*Physics > Big idea PSL: Sound, light and waves > Topic PSL1: Sound and light*

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| **Key concept (age 11-14)** |
| **PSL1.2: Characteristics of light** |

**What’s the big idea?**

A big idea in physics is waves because it is the key to explaining how energy can be transferred from one object to another object by radiation, even when the objects are not touching. Waves carry information that can be detected by humans or manufactured detectors. Understanding waves helps us to communicate, explore the universe, and transfer energy to where we want it.

**How does this key concept develop understanding of the big idea?**

This key concept develops the big idea by building on the understanding that shadows are formed because light travels in a straight line, in order to help develop students’ understanding of how light travels away from a source and how it reflects off mirrors and rough surfaces.

****The conceptual progression starts by checking understanding of how light can form shadows. It then supports the development of a model which explains how light travels in order to enable understanding of how places are lit up and how light reflects off different types of surface.

**How can you use the progression toolkit to support student learning?**

Use diagnostic questions to identify quickly where your students are in their conceptual progression. Then decide how to best focus and sequence your teaching. Use further diagnostic questions and response activities to move student understanding forwards.

**Progression toolkit: Light movement**

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| **Learning focus** | Light travels in straight lines at very high speeds. | | | | |
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| **As students’ conceptual understanding progresses they can:** | **C o n c e p t u a l p r o g r e s s I o n** | | | | |
| Identify the shadow made by an object.  **P** | Describe how light travels in straight lines.  **P** | Explain how shadows are formed. | Explain how light from a bulb illuminates a place. | Explain why light gets dimmer farther from a light source. |
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| **Diagnostic questions** | A penguin’s shadow | Spotting light | Making a shadow | Lighting a room | Night vision |
| A tree’s shadow |
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| **Response**  **activities** |  | Laser shadow | Extra light shadow | Daylight |  |

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| Key: | | | |
| **P** | Prior understanding from earlier stages of learning | **B** | Bridge to later stages of learning |

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| **A penguin’s shadow** | **Spotting light** | **A tree’s shadow** | **Making a shadow** | **Lighting a room** |
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| Simple multiple choice | Simple multiple choice | Simple multiple choice | Simple multiple choice | Confidence grid |
| **Night vision** | **Laser shadow** | **Extra light shadow** | **Day light** |  |
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| Simple multiple choice | Clarifying - demonstration/modelling | Predict, explain, observe, explain | Talking heads |  |

**Progression toolkit: Light reflection**

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| **Learning focus** | Light is reflected from all surfaces, and off a flat mirror it is reflected in a single direction. | | | | |
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| **As students’ conceptual understanding progresses they can:** | **C o n c e p t u a l p r o g r e s s I o n** | | | | |
| Identify surfaces that reflect light.  **P** | Predict the direction in which flat mirrors reflect light. | Draw a ray diagram to show how light reflects off a flat mirror. | Accurately measure angles of incidence and angles of reflection. | Explain how light reflects off rough surfaces. |
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| **Diagnostic questions** | Reflecting light | Which way? | Angle of reflection | Measuring angles | Rough reflection |
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| **Response**  **activities** |  | Reflecting angles | | | Desert island rescue |

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| Key: | | | |
| **P** | Prior understanding from earlier stages of learning | **B** | Bridge to later stages of learning |

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| **Reflecting light** | **Which way?** | **Angle of reflection** | **Measuring angles** | **Rough reflection** |
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| Simple multiple choice | Simple multiple choice | Simple multiple choice | Simple multiple choice | Confidence grid |
| **Reflecting angles** | **Desert island rescue** |  |  |  |
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| Predict, explain, observe, explain | Talking heads |  |  |  |

**What’s the science story?**

*A general model of radiation*

Some objects can affect others at a distance by emitting radiation which travels from one object (the source) to another (the receiver), through the material or the space (the medium) between them. Light is an example of radiation.

Radiation travels out from a source in straight lines in all directions. When it strikes another object, it may go straight through (transmission), bounce off (scattering or reflection), or be stopped (absorption) – or a combination of these. When radiation is blocked by an opaque object, this causes a shadow region. The effects of radiation get steadily less the further it goes, because it is spread over an ever-increasing area, and because it may be gradually absorbed by the medium it is travelling through. When radiation is absorbed by an object, it has an effect on the object; this might be a chemical effect, an electrical effect or a heating effect.

