Pages 234−235 in the Student Book provide an introduction to this module.

When and how to use these pages
These pages summarise what students should already know from KS3 or previous GCSE units and provide an overview of the content that they will learn in this module.

- Use these pages as a revision lesson before you start the first new topic.
- Brainstorm everything that students remember about the different topics using the headings as a starting point. Compare your list with the points on page 234.
- Use the questions on page 234 as a starting point for class discussions.
- Ask students if they can tell you anything about the topics on the right-hand page.
- Make a note of any unfamiliar / difficult terms and return to these in the relevant lessons.

Suitable answers to the questions on page 234 are:

- Light travels in straight lines; much faster than sound (at 300 million m/s in space); can be reflected and refracted,
- It increases.

You could revisit these pages at the following points:

- before lesson p2_06 on ozone, Student Book pages 246−247
- before lesson p2_10 on communicating using electromagnetic waves, Student Book pages 254−255

Overview of module
This module covers work on the electromagnetic spectrum, ionising radiation, waves and communication.

The first five lessons introduce members of the electromagnetic spectrum, link radiation intensity with the photon model of light and introduce the concept of ionisation and the risks from electromagnetic waves.

The module goes on to discuss ozone, the greenhouse effect, carbon cycling and global warming – their causes and their impact on our lives.

The final lessons of the module are about the use of electromagnetic waves for communication, in particular the transmission and storage of digital signals.

Obstacles to learning
There is a lot of specialist vocabulary for students to learn in this module. In particular, students may need extra guidance with the following terms and concepts.

**Electromagnetic waves and photons**
Most electromagnetic waves are invisible, and are detected indirectly by their effects on other objects, which can be confusing. The concept of photons is challenging because it is a description of energy transfer and students cannot relate photons directly to their own experiences. They will be used to thinking of light as a wave – the photon model will be unfamiliar. There is a challenge in starting to visualise massless packets of energy.

**Ionisation**
The process of ionisation cannot be detected directly, and only takes place under certain circumstances. Students may confuse the process and the effects of ionisation with other effects caused when electromagnetic radiation is absorbed (such as heating).

**Microwaves**
Microwaves cannot be seen directly but are detected by their heating effect when absorbed, which can confuse students.

**Risks**
Many students already have preconceptions about risks in everyday life, which may not match the measured risks. They may not recognise that while some activities are inherently more dangerous than others, if risks are well controlled fewer mishaps may occur.
Gamma rays and X-rays
Gamma rays and X-rays are detected only by their effects, and are not part of everyday experiences.

Ozone
Students may be confused that ozone has harmful effects at ground level, but beneficial effects in the outer atmosphere. Its effects cannot be detected directly easily.

The greenhouse effect and global warming
Many familiar analogies of the greenhouse effect do not represent the physical effects taking place. The process is not the same as that which happens in a greenhouse where there is a physical barrier, and clouds do not act 'like a blanket' as is often stated.

Showing the greenhouse effect using a lamp shining on a bottle and measuring the temperature increase inside it can also lead to misconceptions, although this practical is widely described elsewhere. A different demonstration is suggested in this module.

Students may confuse the carbon cycle with a carbon dioxide cycle – they need to realise that the carbon atoms in coal are the same as the carbon atoms in wood and in the atmosphere. Some processes involve the whole Earth while others are microscopic in scale.

Students tend to confuse global warming, greenhouse effect and ozone layer depletion.
There is a lot of very good information available on global warming, but also some very dodgy opinions and information so students need to be sure that their sources are not biased or inaccurate.

Students may make definite statements that are better phrased as possibilities or probabilities.

Correlation and causation
Students often assume that correlation and causation are the same.

Electromagnetic waves for communication
Signals carried by electromagnetic waves are not always detected directly but are converted into electrical energy and then into different forms such as sound, light or electronic data. Signals can be sent locally, across the world or into space, which students find hard to comprehend.

Digital communications
Generally, physical quantities are analogue; it is the equipment that converts and transmits data in digital form.

