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OCR
Oxford Cambridge and RSA

GCSE (9–1)

Delivery Guide

TWENTY FIRST CENTURY SCIENCE PHYSICS B

J259

For first teaching in 2016

Radiation and waves

Version 1

www.ocr.org.uk/physics

Introduction

GCSE (9 –1)
TWENTY FIRST CENTURY SCIENCE PHYSICS B

Delivery guides are designed to represent a body of knowledge about teaching a particular topic and contain:

- Content: A clear outline of the content covered by the delivery guide;
- Thinking Conceptually: Expert guidance on the key concepts involved, common difficulties students may have, approaches to teaching that can help students understand these concepts and how this topic links conceptually to other areas of the subject;
- Thinking Contextually: A range of suggested teaching activities using a variety of themes so that different activities can be selected which best suit particular classes, learning styles or teaching approaches.

If you have any feedback on this Delivery Guide or suggestions for other resources you would like OCR to develop, please email resources.feedback@ocr.org.uk

QUALIFICATION AWAITING ACCREDITATION

'These draft qualifications have not yet been accredited by Ofqual. They are published (along with specimen assessment materials, summary brochures and sample resources) to enable teachers to have early sight of our proposed approach.

Further changes may be required and no assurance can be given at this time that the proposed qualifications will be made available in their current form, or that they will be accredited in time for first teaching in 2016 and first award in 2018.

Subtopic 3 – P1.3 How do waves behave?

Subtopic 4 – P1.4 What happens when light and sound meet different materials? (separate science only)

The images used throughout this guide have been provided to help aid learners' understanding and learning in this topic area.

A brief description is provided below each image.

Curriculum content

Subtopic 1 – P1.1 What are the risks and benefits of using radiations?

P1.1.1	describe the main groupings of the electromagnetic spectrum – radio, microwave, infrared, visible (red to violet), ultraviolet, X-rays and gamma rays, that these range from long to short wavelengths, from low to high frequencies, and from low to high energies
P1.1.2	recall that our eyes can only detect a very limited range of frequencies in the electromagnetic spectrum
P1.1.3	recall that all electromagnetic radiation is transmitted through space with the same very high (but finite) speed
P1.1.4	explain, with examples, that electromagnetic radiation transfers energy from source to absorber
P1.1.5	recall that different substances may absorb, transmit, or reflect electromagnetic radiation in ways that depend on wavelength
P1.1.6.	recall that in each atom its electrons are arranged at different distances from the nucleus, that such arrangements may change with absorption or emission of electromagnetic radiation, and that atoms can become ions by loss of outer electrons
P1.1.7	recall that changes in molecules, atoms and nuclei can generate and absorb radiations over a wide frequency range: Including a) gamma rays are emitted from the nuclei of atoms b) X-rays, ultraviolet and visible light are generated when electrons in atoms lose energy c) high energy ultraviolet, gamma rays and X-rays have enough energy to cause ionisation when absorbed by some atoms d) ultraviolet is absorbed by oxygen to produce ozone, which also absorbs ultraviolet, protecting life on Earth e) infrared is emitted and absorbed by molecules
P1.1.8	describe how ultra-violet radiation, X-rays and gamma rays can have hazardous effects, notably on human bodily tissues
P1.1.9	give examples of some practical uses of electromagnetic radiation in the radio, microwave, infrared, visible, ultraviolet, X-ray and gamma ray regions of the spectrum

P1.1.10 recall that radio waves can be produced by, or can themselves induce, oscillations in electrical circuits

This topic deals with the concept of radiation and its uses and implications. Learners will find out about the electromagnetic spectrum and the fact that the effect EM radiation has on a substance depends on its energy, which in turn depends upon its frequency/wavelength. The effects and characteristics of the different areas of the EM spectrum will be covered in some detail. The topic of absorption and emission of radiation by ordinary matter (including humans) will also be introduced.

The sun is the source of the overwhelming majority of EM radiation in Earth's atmosphere, even in the modern world. The green field might encourage speculation regarding both the life-giving and damaging effects of sunlight.

General approaches:

Learners will find that we are surrounded by radiation, and that it is both essential for life and damaging to it. It might be helpful to point out that the word 'radiation' is connected to the word 'radius' and that the inverse square law is connected to the formula for the area of the surface of a sphere (advanced learners only). Learners will also discover that radiation always transfers energy, and that the amount of energy determines the effect the radiation will have on matter. It is important to remember that physicists often use the word 'light' to refer to the whole EM spectrum; that visible light is only a small part of this spectrum. They will also see that warm objects, such as humans, emit infra-red radiation.

Common misconceptions or difficulties learners may have:

The idea that radiation is always harmful should be dealt with simply enough, but other concepts can be harder. When discussing light, care should be taken to ensure that learners are aware that light itself is not exactly either a particle or a wave; simply swapping between describing light as waves and particles can cause confusion. If learners have trouble with the idea of wave/particle duality, they can be reassured that the greatest minds in physics have also had trouble with this idea, and that it is one of the many puzzling characteristics of quantum theory.

As useful as the 'musical scale' analogy is, it should be pointed out that the way we perceive light and sound are very different, and that a combination of different frequencies are usually present when we see one colour, whereas a combination of different musical frequencies can be heard as a combination of different sounds.

It should also be pointed out that radioactivity and radiation are not the same thing. The electromagnetic radiation we are describing here has a spectrum that includes gamma radiation, but not alpha or beta, which will be dealt with in P5. Learners should also discover that things that are transparent to light are not necessarily transparent to all parts of the EM spectrum, and vice versa.

