key stage three

teaching the *right* science at the *right* time

handbooks for teachers

free sample chapter inside

science

handbooks for teachers, whatever approach or teaching style

key stage three

teaching the *right* science at the *right* time

handbooks for teachers

- Recognise the essential science at Key Stage 3
- Understand the journey from Key Stage 2 to Key Stage 4
- Identify and eliminate misconceptions
- Increase and organise subject knowledge
- Understand and incorporate how science works
- Enjoy teaching with greater confidence

... whatever approach, scheme of work, or teaching style.

Four handbooks support and extend knowledge and understanding of the range and content for science. They show the progression route from Key Stage 2 to Key Stage 4, challenge myths and misconceptions, and suggest how to incorporate how science works throughout lessons. The fifth explains key concepts and key processes.

the books

energy, electricity and forces [148 pages; publication date 31–03–09; ISBN 978-0-9557841-5-6]

organisms, behaviour and health [148 pages; publication date 30–04–09; ISBN 978-0-9557841-6-3]

chemical and material behaviour [148 pages; publication date 30–04–09; ISBN 978-0-9557841-9-4]

the environment, earth and universe [148 pages; publication date 30–04–09; ISBN 978-0-9557841-7-0]

interpreting how science works [68 pages; publication date 30–04–09; ISBN 978-0-9557841-8-7]

more than an aide memoire; less than a weighty tome

content

Topics are arranged in chapters, with the relevant science given on the first double page of each. This has three sections:

- **the journey so far:** a summary of the prior knowledge that you can reasonably expect pupils to have.
- **the science at key stage 3:** an outline of the science necessary for 11-14 year olds; it is written for teachers, so is aimed at fostering *your* understanding – it does not provide a 'script' for lessons.
- **the journey ahead:** a summary of the related science that pupils will encounter as they progress to Key Stage 4.

The rest of the chapter deals with the principal concerns when teaching the topic:

- **teaching issues:** further coverage of the science at a level that extends beyond what pupils need to know – a knowledge base from which you should be able to teach comfortably. This section is split into further sub-sections including **language and vocabulary**, **misconceptions** and **questions**.
- **applications and implications:** a discussion about applications and implications of the science – be it science in the home or science in the workplace.

... as well as one or more of:

- **history and culture:** notes on historical or cultural aspects of the topic.
- **hot topics:** cutting edge science – the sort of things that attract the media.
- **facts and figures:** useful and interesting facts and figures to inform pupils and colleagues.

Throughout each chapter, pupil activities – such as practical work, literacy tasks, debates, presentations, etc. – are included. They are not step by step instructions but, rather, suggestions.

This series complements the information on The Standards Site. It will support any scheme of work. The series collects the scientific knowledge, skills and understanding into manageable handbooks that are more than an aide memoire, less than a weighty tome.

sample chapter

The following eight pages show a sample chapter taken from *energy, electricity and forces*.

the journey so far

Pupils are likely to have:

- encountered forces first as 'pushes and pulls' associated with movement
- experienced forces through working with magnets and springs
- learned to name friction and weight as forces
- used a forcemeter to measure forces
- learned that objects weigh less in water
- investigated stretching elastic bands by hanging masses on them, and the behaviour of paper falling through air when the resistance is changed by scrunching or folding the paper.

Pupils may also have learned that gravity is a force that pulls things downwards (towards the centre of Earth).

the science at key stage 3

Understanding forces

A force can be a push, pull or twist. There are various types of forces, such as gravitational, magnetic, electrical, nuclear, tensile, compressive and frictional forces. All forces:

- are measured in the same units (newtons, symbol N)
- have the potential to make an object move (change position and/or shape).

However, an object does not always move when there is a force on it. Movement, or absence of movement, cannot be used as an indication of the presence or absence of forces.

- An object may experience a force, but something in the way prevents the object moving.
- An object may be experiencing several forces, whose combined effect is to prevent movement.

Some types of forces only occur between objects in contact with each other. These include simple pushes and pulls, tension in ropes or springs, friction, upthrust and air or water resistance.

Other forces can act 'at a distance' between objects that are not touching. These include gravitational forces and magnetic (and electrostatic) attraction or repulsion.

Note: At Key Stage 3, electrostatic forces are best ignored unless raised by pupils themselves.

Situations like these help pupils to understand that it is possible for an object to have forces acting on it without the object moving. The forces may not always be obvious. The gravitational force on a hanging object is balanced by the tension in the support.