Practicals in this module
In this module students will do the following practical work:
- Investigating mobile phone signals
- Investigating the effectiveness of sunscreens
- Modelling the warming and cooling of the Earth and the Moon
- Planning an investigation into the best material to absorb infrared signals
- Comparing analogue and digital equipment
- Comparing analogue and digital sound recordings and image processing and how these are affected by noise
- Investigating sound-editing software

Key vocabulary covered in this module
- electromagnetic radiation • transmit • transparent • absorb • translucent • reflect • vacuum • electromagnetic spectrum • photon
- solar cells • intensity • photons
- electron • atom • molecule • ion • ionisation • ionising radiation • mutation
- gamma rays • radioactive • X-rays • radiographer
- absorb • microwave • sample • bias
- ozone
- atmosphere • greenhouse effect • principal frequency • methane
- photosynthesis • respiration • fossil fuels • deforestation • correlation
- global warming • convection • hypothesis • computer model
- optical fibre • carrier wave • modulated • signal • analogue broadcasting • analogue signal
- digital signal • analogue signal • pulse • decode • noise
- binary digit • byte • pixel • resolution
P2 Module Checklist

Pages 262–263 in the Student Book provide a student-friendly checklist for revision.

When and how to use these pages

This checklist is presented in three columns showing progression, based on the grading criteria. **Bold italic** means Higher tier only.

Remind students that they need to be able to use these ideas in various ways, such as:
- interpreting pictures, diagrams and graphs
- applying ideas to new situations
- explaining ethical implications
- suggesting some benefits and risks to society
- drawing conclusions from evidence they have been given.

These pages can be used for individual or class revision using any combination of the suggestions below.
- Ask students to construct a mind map linking the points on this checklist.
- Work through the checklist as a class and note the points that need further class discussion.
- Ask students to tick the boxes on the checklist worksheet (on the Teacher Pack CD) if they feel confident that they are well prepared for the topics. Students should refer back to the relevant Student Book pages to revise the points that they feel less confident about.
- Ask students to use the search terms at the foot of the relevant Student Book pages to do further research on the different points in the checklist.
- Students could work in pairs and ask each other what points they think they can do, and why they think that they can do those and not others.
Module summary
In the introduction to this module, students were presented with a number of new ideas. Work through the list below as part of their revision. Ask students to write their own summaries and mind maps, using this list as a starting point.

Electromagnetic radiation
- Electromagnetic waves of different frequencies make up the electromagnetic spectrum
- The energy of electromagnetic radiation is transferred in ‘packets’ called photons
- The intensity of a beam of electromagnetic radiation depends on the number of photons making up the beam and on the amount of energy each photon transfers
- The higher the amount of energy of a photon, the higher the frequency of the radiation

Ionisation
- Ionising radiation has enough photon energy to knock an electron out of an atom or molecule when a photon is absorbed
- Gamma rays, X-rays and high-frequency ultraviolet radiation can cause ionisation

Absorption of radiation
- All radiation causes heating when absorbed
- Microwave radiation is strongly absorbed by water and the heating effect may present a risk to living cells
- Radio waves, infrared radiation, visible light and low-frequency ultraviolet radiation cannot cause ionisation when absorbed
- Ultraviolet radiation is absorbed by the ozone in the atmosphere, and by sunscreen applied to skin

Health risks
- There is no clear evidence of harm caused by microwave exposure during mobile phone use
- Exposure to excess ultraviolet radiation can cause sunburn and can lead to skin cancer and eye damage
- Exposure to ionising radiation, especially gamma rays, can damage body cells — and if DNA is affected, cancer can result

The greenhouse effect
- Greenhouse gases such as carbon dioxide in the atmosphere absorb infrared radiation from the Earth and re-radiate it back to Earth
- The amount of carbon dioxide in the atmosphere was kept constant by the natural carbon cycle
- For the last 200 years or so the amount of carbon dioxide in the atmosphere has been steadily increasing
- Increased levels of greenhouse gases is causing global warming, because of the greenhouse effect
- Global warming may result in climate change, melting of ice sheets, raised sea levels, flooding and severe weather

Using electromagnetic waves for communication
- Radio waves, microwaves, infrared radiation and visible light can be used to send information from place to place
- In analogue transmission, the information signal is added to a carrier wave by ‘modulation’, and it can take any value
- In digital transmission, the signal is coded as a series of on (1) and off (0) pulses, which is decoded at the receiver
- Digital signals suffer much less from ‘noise’, and can be directly stored or processed by computers
Checklist P2  Aiming for A

Use these checklists to see what you can do now. Refer back to the relevant topic in your Student Book if you are not sure. Look across the rows to see how you could progress – **bold italic** means Higher Tier only.