Conceptual links to other areas of the specification – useful ways to approach this topic to set learners up for topics later in the course:

Much of the information about the EM spectrum in this topic connects directly with P1.3, in which more details about the relationship between frequency, wavelength, speed and energy are given. This applies particularly to the activities in which white light is split into a spectrum, which depends on the principle of refraction. There will also be some crossover with C2.1, particularly when considering the effect of ionising radiation.

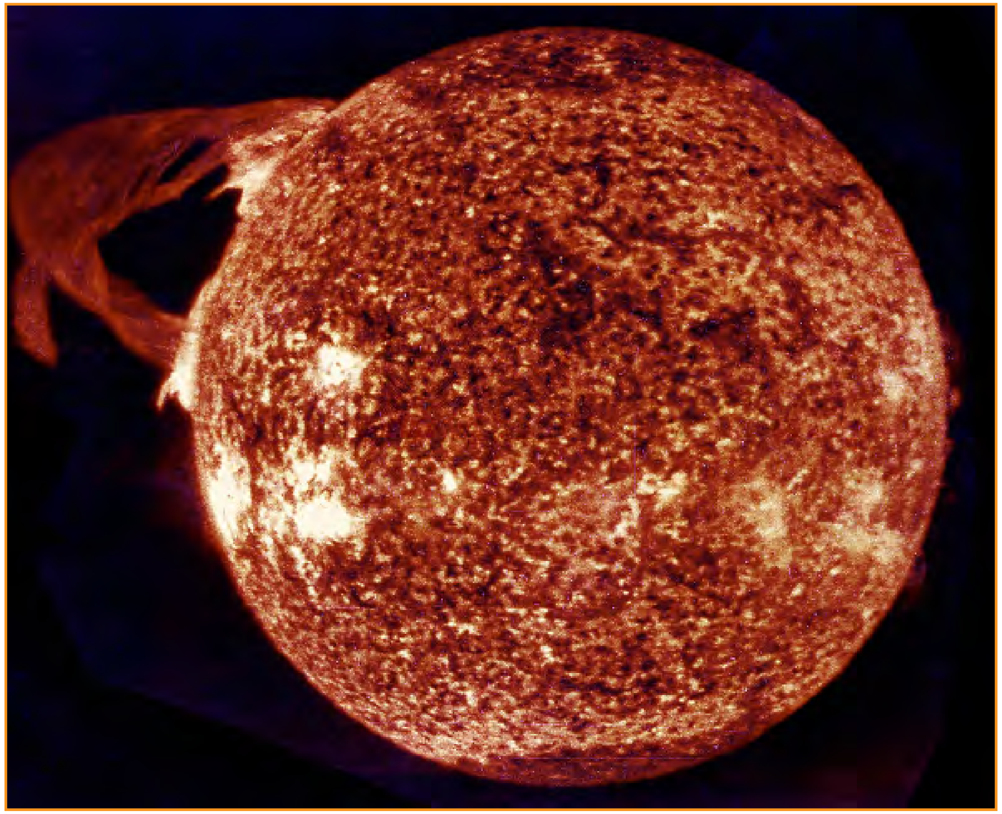
The question of how and why objects fluoresce, as mentioned in the 'Ultraviolet – an introduction' video may also provide a link to aspects of the chemistry course.

This reminds us that, in some cases, exactly the thing that is useful about a type of EM radiation can also be what is dangerous about it. In this case, the high energy required to pass through soft tissue also makes the radiation ionising, and therefore potentially harmful.

Approaches to teaching the content:

The activities involving infrared and ultraviolet light can be used to introduce learners to the idea that the EM spectrum does not consist of separate and distinct bands of radiation but is instead a continuum, and that, for instance, infrared is only quantitatively different from red except insofar as it is invisible to the human eye.

The fact that radiation is all around us at all times can be used as a springboard for learners to consider the various ways in which it affects us.



This picture could provide a helpful reminder that the sun gives off EM radiation at a variety of frequencies, many of which cannot be seen with the human eye and/or do not penetrate the Earth's atmosphere.

Activity 1

Herschel's Infrared Experiment

Caltech/NASA
http://coolcosmos.ipac.caltech.edu/cosmic_classroom/classroom_activities/herschel_experiment2.html

An outdoor version of Herschel's experiment showing the existence of the infrared part of the spectrum of sunlight.

This experiment obviously works best in strong sunlight. Experiments using artificial light may suffer from the fact that artificial lights have variable spectra. However, a normal incandescent bulb should radiate enough infrared for the experiment to work.

Activity 2

Ritter's Ultraviolet Experiment

Caltech/NASA
http://coolcosmos.ipac.caltech.edu/cosmic_classroom/classroom_activities/ritter_example.html

An outdoor experiment similar to the Herschel infrared experiment to demonstrate the ultraviolet part of the spectrum of sunlight. Again, this experiment works best in strong sunlight, and similar caveats apply when using artificial light.

Activity 3

The EM Spectrum

Bozeman Science - YouTube
https://www.youtube.com/watch?v=OzFU6XvzzgA

A video summarising the electromagnetic spectrum with a brief guide to the characteristics of each part. This contains a brief explanation of Herschel's infrared experiment, and so may be useful in conjunction with it.

Activity 4

The EM Spectrum – Interaction With Matter

Hyper Physics
http://hyperphysics.phy-astr.gsu.edu/hbase/mod3.html

A more detailed guide to the electromagnetic spectrum and its effects on matter. Potentially more use as a reference guide than the previous video.

Activity 5

Radiation In Medicine

NHS
http://www.nhs.uk/conditions/Radiation/Pages/Introduction.aspx

Medical information about the uses and dangers of various types of EM radiation. An NHS webpage, featuring simple and clearly presented information; this should be useful in discussing the potential dangers of radiation.