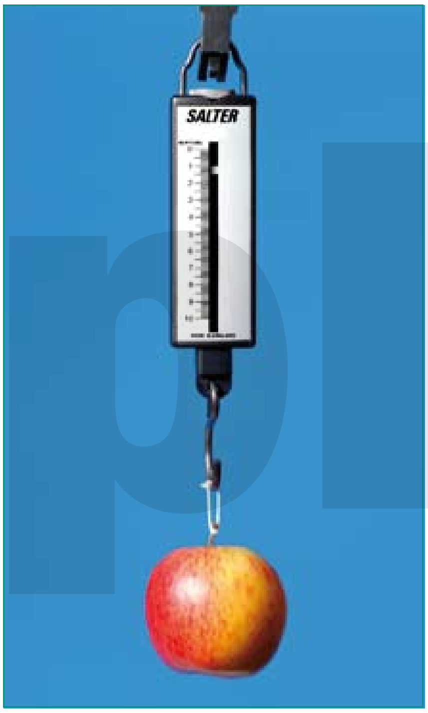
Force, energy and weight

There is a clear difference between force and energy:

- a force (measured in newtons) can be 'pictured' as a push, pull or twist acting on an object
- energy (measured in joules, symbol J) is a property of the object; not something that acts on it
- a force acting on an object may change the object's energy, but only if something moves.

Weight should not be confused with mass.

- Weight, in newtons, is the force on an object due to gravity. It is measured using a newtonmeter (forcemeter).
- Mass, in grams or kilograms, expresses how much 'stuff' an object contains. It depends on the number and type of atoms in the object.
- If an object moves to a different place, its weight may change, but its mass stays the same.
- Weight depends upon the gravitational force. Gravitational force acts between masses everywhere, including in space, but is weaker between masses that are smaller or further apart.



Pupils measure weight using a spring balance (newtonmeter or forcemeter). How much the spring stretches is a measure of weight (the force due to gravity attracting the mass). The weight is directly proportional to the mass of the object. The weight, and therefore mass, of an object can also be found from how much the object compresses a spring. Both instruments are calibrated by measuring the extension or compression caused by a known mass.

the journey ahead

During Key Stage 3 pupils look further at the effects of forces acting in different situations. They:

- **learn how the shape of an object and its speed or direction of movement are affected by balanced and unbalanced forces**
- **use forces to explain turning effects, floating and sinking, air resistance and streamlining**
- **learn how forces are related to speed and acceleration, using both force diagrams and calculations to describe and explain the effect a force has**
- **learn the relationship between force, area and pressure, relating pressure to the particle model of materials.**

At Key Stage 4 and beyond pupils will make further links between force, work, energy and power and will further develop their understanding of weight, gravity and acceleration in different situations.

teaching issues

Prior learning

1. Give pupils a few minutes to write down some things they know about forces. Use these as the starting point for class discussion to establish prior learning and any obvious misconceptions.

2. Ask pupils to identify the type of force acting in a range of situations, either real examples or pictures. Identify whether the force is a 'contact force' or a 'remote force'.

Definitions

A typical scientific definition of force is 'an influence that can cause a body to alter its state of rest or uniform motion.'

Although pupils do not need to know formal definitions at this stage, writing and discussing group or class definitions of scientific terms can aid understanding and memory.

Vocabulary and language

Force, energy, work and power are frequently used interchangeably in everyday language, but have specific meanings in science. Force and energy are explained in *the science at key stage 3*.

A force does work when it makes an object move. The amount of work done equals the amount of energy the object gains. It depends on the size of the force and the distance it moves the object. Work and energy are measured in joules (J).

Power is a measure of how *quickly* something does work. It is measured in watts (symbol W). One watt = 1 joule per second (J/s).

Note: In a wider sense, even where no mechanical work is done, power (in watts) is the rate at which energy is transformed (in joules per second). For instance, a 60 W light bulb transforms 60 joules of electrical energy into heat and light every second.

Cutting edge problem

Pupils – and teachers – are not alone in having problems understanding forces. For many decades, physicists have been trying to develop a Grand Unification Theory (or Grand Unified Field Theory) to explain the action of all forces, using a single theory. These forces are: strong and weak nuclear forces (those acting within atomic nuclei), electromagnetic forces and gravitational forces. Scientists still cannot explain the cause of gravitational forces or how forces acting remotely, such as gravitational forces or magnetism, are able to act instantaneously at a distance.