Remember that you will need to be able to use these ideas in various ways, such as:
- interpreting pictures, diagrams and graphs
- applying ideas to new situations
- explaining ethical implications
- suggesting some benefits and risks to society
- drawing conclusions from evidence that you are given.

### Working towards an A grade

<table>
<thead>
<tr>
<th>Aiming for Grade C</th>
<th>✓</th>
<th>Aiming for Grade A</th>
<th>✓</th>
</tr>
</thead>
<tbody>
<tr>
<td>understand that a source emits electromagnetic radiation which is reflected, transmitted or absorbed by materials, and which affects a detector when it is absorbed;</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>list the electromagnetic radiations in order of frequency, and recall their speed through space</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>understand that the energy transferred by electromagnetic radiation depends on the frequency and number of photons arriving</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>understand that electromagnetic radiation is less intense further from the source</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>relate the heating effect of radiation to the intensity of the radiation and its duration; understand that water molecules strongly absorb microwave energy</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>explain why evidence for the health risk from microwaves is disputed</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>understand that photons of ionising electromagnetic radiations have enough energy to remove electrons from atoms or molecules when absorbed by substances</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>understand that ionised molecules can take part in chemical reactions</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>recall that sunscreen and clothing absorb ultraviolet radiation; understand that the ozone layer absorbs ultraviolet radiation from the Sun, protecting living organisms</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>understand that chemical changes occur in the atmosphere when ozone absorbs ultraviolet radiation</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aiming for Grade C</td>
<td>✓</td>
<td>Aiming for Grade A</td>
<td>✓</td>
</tr>
<tr>
<td>--------------------</td>
<td>---</td>
<td>--------------------</td>
<td>---</td>
</tr>
<tr>
<td>apply understanding of the behaviour of X-rays to explain how images are produced</td>
<td>✓</td>
<td>understand that radiation emitted by the Earth <strong>has a lower principal frequency than radiation from the Sun, and that this radiation</strong> is absorbed or reflected back by some gases in the atmosphere</td>
<td></td>
</tr>
<tr>
<td>understand that all objects emit electromagnetic radiation, with a principal frequency that increases with temperature</td>
<td>✓</td>
<td>recall that greenhouse gases include methane and water vapour</td>
<td></td>
</tr>
<tr>
<td>recall that carbon dioxide is a greenhouse gas present in the Earth’s atmosphere; and explain the causes of the greenhouse effect</td>
<td>✓</td>
<td>understand that computer climate models provide evidence that human activities are causing global warming</td>
<td></td>
</tr>
<tr>
<td>use the carbon cycle to explain why the amount of carbon dioxide in the atmosphere was constant, and that it is now increasing due mainly to burning fossil fuels and deforestation</td>
<td>✓</td>
<td>explain that increased convection and more water vapour in the warmer atmosphere can cause more extreme weather</td>
<td></td>
</tr>
<tr>
<td>understand that global warming causes climate change and describe some of these effects</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>explain and compare different ways in which electromagnetic radiation can transmit information</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>understand the advantages of digital signals over analogue signals</td>
<td>✓</td>
<td>explain why digital signals are less prone to noise than analogue signals</td>
<td></td>
</tr>
<tr>
<td>understand that digital information is carried as pulses of an electromagnetic carrier wave, which are decoded when received</td>
<td>✓</td>
<td>understand how pulses of an electromagnetic carrier wave are created, used to carry digital information, and decoded</td>
<td></td>
</tr>
<tr>
<td>recall that higher quality sound or images use more digital information</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Checklist P2  Aiming for C

Use these checklists to see what you can do. Refer back to the relevant topic in your Student Book if you are not sure.

Remember that you will need to be able to use these ideas in various ways, such as:
- interpreting pictures, diagrams and graphs
- applying ideas to new situations
- explaining ethical implications
- suggesting some benefits and risks to society
- drawing conclusions from evidence that you are given.