Activity 6

Radiation In Medicine

Harvard University
http://www.health.harvard.edu/newsletter_article/Radiation-in-medicine-a-double-edged-sword

More information about the medical uses and effects of EM radiation. Some learners may find this a touch dry, but it does contain specific information about radiation doses that may be useful.

Activity 7

Infrared Light Physics Experiments

AAPT films - YouTube
https://www.youtube.com/watch?v=iOVZBJ8CuZU

A video about infrared radiation and its characteristics. Some more about Herschel's experiment, followed by plenty of visuals to give learners an intuitive idea of how infrared is emitted by warm objects but behaves like normal visible light in other ways.

This video also contains an explanation of different frequencies of infrared.

Activity 8

Ultraviolet – An Introduction

Lammas School – YouTube
https://www.youtube.com/watch?v=5kEzooS7bKU

A video containing some additional information about ultraviolet light. This contains a cursory account of fluorescence, as well as a fairly standard 'educational'-style presentation of a digest of interesting aspects of ultraviolet radiation. The ending is rather abrupt.

Activity 9

Why Do Ultraviolet Levels Vary? Getting Sunburnt On A Cloudy Day

Clinuvel – YouTube
https://www.youtube.com/watch?v=oz9wfuYH91A

A commercial video explaining that UV exposure is not always greatest when it seems the sun is shining brightest. This video contains an interesting explanation of some of the more counterintuitive aspects of UV in the atmosphere.

Activity 10

Thermal Fart

YouTube
https://www.youtube.com/watch?v=md-cv2hyc8w

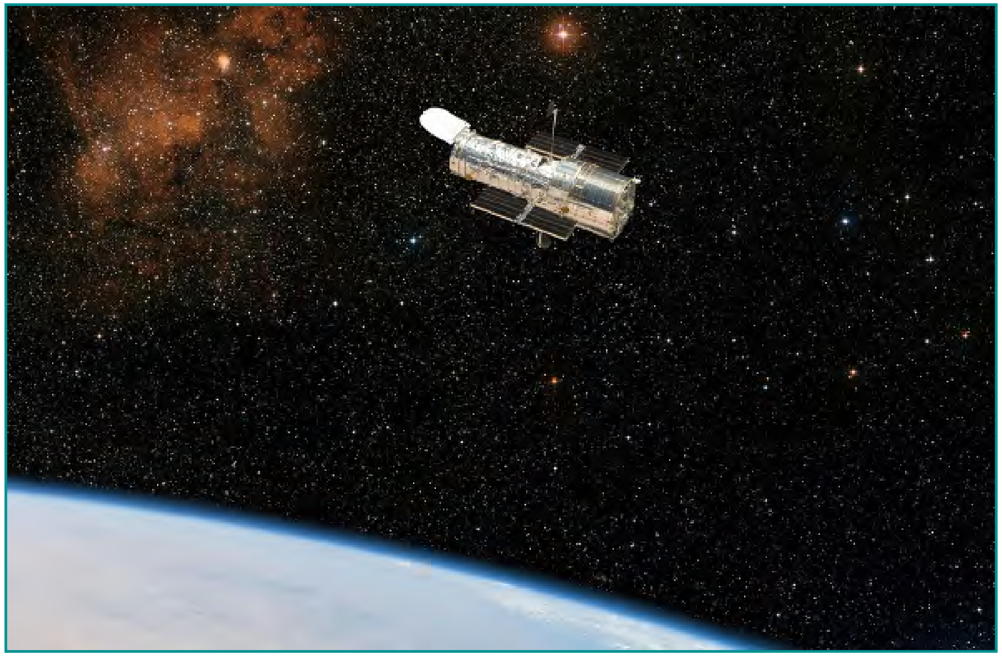
Thermal fart – a short video showing a fart as seen through a thermal imaging (infrared) camera. Short, simple comic relief.

Activity 11

Create a mnemonic for the names of the regions of the EM spectrum

Learner Resource 1

The electromagnetic spectrum is divided by scientists into bands according to characteristics of radiation at different frequencies. This activity gives learners the chance to try to come up with their own mnemonic (memory aid) to help them remember the order.



In order to see more of the light of objects in the sky, the Hubble telescope needs to be outside the Earth's atmosphere, which is opaque to many frequencies/wavelengths.

P1.2.1	explain that all bodies emit radiation, and that the intensity and wavelength distribution of any emission depends on their temperatures
P1.2.2	**explain how the temperature of a body is related to the balance between incoming radiation, absorbed radiation and radiation emitted; illustrate this balance, using everyday examples including examples of factors which determine the temperature of the Earth**

Learners will address the issues facing climate scientists in assessing what phenomena affect climate. They will learn that the planet and the atmosphere absorb and reflect different frequencies of radiation to different degrees, and that the balance between these processes determines atmospheric conditions to a great extent. They will be introduced to some of the ways climate scientists gather data and model climates, including methods of discounting non-anthropogenic factors, such as solar activity and variations in the Earth's orbit, when assessing the degree to which human activity affects climate.

The Earth's climate, seen from a distance, resembles many turbulent dynamic fluid systems.

General approaches:

It is extremely difficult to collect evidence for long-term global climate activity in a classroom. Thus, activities within this topic will focus on how scientists assess data collected elsewhere, and on assessing the accuracy of various different models and predictions. Thus, this topic is mostly concerned with assessing data gathered in a variety of ways and the collation thereof by climate scientists.

Common misconceptions or difficulties learners may have:

Talking to laypeople, the idea that there is some controversy within the scientific community over the extent to which human activity contributes to climate change seems to come up a lot. Without coming across as politically motivated or 'preachy', it is necessary to dispel this illusion.

