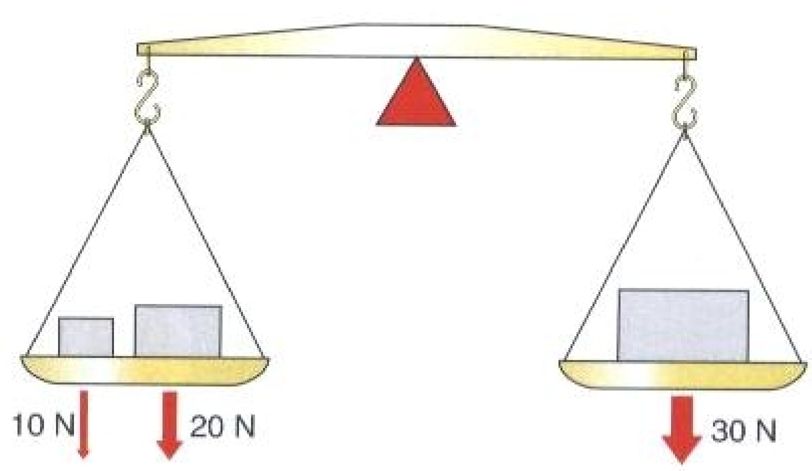
It is harder to get a massive object moving, and it is harder to stop it once it is moving.



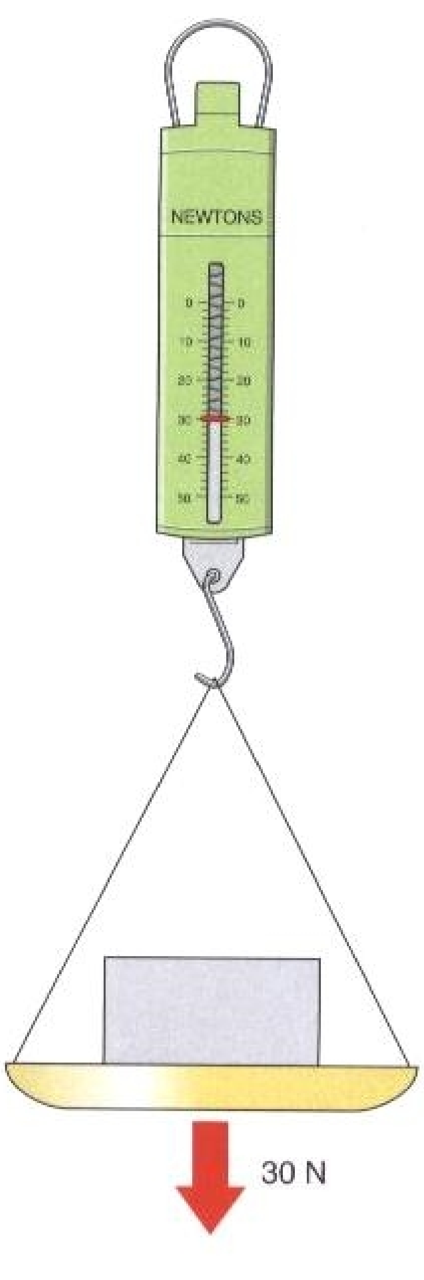
A supertanker laden with oil and travelling at 18 km/hr will take over 12 km to stop. A speedboat travelling at the same speed will take less than 100 m. The difference is due to the mass of the tanker.

HOW DO YOU WEIGH SOMETHING?

The balance is level when the forces pulling down both sides are the same. In the balance shown, the forces of 10 N and 20 N on the one side balance the force of 30 N on the other side. The balance compares the weight of the objects on each side. If the balance is on the surface of the Earth, then the masses of these objects are 1 kg and 2 kg on one side, and 3 kg on the other. So the balance also allows you to compare masses.



Note that this type of balance would also work on the Moon.



THE SPRING BALANCE

A spring balance can also be used for weighing things, but works in a different way.

The top of the spring is hung from a hook, and the spring is stretched by the weight of the pan attached to its lower end. The scale can then be adjusted so that the pointer is aligned with the 'zero' mark.

When a known mass is placed in the pan, the spring stretches further due to the extra weight, and the new pointer position can be marked. In the spring balance shown, the pointer should be at the 30 N mark if the scale is set correctly. If this balance were moved to the Moon, the weight would be less, and the spring would not stretch so far. In fact the pointer would indicate a weight of 4.8 N.

So the spring balance measures the weight of the object in newtons. For non-scientific use, these balances are often given a scale that indicates the mass of the object in kg, without the need for any calculations. This scale gives the correct mass on the surface of the Earth, but would definitely not give the correct mass if the spring balance were moved to the Moon.

See page 28 for more about springs.

REVIEW QUESTIONS

Note that the gravitational field strength on the surface of Mars is 3.8 N/kg.

Q1 A teenage astronaut has a mass of 60 kg when she gets into her spacecraft on Earth.

a What is her weight on Earth?

Parts b–e refer to the situation on the surface of Mars.

b What is her mass now?

c What is her weight now?

d If she stands in one pan of a large balance, what masses would be needed in the other pan to balance her?

e If she stands on bathroom scales (which are a type of spring balance) what would be the reading in Newtons?

Q2 The height that you can jump depends inversely on the gravitational field strength. So if the field strength doubles, the height halves. If the Olympic Games were held on Mars in a large dome to provide air to breathe, what would happen to the records for:

a weight lifting (weight in N)

b high jump (height)

c pole vault (height)

d throwing the javelin (distance)

e the 100 m race (time)?

In every case, state whether the record is likely to increase, stay similar or decrease, and explain your choice.

More questions on the CD ROM

Examination questions are on page 50.