Physics

Big idea (age 11-14)
PES: Earth in space

What's the big idea?

The idea of Earth in space is important because we live on the Earth and it is the only planet that we know to have abundant and complex life. Understanding how the Earth and space systems interact, how they affect us, and how we affect them is vital for our survival. Exploring our origins and our place in the universe feeds the intrinsic curiosity of humans and develops a sense of wonder.

Topics

The big idea is developed through a series of key concepts at age 11-14, which have been organised into teaching topics as follows:

Topic PES1 **Solar system and beyond**	Topic PES2 **Earth and sun**
Key concepts: 1.1 Planets and the solar system 1.2 Gravity 1.3 The night sky, stars and galaxies	Key concepts: 2.1 Days and seasons

The numbering gives some guidance about teaching order based on research into effective sequencing of key concepts. However, the teaching order can be tailored for different classes as appropriate.

Guidance notes

Naming convention

The Earth, Sun, the Moon, Jupiter, Europa, Milky-Way and other specific astronomical bodies begin with capital letters; and generic bodies such as galaxies, stars, moons, planets do not.

Phases of the Moon

This has not been covered in this big idea and it is not included in the National Curriculum in England. Research suggests students can readily describe the changing shape of the Moon, during an approximate 28-day cycle, as it orbits the Earth. The observation of this pattern is evidence that the Moon is orbiting the Earth. *Explaining* how the phases of the Moon occur is very challenging, even for older students and adults, and its absence from the curriculum, at this stage of learning, does not hinder learning elsewhere.

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Learning progression

The science story associated with the big idea develops from age 5 to age 16, and could be summarised as follows:

Science story at age 5-11

Earth and Sun

The length of day changes through the year. In summer days are longer and in winter they are shorter.

The position of the Sun in the sky changes during the day. It is highest in the sky in the middle of the day.

An object casts a shadow pointing away from the Sun. At sunrise, when the Sun is low in the sky, the shadow of a vertical object is long. As the Sun moves across the sky (as Earth rotates) the shadow moves round so that it always points away from the Sun, and shortens as the Sun gets higher in the sky. The shadow is shortest at midday and (in the northern hemisphere) points north as the Sun is seen in the south. The position of the shadow can be used to mark out the passing of time on a sundial. (In the northern hemisphere the shadow moves clockwise. Clocks were originally made as mechanical imitations of sundials.)

The position of the Moon and the stars in the sky changes during the night. The stars all move together, so that their patterns remain the same. Groups of stars are called constellations (for example, the Plough, Orion).

The Earth is a sphere. It appears locally flat because it is very big. Day and night, and the apparent motions of Sun, Moon and stars are due to the rotation of the Earth on its axis. A full rotation takes 24 hours.

The Sun is also a sphere. It is very hot. It (emits radiation that) illuminates and warms the Earth. Solar radiation illuminates the half of the Earth's surface that is facing towards the Sun. The Sun is many times bigger than the Earth and looks small because it is far away.

The Earth orbits the Sun once every year (365¼ days), which means it moves around the Sun in (roughly) a circle.

Earth and Moon

The Moon is a cold rocky sphere that does not produce its own light. The moon is much smaller than the Earth (as its diameter is 4.6 times smaller). The Sun lights up the half of the Moon that is facing towards it.

The appearance of the Moon changes on a regular cycle. This happens because the Moon orbits the Earth, taking approximately 28 days. We see the part of the Moon that is lit up by light from the Sun.

Planets and the solar system

The Earth is a planet. There are seven other planets orbiting the Sun. In order of increasing distance from Sun: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune. Most of these planets have moons that orbit them. (Pluto is a one of five dwarf-planets that are known.)

The Sun, planets and other orbiting objects are collectively known as the Solar System.

Science story at age 11-14

Gravity

All objects are attracted to the centre of the Earth by the force of gravity, so an object that is free to fall moves towards the Earth. So, at all locations on Earth, our perception of 'down' is always towards the centre of the Earth. Gravity is an example of a force that can act between two objects even though they are not touching. (Gravity is an attractive force between all objects with mass).

The downward gravitational force attracting an object towards the Earth is called the object's weight.

The weight of an object on or near Earth's surface is about 10 N for every kg of the object's mass. As it is a force, weight is measured in units of force: Newton (N). Weight of an object (in N) = mass of object (in kg) x 10.

Close to the Moon, the nearest massive object is the moon itself. All objects on or near the moon are attracted to it by the force of gravity, and 'down' is towards the centre of the moon. Similarly, near a planet …

The greater the mass of a planet, the bigger its gravitational attraction. The gravitational attraction of the Sun is much greater than that of any planet because it has much more mass.

The gravitational force between two objects gets weaker as they (their centres of mass) get further apart. This weakening is gradual and there is *no* sudden cut-off beyond which the force ceases to act. The force of gravity from planets and other astronomical bodies is felt, albeit weakly, in space. Planets orbit the Sun and moons orbit planets because of the force of gravity.

The night sky

The Sun is a star. Like the Sun, other stars are very hot and emit radiation. They appear very much smaller and fainter than the Sun because they are at vastly greater distances.

A convenient unit for measuring such distances is the light-year, ly. 1 ly = distance light travels through space in 1 year ($\approx 10^{16}$ m). (The nearest stars to the Sun are a few light years away. For comparison, light from the Sun’s surface takes only a few minutes to reach Earth, and a few hours to reach Neptune. Stars further than a few hundred light years away are too faint to see with the naked eye)

In space stars are found in groups called galaxies. Each galaxy contains hundreds of billions of stars. (Evidence for galaxies was discovered in 1929.)