Also, the difference between weather – local and short-term changes – and climate must be emphasised, and the notion that scientists have failed to take account of non-anthropogenic sources of climate change must also be dealt with clearly.

Conceptual links to other areas of the specification – useful ways to approach this topic to set learners up for topics later in the course:

This topic connects not only with others taught in science (specifically C1.3, B3.4 and B6.3), but also with subjects such as geography and politics. In addition, ideas used in this topic will connect directly with IaS topics, since much of the evidence we will be considering is based on techniques that learners will not yet have mastered, some care must be taken not to oversimplify the subject to the point of inaccuracy.

An example of the reality of the atmospheric effects of human activity.

Approaches to teaching the content:

This is a difficult topic to teach in a 'hands-on' way, owing to the difficulty of extrapolating local and short-term observations to long-term trends. The main focus of activities is on assessing data already gathered and the reliability of models. While learners should, as always, be encouraged to draw their own conclusions, this topic can be used to explore the idea of how we make decisions based on ideas we cannot personally verify with experiment.

Potentially useful when discussing ways of reducing carbon emissions.

Activity 1

An Experimental model to understand temperature regulation

Carboeurope
http://www.carboeurope.org/education/CS_Materials/AnExperimental Model.pdf

An open-ended experimental framework to enable learners to visualise what happens when different layers of reflection and absorption intermediate between a surface and a radiation source.

Since the long version of this experiment can take a long time, it is perhaps advisable to set up several versions of the experiment instead of varying conditions in just the one experimental setup. It should be stressed that this is merely a model, and not in itself evidence of anthropogenic climate change.

Activity 2

The Very Very Simple Climate Model

UCAR
http://scied.ucar.edu/simple-climate-model

An interactive resource which projects temperature change over time based on CO_2 emissions.

Have fun scaring learners by showing them that even keeping CO_2 emissions at current levels will continue to increase atmospheric temperature at an alarming rate.

Activity 3

Causes Of Climate Change

EPA
http://www3.epa.gov/climatechange/science/causes.html

A web page containing several infographics concerning climate change and scientific understanding.

A slightly dry page, this has some useful infographics concerning several climatic mechanisms; this helps explain just how many factors are taken into account when devising climate models.

Activity 4

What's Really Warming The World?

Bloomberg
http://www.bloomberg.com/graphics/2015-whats-warming-the-world/

A web page containing an infographic that superimposes data on non-anthropogenic sources of climate change one by one on temperature records before combining data to show how the correlation between CO_2 emissions and temperature is by far the strongest.

A somewhat clearer exposition of the reasons behind the conclusion that climate change is man-made.

Activity 5

How Do Greenhouse Gases Actually Work?

MinuteEarth – YouTube
https://www.youtube.com/watch?v=sTvqIijqvTg

A video containing a brief explanation of the way greenhouse gases create the greenhouse effect. More advanced learners may enjoy the hints of chemistry and subatomic physics contained in this video.

Activity 6

History of atmospheric CO_2 levels

Carbontracker - YouTube
https://www.youtube.com/watch?v=t0dXjmoA0dw

A video showing atmospheric CO_2 levels over time with information about data sources. More ways to scare learners with the incredibly short timescale over which recent climatic changes have occurred when compared with historical data.

Activity 7

Antarctic cooling, global warming

Realclimate
http://www.realclimate.org/index.php/archives/2004/12/antarctic-cooling-global-warming/

A web article about recent cooling of the Antarctic, with possible explanations. An interesting aside, providing valuable insight into how the effects of climate change are not always uniform or predictable.

Activity 8

History Of Climate Science (Extract)

Edinburgh University
http://demo.climate.ed.ac.uk/demo-04.php

A page containing a short extract from a lecture on climate science, with an infographic about factors affecting climate regulation. Some learners may enjoy the knowledge that they are watching a University lecture and not feeling out of their depth.

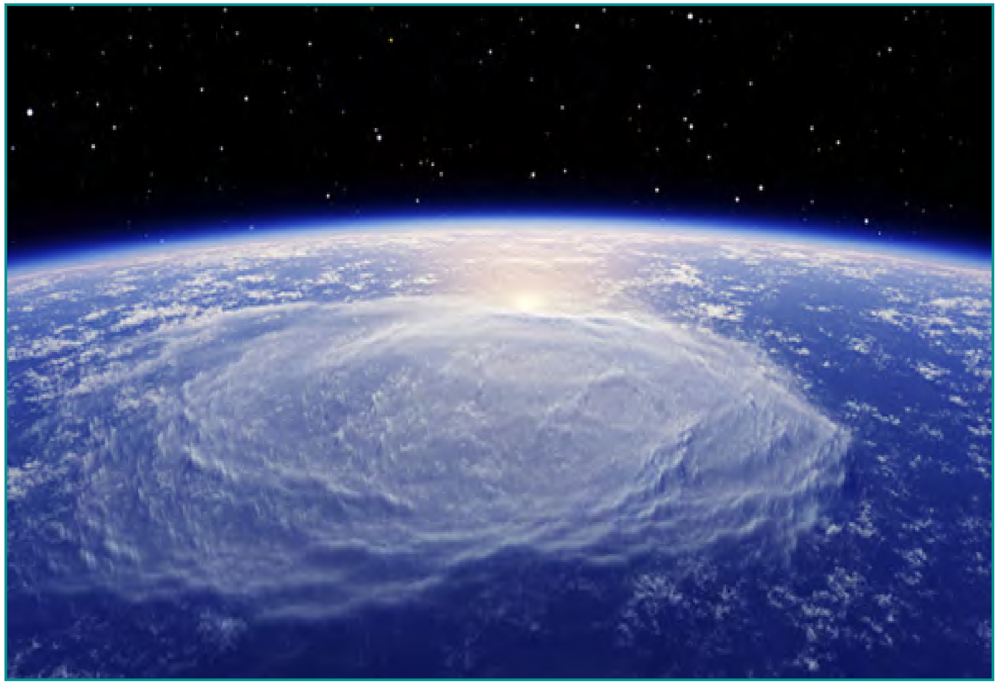
Activity 9

Climate Challenge

BBC
http://www.bbc.co.uk/sn/hottopics/climatechange/climate_challenge/

A web-based Flash game in which you play the President of Europe (!) and have to make various political and economic decisions affecting CO_2 emissions.