Mass, weight and gravity

Gravity is the mutual attraction between two objects due to their mass (as opposed to magnetic attraction, for instance); the greater the masses, the stronger the attraction. Gravity is a two-way force, pulling the objects towards each other – the Earth pulls down on us, but we also pull upwards on the Earth.

Since weight is the force due to gravity, weight is also, strictly speaking, a two-way force. At Key Stage 3, however, we can consider weight as a one-way force – the downward force (in newtons) that an object experiences as a result of Earth's gravitational attraction.

Gravitational forces always act along a line joining the centres of gravity of the two objects. So, on Earth, weight is a downward force towards the centre of the Earth. The weight of an object (that is, the size of the downward force) depends on **both** masses, so an object with a given mass would weigh less on the Moon and more near Jupiter.

Astronauts can jump about six times higher on the Moon than on Earth. The astronaut's mass doesn't change but, because the mass of the Moon is much smaller than the mass of the Earth, his weight changes. The force pulling downwards on the astronaut is much less on the Moon, so his muscles are able to make him jump higher.

Definitions

The centre of gravity of an object is the point where the force due to gravity (weight) appears to act. This is the same as the centre of mass, the point that has an equal amount of mass all round it. So for a sphere, it will be at the centre. For something like a cone that has much more mass at one end, the centre of mass will be near the wide end of the cone, and on the axis that runs down the middle of the cone.

Gravitational attraction also decreases as the distance between two objects increases. If you could get far enough away from all other masses, such as stars or planets, your weight would be zero, but there is nowhere in our solar system that is far enough away from the Sun for this to happen.

Later chapters look at what being weightless actually means.

Beyond Key Stage 4 pupils will learn the equation that relates gravitational force to mass and distance.

Force and acceleration

You may see statements such as *the force of gravity is 10 N/kg*. These are incorrect, since the unit of force is just newtons.They should say *the force of gravity acting on each kilogram (i.e. its weight) is 10 N*.

This force produces a downwards acceleration: the acceleration due to gravity, g (10 m/s^2).

Note: force = mass x acceleration (F = ma)

therefore, force ÷ mass = acceleration

and 10 N/kg = 10 m/s^2, since the dimensions of N are kg m s^{-2}

It may seem counter-intuitive, but the gravitational pull of an object on the Earth equals the pull of the Earth on the object – the force is the same. However, the effect of the force (the acceleration it produces) is very different.

F = ma, so **a** is inversely proportional to **m**.

Object: small mass and large downwards acceleration

Earth: enormous mass and infinitesimal upwards acceleration

Even when the ball is still, the person pushing feels a force trying to push them down the slope. Examples like this could be used to introduce the idea of more than one force acting. The person feels the ball pushing them, and also knows they are pushing on the ball.

Misconceptions

There are numerous common misconceptions related to forces. Many can be prevented by recognising the potential for confusion, taking extra care with explanations and using correct scientific terminology from the start.

Forces in general

Misconception: Stationary objects do not have forces on them. See *the science at key stage 3 – Understanding forces*.

Misconception: Only moving objects can exert a force; stationary objects cannot. Use examples such as a stretched rubber band or the spring in a clothes peg holding objects together. Note: the force transfers no energy whilst stationary. (Energy transfer = work done = force x distance moved)

Misconceptions: Objects must be in contact to exert forces on each other and **larger magnets are stronger than smaller magnets.** Relate each of these to work on magnets.

Gravity

Two common misconceptions have already been addressed:

Misconception: Mass and weight are the same.

Misconception: Gravity is a one-way force that acts downwards.

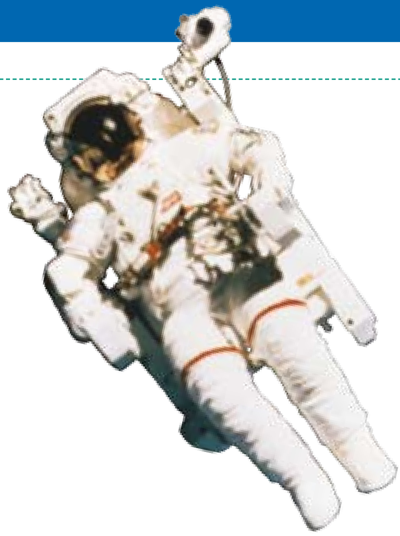
Other common misconceptions include:

Misconception: Things fall naturally and barriers stop things falling. Pupils may think that things ‘just fall’, rather than recognising falling as the result of an attraction between two masses. Henry Cavendish demonstrated this attraction in 1798 by using a torsional balance to show that a small lead sphere and a large lead sphere moved towards each other.