*Some characteristics of light*

The speed of light is very much higher than sound, though it does travel at a finite speed.

When light hits a surface, some of it is usually reflected diffusely (scattered) in all directions. For surfaces which are very smooth (such as a mirror, shiny metal, or a water surface), an incident light beam of light is reflected as a beam, at the same angle as it hits the surface. This is known as specular reflection.

A light ray is an imaginary line that shows the direction in which light is travelling.

**What does the research say?**

Most 10 and 11 year olds think that light is found only in bright areas and not in the space between, for example, a source of light and the patch of light it makes (Guesne, 1985; Allen, 2014).

(Guesne, 1985) found many students aged 10-11 viewed shadows as a reproduction of an object’s shape. Young children confuse ‘shadow’ and ‘reflection’ and may draw faces on a shadow. Some may think a shadow is part of an object which is made visible by light. By age 14 Guesne found the majority of students recognised light as an entity and could use this notion to explain shadows in bright light. She also found that many did not think shadows formed when the light was less than bright.

In a study of 456 15-year-olds (Ramadas and Driver, 1989) found that many students thought light rays were not like ordinary light, but described them variously as long, thin or flashing. This was not helped by the fact that students could not see the path light takes in normal circumstances.

When students think of light, they do not necessarily think of it as travelling. They may instead think of rays as like ‘wires of light’ or roads going from A to B (Driver et al., 1994). Allen (2014) describes how a few students imagine that light moves from a candle, say, to fill a limited space and then stays still. They may think that the light does not travel as far as the dark corners of a room.

Stead and Osborne (1980) found that most students do not think of light travelling out very far from the source, particularly in day time. Perhaps because torches can be seen to illuminate and change the brightness of distant objects at night, but have no noticeable effect during the day. It has been found that about 40% of 13-15 year olds think that light travels different distances depending on whether it is night or day (Fethersonhough and Treagust, 1990).

When light reflects, Anderson and Smith (1986) found that, out of 125 ten and eleven year olds, about 60% described light bouncing off only mirrors and not off other opaque objects. Just 20% thought light did bounce off opaque objects, with only 2% suggesting it is scattered. Anderson and Smith also found that when light reflects off a mirror: just under half of the students correctly predicted that the angle it reflects at is the same as the angle it hits the mirror, 28% thought light reflected at a different angle and 7% that more than one ray is reflected.

Students following the national curriculum of England are likely to learn how to draw given angles, and measure them in degrees (o) when they are aged nine or ten (DFE, 2013).

The progression toolkit for *light movement* reminds students that shadows form because light travels in straight lines and is blocked by opaque objects. By predicting and observing how shadows form in new situations students are given the opportunity to consolidate this understanding. Their thinking is developed further by using these ideas about the movement of light to explain a variety of everyday experiences, that often reveal misunderstandings, in order to develop a general model of how light travels away from a source.

The progression toolkit for *light reflection* begins by reminding students that light reflects off all everyday objects. Through investigation students develop some practical skills and work out the law of reflection from their observations. By considering how light reflects off rough objects students are given the opportunity to see how the law of reflection can be applied to explain the seemingly unconnected phenomenon of diffuse reflection.

**Guidance notes**

Ideas about the nature of light are often taken for granted at this stage of school science. This is not helpful as it is common for students to have persisting misunderstandings that need to be addressed in order for them to develop a clear understanding of the refraction, diffraction and dispersion of light they will encounter in their future studies. For this reason the ideas covered in progression toolkit: *light movement* need careful consideration.

*Types of reflection*

Specular reflection is the reflection of a ray of light in one direction off a mirror surface. The term ‘specular’ originates from the Latin word *speculum* which means ‘mirror’.

Diffuse reflection is the scattering of a ray of light reflecting off a rough surface in many different directions. A rough surface can be thought of as many (imperfectly reflecting) mirrors, each tilted at a different angle to the others.

*‘Real’* mirrors

A household mirror is typically made from a piece of glass which is silvered on the back. A protective coating is painted over the silvering, which by itself is easily scratched and damaged.

If you touch the front of this type of mirror, you will see a strong reflection of your finger off the back of the mirror (from the silvering) and also a very faint reflection off the front of the mirror’s glass.

When a very high quality of reflection is necessary, in a telescope for example, the silvering is applied to the front of the mirror and there is only one reflection.

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