This is quite a time-consuming and complicated game, but its very complexity might help learners understand the difficulty politicians face when making decisions on environmental issues.



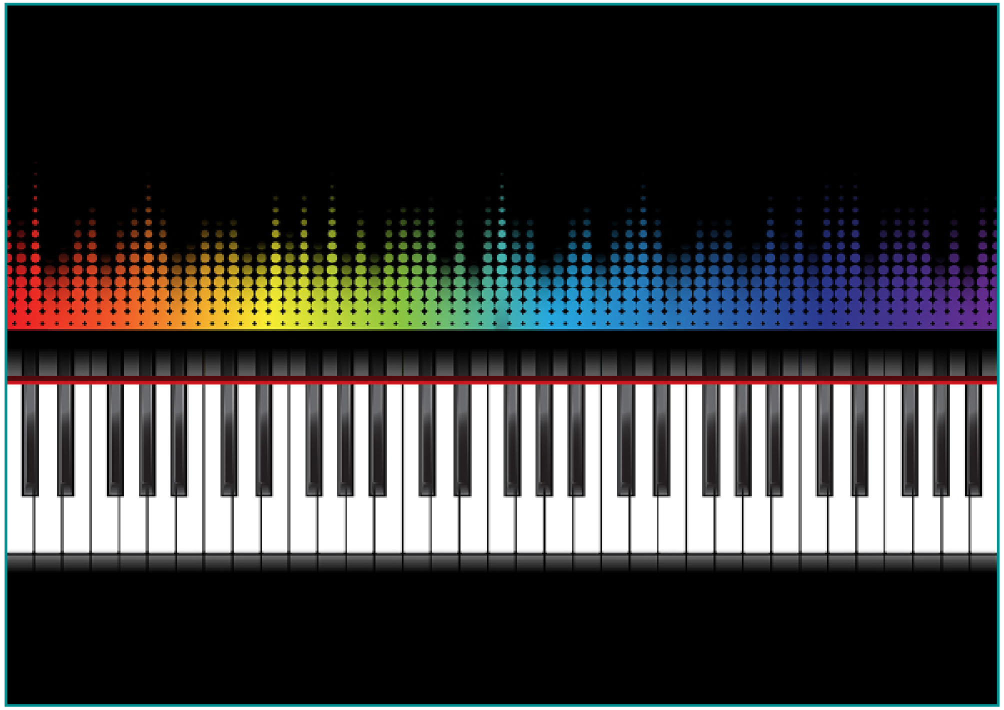
Seeing the sun's light visibly reflecting off the Earth can help learners visualise the global system in terms of reflection and absorption.

Curriculum content

Subtopic 3 – P1.3 How do waves behave?

P1.3.1	describe wave motion in terms of amplitude, wavelength, frequency and period
P1.3.2	describe evidence that for both ripples on water surfaces and sound waves it is the wave and not the water or air itself that travels
P1.3.3	describe the difference between transverse and longitudinal waves
P1.3.4	describe how waves on a rope are an example of transverse waves whilst sound waves in air are longitudinal waves
P1.3.5	define wavelength and frequency
P1.3.6.	recall and apply the relationship between speed, frequency and wavelength to waves , including waves on water, sound waves and across the electromagnetic spectrum: wave speed (m/s) = frequency (Hz) x wavelength (m)
P1.3.7	a) describe how the speed of ripples on water surfaces and the speed of sound waves may be measured b) describe how to use a ripple tank to measure the speed/frequency and wavelength of a wave PAG4
P1.3.8	a) describe the effects of reflection and refraction of waves at material interfaces b) describe how to measure the refraction of light through a prism PAG8 c) describe how to investigate the reflection of light off a plane mirror PAG8
P1.3.9	**recall that waves travel in different substances at different speeds and that these speeds may vary with wavelength**
P1.3.10	**explain how refraction is related to differences in the speed of the waves in different substances**
P1.3.11	recall that light is an electromagnetic wave
P1.3.12	recall that electromagnetic waves are transverse

Learners should already be familiar with the basic concept of a wave; this topic will introduce them to reflection, refraction, diffraction and absorption in both mechanical and electromagnetic waves. It will also approach the evidence which originally led scientists to deduce that light was a wave. Learners should also be aware of the equations governing all waves: wave speed (m/s) = frequency (Hz) x wavelength (m), and the important difference between mechanical waves, which require a medium to travel through, and electromagnetic waves, which do not.



The frequencies of the notes on the keyboard and the frequencies of light both increase from left to right.

General approaches:

It is simple enough to demonstrate reflection, refraction and diffraction with light and water waves; less so with sound. Diffraction of sound is especially hard to demonstrate without specialist equipment, and can be left out of experimental examples if necessary.

Common misconceptions or difficulties learners may have:

Confusions often arise around the idea of increasing frequency/decreasing wavelength, and about the difference between frequency and speed. It should also be pointed out that, since mechanical waves require a medium to travel through, they always lose energy as they travel, whereas electromagnetic waves do not.