Misconception: Gravity stops acting when something reaches the ground. The force due to gravity acts all the time everywhere on Earth. It is wrong to assume that because an object is not moving there are no forces on it.

Misconception: Gravity only affects heavy things. To many pupils this may appear obvious because they are assuming that weight and gravity are the same thing. Avoid using the term ‘gravity’ loosely. Gravity is the attraction between two objects; weight is the effect of that attraction. The weight of an object is the force on it due to the gravitational attraction between the object and Earth. The Earth ‘pulls’ equally hard on each unit mass of every object, so an object with a smaller mass feels less ‘pull’. Gravity does affect light objects, but the effect is smaller, so less noticeable.

Misconception: Gravity gets bigger as you go higher up. Pupils may believe this because things from higher up hit the ground harder. The explanation is not higher gravity, but higher speed. The gravitational force causes acceleration, increasing the speed at which objects fall. Something that started higher up has been accelerating for longer. This is covered in more detail in later chapters.



Misconception: Things float because there is no gravity in water, or because gravity doesn't work through water. Things float because they have other forces acting on them as well as gravitational force. This is covered in the chapter on balanced and unbalanced forces.

Misconception: Astronauts float around in space because there is no gravity so they are weightless. Gravitational attraction acts everywhere, including space. The apparent weightlessness of astronauts is caused by their speed and acceleration. It is possible to create situations on Earth where people feel 'weightless'.

Questions

Question: If the force of gravity gets less when things are further apart, why don't I weigh less at the top of a mountain?

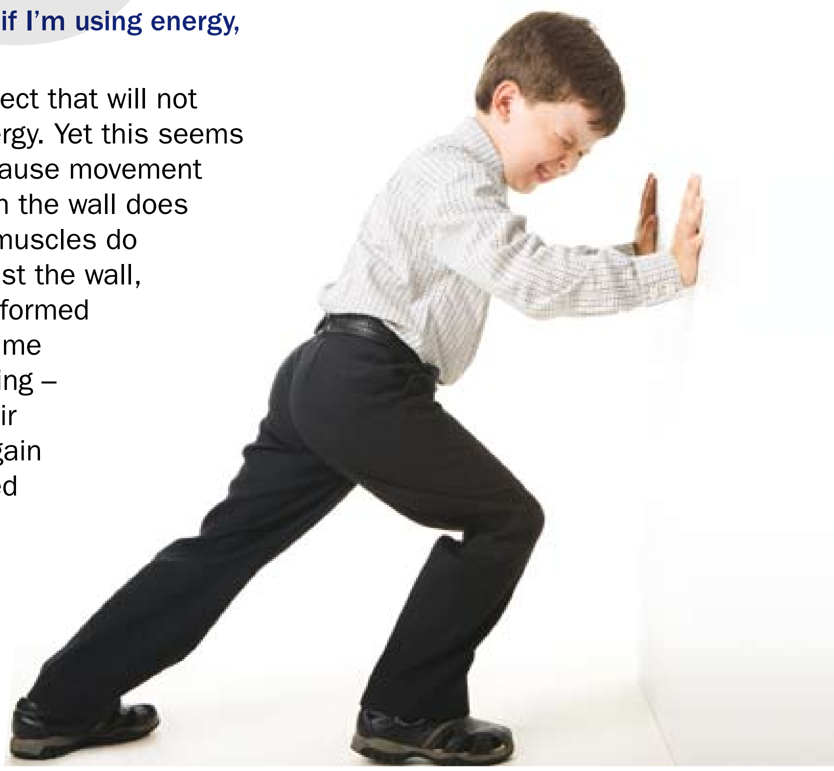
You do weigh less, but your change in weight is not enough to notice with ordinary measuring equipment. If you imagine the world as the size of a football, the tallest mountain in the world only sticks up the thickness of a human hair. The increase in distance between the centres of mass is only tiny, so the change in weight is also tiny. That is why, in calculations later on, it is assumed that the gravitational force is the same size everywhere on Earth.

Question: When a magnet attracts an iron bar, does the iron bar pull on the magnet as well, and which pulls harder?