Day and night

The Earth is rotating about an axis that defines the (geographic) North and South Poles and Equator. As it rotates, different parts of its surface are illuminated. One complete rotation of Earth = 1 day.

We experience daylight everywhere on the half of Earth's surface that is illuminated by the sun. Night occurs everywhere in the half that is not illuminated.

As Earth rotates, we see the Sun in different positions in the sky. The Sun comes into view (rises) in the east, is seen to travel E-W in an arc across the sky, (E-S-W in the northern hemisphere, E-N-W in the S hemisphere) and disappears (sets) in the west.

Seasons

The Earth moves round the Sun in an approximately circular orbit. The Earth's own rotation axis is tilted (at about 23°) relative to the axis of its orbit.

The direction of the tilt remains constant in space as Earth travels round the Sun. So the Earth's rotation axis not (usually) at right-angles to a line drawn between Earth and Sun. If it was, all parts of Earth would always get equal periods of daylight and night.

When the North Pole is tilted towards the Sun, daylight lasts for more than 12 hours in the northern hemisphere and less than 12 hours in the southern hemisphere; it is summer in the northern hemisphere and winter in the southern hemisphere. Similarly, at the opposite side of the orbit, when the South Pole is tilted towards the Sun, it is winter in the northern hemisphere (less than 12 hours daylight) and summer in the southern hemisphere. Mid way between these two extremes, Earth's rotation axis *is* at right-angles to a line drawn between Earth and Sun. At these times, (the equinoxes: 'equal night') all parts of Earth get equal periods of daylight and night.

One complete orbit around the Sun = 1 year ≈ 365.25 days

In winter, at any given time of day the Sun is lower in the sky than it is in summer; solar radiation meets the Earth's surface at a more oblique angle so it is less intense (= spread out over a greater area) and so feels less hot. The radiation has also travelled through a greater depth of atmosphere (compared to when the Sun is higher in the sky) so more is absorbed en route before reaching the surface. And the shorter period of daytime in winter means that a given location is warmed for a shorter time in winter than in summer. All of these factors lead to the Earth's surface at any given location being colder in winter than in summer. The first two also explain why the equator is hotter than the poles.

At the equinoxes, the Sun is overhead at midday on the Equator, and at the poles it moves around the horizon.

When it is midsummer in the northern hemisphere, the sun is overhead at midday at a latitude of 23°N (Tropic of Cancer); further north than latitude 67°N (Arctic Circle) the Sun is always above the horizon (it never sets); and south of latitude 67°S (Antarctic Circle) the Sun never rises.

Science story at age 14-16

The night sky

The Moon is the brightest natural object in the night sky because it is so close to Earth compared to the stars. We see the light from the Sun that reflects off its surface. Some planets are visible from the Earth because of the light they reflect from the Sun, they appear as bright stars.

Stars produce their own light and the Sun is an example of a typical star. They are not very bright because they are so far away.

Other objects are occasionally seen by naked eye in the night sky. Comets move relative to stars, characterised by tail (that points away from Sun) – noticeable movement takes hours/days/weeks. Meteors (known as shooting stars): small fragments of rock that burn up as they fall through the atmosphere (called meteorites if they land on Earth's surface); movement is rapid – across the sky in several seconds.

Planets and the solar system

There are some other objects that orbit the Sun. Asteroids: small rocky objects mostly orbiting between Mars and Jupiter. Comets: icy objects in highly elongated orbits. Pluto and other dwarf planets orbiting (in the Kuiper belt) beyond Neptune.

Like Earth, other planets travel around the Sun in approximately circular orbits. The orbits all lie in approximately the same plane, at different distances from the Sun; planets furthest from the Sun take longest to travel once around their orbits.

Like Earth, planets rotate about their own axes. Like Earth, their rotation axes are tilted relative to their orbital axes (by different amounts, not 23^o). Most solar-system planets also have one or moons.

The planets in the solar system have a wide range of properties: for example Mercury, Venus and Mars are rocky like Earth, but Saturn, Jupiter, Neptune and Uranus are made mostly of dense gas and icy materials. The rocky planets are similar in size to Earth (slightly smaller) and the gas/icy planets are very much bigger than Earth (though still much smaller than sun).

Planet surface temperatures decrease with increasing distance from Sun.

Earth is the only planet (in the Solar system) with an oxygen-rich atmosphere and liquid water on the surface that supports life. No good evidence has yet been found for life on other solar system planets or their moons.

Gravity

We can use the idea of a 'field' to describe the strength of gravitational force. Gravitational field strength is the gravitational force acting on a mass of 1 kg. It is given the symbol g and its SI units are Newton per kilogram (N/kg). On or near Earth's surface, g = 10 N/kg. (On or near moon's surface, g = 1.6 N/kg. On or near Sun's surface, g = 28 N/kg). For an object mass m, its weight is $W = mg$.

Gravity in space

To make a moving object follow a curved path, there must be a force pushing/pulling it towards the centre of the curve. If the force stops acting, the object moves in a straight line at a tangent to the curve. (Example: whirling a bung on a string – cut the string and the bung flies off along a straight line.)

If you throw an object horizontally, it travels in a downward curve. It is pulled into the curved path by the force of gravity. (Newton's thought experiment: if you throw the object faster, it travels further before hitting the ground. Throw it fast enough and the earth's surface curves away at the same rate that the object falls – it goes into orbit.)

An object in orbit is pulled into a circular (or elliptical) path by the gravitational force between it and the object that it's orbiting. For example the gravitational force between the Moon and Earth keeps the Moon in orbit and the gravitational force between Earth and a satellite keeps the satellite orbiting Earth.