It might be worth emphasising that, while increasing energy can increase the amplitude and/or frequency of a wave, its speed of propagation depends on the medium through which it is travelling; in the case of EM waves, no medium is necessary, but of course if a medium is present, this affects the speed. Learners may question the use of the speed of light in a vacuum when discussing light in air; it should be simple enough to explain that the difference in speed due to air is small enough to be negligible.

Conceptual links to other areas of the specification – useful ways to approach this topic to set learners up for topics later in the course:

Much of the subject matter in this topic has been introduced to some extent in previous P1 topics; knowledge of the fact that EM radiation can be reflected and absorbed is essential to understanding both P1.1 and P1.2. In addition, ideas explored in P3.4, P4 and P6 are introduced to some extent. It might be useful for more advanced learners to consider how the wave model and the particle model differs from the wave model in terms of explaining and describing the transfer of energy.

Interference is one of the distinctive behaviours of waves that lead scientists to deduce the wave nature of light when it was exhibited. Learners may wish to connect such a simple image with the explanations for wave behaviour that they have seen elsewhere.

Approaches to teaching the content:

It is useful to provide as many examples of the same behaviour in different types of wave as possible; the more media that can be used to show the same behaviours occurring, the better. The important thing to communicate about waves is that periodic oscillations can occur in a variety of contexts and for many different reasons, and that these oscillations can propagate in a variety of ways. Thus, comparisons between light, sound, water and other waves should be made whenever possible.

This image can be related to many areas of the curriculum, particularly in comparison with 1.1 – the damage that energetic waves do can be cumulative and cause greater damage in the long term than it would appear.

Activity 1

Young's fringes with sound

Nuffield Foundation
http://www.nuffieldfoundation.org/practical-physics/youngs-fringes-sound-waves

A demonstration of interference fringes in sound waves. Sound is arguably the hardest medium in which to demonstrate some of these principles; this experiment should be reasonably convincing.

Activity 2

Simple Wave Simulator

The Physics Classroom
http://www.physicsclassroom.com/Physics-Interactives/Waves-and-Sound/Simple-Wave-Simulator/Simple-Wave-Simulator-Interactive

A simple online wave simulator, allowing learners to observe the visible effect of altering a wave's frequency, speed and amplitude. A potentially useful aide-memoire when thinking about the potentially confusing array of terms used to describe waves.

Activity 3

What is a wave?

Aspire Lab
http://www.pbslearningmedia.org/resource/lsps07.sci.phys.energy.waves/what-is-a-wave/

A web page containing interactive demonstrations of wave behaviour. Particularly useful in that the interactive graphic allows both transverse and longitudinal waves to be created, and also provides an intuitive explanation of the relationship between density and propagation speed in mechanical waves.

Activity 4

Measure the speed of sound

Instructables
http://www.instructables.com/id/How-to-measure-the-speed-of-sound-with-two-lumps-o/?ALLSTEPS

A simple activity in which learners measure the speed of sound using an echo. Variations on this experiment include measuring the speed of sound under different conditions (temperature, humidity, etc.).

Activity 5

Measure the speed of light with chocolate

Laser classroom
http://laserclassroom.com/measure-speed-light-chocolate/

An experiment in which learners measure the speed of light using a microwave oven. As well as giving learners the opportunity to investigate a phenomenon they might expect to be impossible without specialist equipment, this provides a handy reminder that microwaves and light are both electromagnetic waves and therefore move at the same speed.

Activity 6

Wave machine demonstration

National STEM centre - YouTube
https://www.youtube.com/watch?v=VE520z_ugcU

A wave machine made from wooden skewers, duct tape and jelly babies. Simple enough to build in the classroom, this also involves sweets, although non-edibles can be substituted if necessary.

Activity 7

Virtual keyboard with frequency display and oscilloscope

PCCL

http://www.physics-chemistry-interactive-flash-animation.com/electricity_electromagnetism_interactive/oscilloscope_description_tutorial_sounds_frequency.htm

A simple online virtual musical keyboard which displays frequency as it plays notes, and displays the audible wave on a virtual oscilloscope. The relationship between audible pitch and frequency. It should also be mentioned that the frequency of the wave is unaffected by its speed of propagation.

Activity 8

Waves using trolleys

Nuffield Foundation

http://www.nuffieldfoundation.org/practical-physics/waves-trolleys

A demonstration of transverse and longitudinal waves using trolleys. Another simple classroom experiment, this also has the advantage of demonstrating both longitudinal and transverse waves.

Activity 9

The Mantis Shrimp – most complex eyes in the animal kingdom

YouTube

https://www.youtube.com/watch?v=glOsvm9t7ec

A short video about an animal that can see infrared, ultraviolet and two types of polarised light.

When we describe light as a transverse wave, it can be difficult for learners to visualise (excuse the pun) what this means, because our eyes cannot detect polarisation. This video gives a relatively simple introduction to the idea, as well as potentially informing discussion about what happens when we see colour.