Yes, the iron bar pulls on the magnet as well. Like gravity, magnetic attraction operates in both directions, pulling the magnet and the iron bar together. Each is being pulled equally hard towards the other, though if one is lighter than the other, it may move more easily. This idea generally becomes clearer when pupils look at balanced and unbalanced forces later.

Question: If I push hard against a wall, I feel as if I'm using energy, even though the wall doesn't move. Why?

Pupils know that if they struggle to push an object that will not move, they get tired. They actually do 'use' energy. Yet this seems to contradict the idea that if a force does not cause movement there is no change in energy. In reality, although the wall does not move, and their whole body may not, their muscles do move. As their muscles contract, to push against the wall, chemical energy stored in the muscles is transformed into heat energy. Work has to be done all the time the muscles remain contracted – to keep pushing – otherwise the muscles 'relax' and return to their 'resting' length. The immovable wall does not gain or lose any energy. If a heavy object were leaned against the wall of the house, pushing as hard the person did, that object would not gain or lose energy either. Similarly, if a person simply leaned against a wall, without pushing, they would not transfer energy.



applications and implications

As with energy, understanding forces and their effects is essential to most science and engineering. Although many examples are complex, some are readily understandable at this stage.

Science at work

A funicular railway in Budapest, Hungary. It relies on balancing forces.

Designing suspension bridges

The flat road or path section of a suspension bridge is suspended by vertical wires from the main weight-bearing cables attached to the vertical supports at each end of the bridge. Engineers have to correctly calculate the size of the forces on each of these cables, and how much these forces will make the cables stretch, otherwise the bridge will not be level. They base their calculations on scientific principles and equations.

Funicular railways

Funicular railways transport people up and down very steep cliffs or hills, where a normal train would be unable to go. A funicular railway consists of two carriages, joined together by a cable which passes over a pulley at the top. One carriage travels downhill as the other carriage travels uphill. The weight of the carriage going downhill helps pull the other carriage up, and the carriage going uphill helps slow the one going downhill, so it does not 'fall' too quickly. A small amount of energy is 'used' to operate the funicular railway, to overcome friction and any weight difference between the two carriages, due to their passengers.

Science at home

There are many places where surfaces are designed to have either low or high friction.

Rubber bath mats have a high friction between the mat and the bath, and between the mat and your feet, so that you don't slip over in the bath or shower.

Handles on equipment such as sports rackets or pliers often have rubber or soft plastic covering to increase friction and improve grip.

Vacuum cleaners and lawn mowers often have wheels; if they didn't, the high friction would make them difficult to move around.

Sledges and ice skates have very smooth runners and blades so that the friction is small and they slide easily.

Fridge magnets show not only magnetic forces in action, but also that magnetic forces can act through some materials (including paint). They also show the effect of the thickness of the material on the size of the force.

Profit from science

Pupils know intuitively that larger masses require larger forces to make them move. This knowledge is used by scientists building both satellites and aircraft. The more massive the aircraft, the more powerful the engine and the more fuel required to make it move. Both satellite and aircraft engineers try to reduce the mass of the craft they build. In 2007, Boeing revealed that about 50% of the structure of its new Dreamliner planes would be built from carbon-fibre materials instead of metal, because carbon-fibre is less dense.

history and culture

Before Isaac Newton, several scientists had investigated falling objects on Earth and the movement of planets and their natural satellites (moons), and had formulated laws to explain their observations. Newton was the first scientist to make a connection between both types of movement, realising that they were both examples of the effect of the force due to gravity. The story of an apple falling on Newton's head is apocryphal, but a falling apple may well have triggered his thoughts.

facts and figures

How big is a force of 1 newton? 1 N is the downward gravitational force on a mass of approximately 100 g. That is roughly the force you would feel pushing downwards on your hand if you held a large tomato or small apple.

hot topics

In December 2003, scientists lost contact with Beagle 2, a small space craft intended to land on the surface of Mars. They don't know if it missed Mars altogether or crash landed and broke. Two years later they spotted what might be the wreckage of Beagle 2 on the surface of Mars. An incorrect calculation or an incorrect prediction about the forces acting on a space 'lander' craft can result in a very expensive mistake. In many places it is not possible to use a parachute to slow down the falling space craft because there is no atmosphere; pupils will find out more about this later on. Often, scientists use squashy padding to 'break the fall'; pupils will find out more about this too.

Science club

Ask pupils to design a container, or suitable packaging to go inside a container they are given, to enable a raw egg to be dropped from as high as possible without breaking.

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