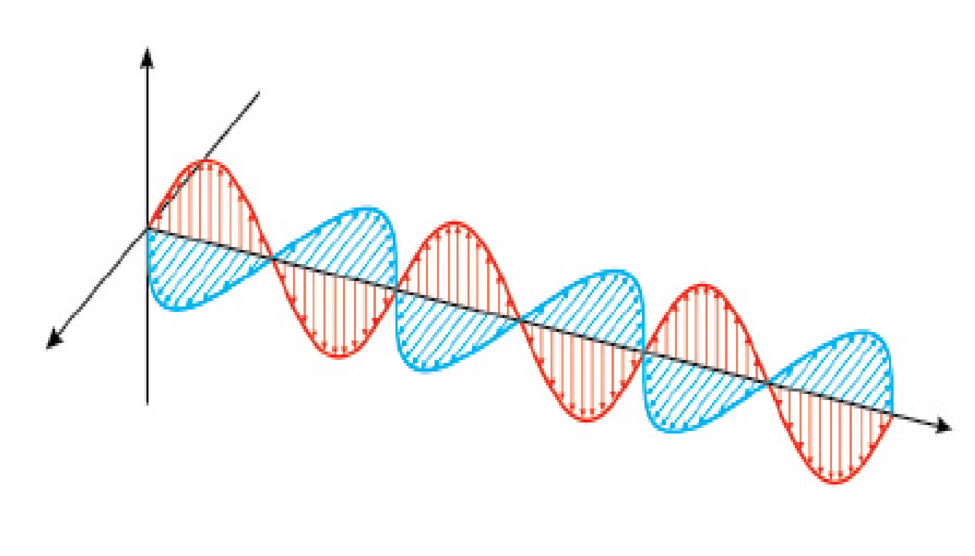
Activity 10

Estimating wavelength, frequency and velocity of ripples

Nuffield Foundation

http://www.nuffieldfoundation.org/practical-physics/estimating-wavelength-frequency-and-velocity-ripples

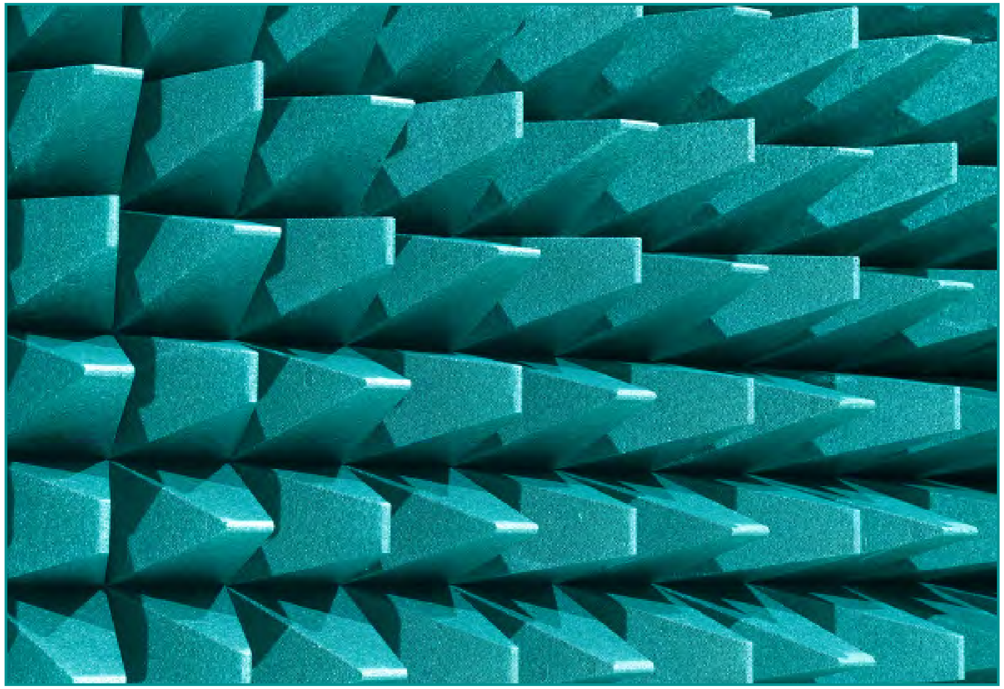
A ripple tank experiment in which learners measure wave properties and observe the relationships between them. If the teacher is feeling adventurous, this activity could be used to provoke learners to work out the relationship between frequency, wavelength and propagation speed of waves for themselves.



More advanced learners might be pleased to know exactly what is meant by the term 'light is a transverse wave'; polarisation is of course invisible to the human eye, at least directly.

P1.4.1	construct and interpret two-dimensional ray diagrams to illustrate specular reflection by mirrors qualitative only
P1.4.2	construct and interpret two-dimensional ray diagrams to illustrate refraction at a plane surface and dispersion by a prism qualitative only
P1.4.3	use ray diagrams to illustrate the similarities and differences between convex and concave lenses qualitative only
P1.4.4	describe the effects of transmission, and absorption of waves at material interfaces
P1.4.5	explain how colour is related to differential absorption, transmission, and scattering
P1.4.6.	**describe, with examples, processes in which sound waves are transmitted though solids**
P1.4.7	**explain that transmission of sound through the bones in the ear works over a limited frequency range, and the relevance of this to human hearing**
P1.4.8	**explain, in qualitative terms, how the differences in velocity, absorption and reflection between different types of waves in solids and liquids can be used both for detection and for exploration of structures which are hidden from direct observation, notably** **a) in our bodies (ultrasound imaging)** **b) in the Earth (earthquake waves)** **c) in deep water. (SONAR)**
P1.4.9	show how changes, in speed, frequency and wavelength, in transmission of sound waves from one medium to another, are inter-related M1c, M3c

Reflection and absorption have already been mentioned in P1.1 and P1.2; this topic introduces refraction and diffraction, as well as exploring the behaviour of materials that react differently to different frequencies of light and sound. In much the same way as we saw that the atmosphere transmits, reflects and absorbs various frequencies within the electromagnetic spectrum, coloured objects reflect, transmit and absorb different frequencies of visible light.



A combination of absorption and diffuse reflection are used to minimise audible reverberation in sound.

General approaches:

Although light and sound are in many ways different, their similarities are emphasised when we consider them as waves, and observe the fact that much of the light and sound we perceive is mediated by the processes of reflection, refraction, diffraction and so on. The clichéd question "why is the sky blue?", for instance, can be seen to be a correlate of the question of why the sun appears yellow when its light is described as white.

Common misconceptions or difficulties learners may have:

When discussing refraction of light, learners can easily get the impression that all waves slow down as media become more dense; of course, while this is technically true, the stiffness of most dense materials more than compensates for the slowing effect, and sound is usually faster in denser materials as a result. It is also useful to emphasise that mechanical waves, such as sound, only exist when there is a material for them to interact with; they are defined as emergent features of the media through which they travel, whereas electromagnetic waves exist regardless of medium (as far as science is currently aware!).

Difficulties can arise when considering colour; a small amount of information about how we perceive colour is necessary when considering, for instance, how a computer screen can display a picture of a spectrum using only three different colours of light. This will also help clear up misunderstandings about the difference between additive and subtractive colour mixing: why computers use red, green and blue light sources while printers use cyan, magenta and yellow ink, and so on.

Conceptual links to other areas of the specification – useful ways to approach this topic to set learners up for topics later in the course:

The relationship between the small-scale structure of substances and their acoustic and optical properties connects to a great extent with areas of the Chemistry syllabus; the reflection, absorption and transmission of energy can be related to the atomic structure of substances, and question of why many metals and crystals are specular reflectors can provoke interesting discussions.

The atmosphere reflects and refracts sunlight. Learners can have fun discussing possible reasons why the second rainbow has the colours going in the opposite direction.

Approaches to teaching the content:

Since the interactions of light and sound with matter are at the root of the way we use hearing and vision to perceive the world, there is no shortage of opportunity for application of the principles discussed in this topic in learners' experience of life. Learners should be encouraged to investigate the properties of different materials and environments and ask how the interaction of energy in the form of waves and matter affect our perception in general. Questions such as "why are gyms noisier than bedrooms?"can encourage learners to apply the ideas in this topic in all sorts of areas. In many ways, this is one of the topics most amenable to consideration in a variety of contexts; questions about the behaviour of light and sound in general can be encouraged with little fear of the explanation being too advanced, unless, of course, learners are particularly interested in wave/particle duality.

Ordinary objects and materials can interact with waves in unexpected ways.

Activity 1

Direction of bending

The Physics Classroom
http://www.physicsclassroom.com/class/refrn/Lesson-1/The-Direction-of-Bending

A page of explanations and analogies designed to help remind learners how waves will refract in different media. A fairly comprehensive catalogue of analogies, which includes links to interactive resources near the bottom of the page.

Activity 2

Newton's prism experiments

Creative Science Centre
http://www.creative-science.org.uk/prism.html

A version of Newton's experiments with prisms that demonstrate with refraction the hypothesis that white light contains a mixture of different colours. Perhaps useful to relate to Herschel's infrared experiment and others mentioned in 1.1.

Activity 3

Refraction interactive

Physics classroom
http://www.physicsclassroom.com/Physics-Interactives/Refraction-and-Lenses/Refraction/Refraction-Interactive

An interactive tool simulating refraction and reflection of light in different media. Learners can use this to predict how light will behave in different physical media and check the results against experimental data.

Activity 4

Experiments in refraction, reflection and total internal reflection

George Panagiotakopoulos - YouTube
https://www.youtube.com/watch?v=gDA_nDXM-ck

A video featuring refraction, reflection and total internal reflection of light in different media. Not particularly HD, but a bit of fun; the point that transparent materials are visible largely because of their reflective and refractive properties is made implicitly.

Activity 5

Speed of sound in different media

We are showboat - YouTube
https://www.youtube.com/watch?v=-ANOqBvPI90

A video explaining the relationship between a medium's physical properties and the speed of sound within it. While the laws described may be beyond GCSE level, the concepts involved should be easy enough for learners to understand; this may help them avoid confusion when describing refraction in sound.

Activity 6

Wave diffraction

Salford University
http://www.acoustics.salford.ac.uk/feschools/waves/diffract3.php

A web page containing several interactive animations showing principles of diffraction, as well as a two-slit experiment. A helpful introduction to the more difficult concept of diffraction, which can seem counterintuitive.

Activity 7

Refraction of sound

The point studios - YouTube
https://www.youtube.com/watch?v=LkFQg1zhi2o

A short video about refraction of sound in warm and cold air. Most people do not realise the extent to which the behaviour of sound is affected by changes in the medium, even when that medium is air and the behaviour of light is not noticeably affected.

Activity 8

Specular and diffuse reflection

Science Primer
http://scienceprimer.com/specular-diffuse-reflection

A web page containing an interactive graphic to help visualise the difference between specular and diffuse reflection.

Ask learners which is more reflective: a white sheet of paper or a mirror. Many will assume that it's the mirror. This explains why you can't see your reflection in paper. You could also add that the texture of specular and diffuse reflectors can usually be distinguished with the sense of touch.

Activity 9

Light absorption, reflection and transmission

Bozeman physics - YouTube
https://www.youtube.com/watch?v=DOsro2kGjGc

A video illustrating how colour relates to transmission, reflection and absorption of light, using gummy bears. Learners can become confused about the difference between the colours reflected by an object and those absorbed by it. Red objects, for instance, do not necessarily block green light.

Activity 10

The wikidrummer

Touché Videoproduktion Creative - YouTube
https://www.youtube.com/watch?v=mY-f68J5PPo

A video in which a drummer plays in a variety of acoustic environments, illustrating the effect of reflected sound. Reflected sound is often perceived unconsciously; this video helps show just how much of a difference it can make to what we hear.

Learners can speculate as to what is making the sound: the glass? The water? The air in the glasses?

The small print

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Telephone 01223 553998
Facsimile 01223 552627
Email general.qualifications@ocr.org.uk