Working towards a C grade

<table>
<thead>
<tr>
<th>Aiming for Grade E</th>
<th>✓</th>
<th>Aiming for Grade C</th>
<th>✓</th>
</tr>
</thead>
<tbody>
<tr>
<td>understand that a source emits electromagnetic radiation which is reflected, transmitted or absorbed by materials, and which affects a detector when it is absorbed;</td>
<td></td>
<td>understand that the energy transferred by electromagnetic radiation depends on the frequency and number of photons arriving; understand that electromagnetic radiation is less intense further from the source</td>
<td></td>
</tr>
<tr>
<td>list the electromagnetic radiations in order of frequency, and recall their speed through space</td>
<td></td>
<td>relate the heating effect of radiation to the intensity of the radiation and its duration; understand that water molecules strongly absorb microwave energy</td>
<td></td>
</tr>
<tr>
<td>understand that absorbed electromagnetic radiation can heat and damage living cells</td>
<td></td>
<td>explain why evidence for the health risk from microwaves is disputed</td>
<td></td>
</tr>
<tr>
<td>understand that some people worry about health risks from low intensity microwave radiation; and that evidence for the health risk from microwaves is disputed</td>
<td></td>
<td>understand that photons of ionising electromagnetic radiations have enough energy to remove electrons from atoms or molecules when absorbed by substances</td>
<td></td>
</tr>
<tr>
<td>understand that high-energy ultraviolet radiation, X-rays and gamma rays are ionising radiation; and understand that exposure to ionising radiation can damage living cells</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aiming for Grade E ✔</td>
<td>Aiming for Grade C ✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------</td>
<td>---------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>recall that sunscreen and clothing absorb ultraviolet radiation; understand that the ozone layer absorbs ultraviolet radiation from the Sun, protecting living organisms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>understand that lead and concrete absorb X-rays; describe how X-rays can produce shadow pictures</td>
<td>apply understanding of the behaviour of X-rays to explain how images are produced</td>
<td></td>
<td></td>
</tr>
<tr>
<td>recall that some radiation from the Sun passes through the Earth’s atmosphere, warming the Earth’s surface</td>
<td>understand that all objects emit electromagnetic radiation, with a principal frequency that increases with temperature</td>
<td></td>
<td></td>
</tr>
<tr>
<td>recall that carbon dioxide is a greenhouse gas present in the Earth’s atmosphere; explain the causes of the greenhouse effect</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>interpret diagrams representing the carbon cycle; recall that over the last 200 years the carbon dioxide in the atmosphere has been steadily increasing</td>
<td>use the carbon cycle to explain why the amount of carbon dioxide in the atmosphere was constant, and that it is now increasing due mainly to burning fossil fuels and deforestation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>understand that global warming causes climate change and describe some of these effects</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>recall that information can be superimposed onto an electromagnetic carrier wave to create a signal that can be transmitted</td>
<td>explain and compare different ways in which electromagnetic radiation can transmit information</td>
<td></td>
<td></td>
</tr>
<tr>
<td>recall the features of an analogue signal and a digital signal; and recall some advantages of digital signals over analogue signals</td>
<td>understand the advantages of digital signals over analogue signals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>recall that a digital signal is transmitted as pulses of an electromagnetic wave</td>
<td>understand that digital information is carried as pulses of an electromagnetic carrier wave, which are decoded when received</td>
<td></td>
<td></td>
</tr>
<tr>
<td>recall that higher quality sound or images use more digital information</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**When and how to use these pages**

This activity provides an opportunity to build and assess the skills that students will use when analysing and evaluating data.

Ask students to:
- read through the context and tasks, listing any terms that they do not understand
- as a whole class or in small groups, discuss the tasks to ensure that all students understand the terminology used and to clarify what is required
- work in small groups or individually to answer the questions for each task.

If time allows, ask the students to mark one another’s work using the mark scheme provided.

**Notes**

The students need to interpret and make sense of information about a context that they will know little about. The questions may be answered more successfully if students work in small groups, developing responses and agreeing on a high-quality set of answers. This allows the teacher to encourage the drawing out of the characteristics of successful responses that will access higher grades.

**Answers**

**Task 1**
- Telstar was fitted with solar cells, which absorbed energy radiated by the Sun and transferred it as electricity to power the circuits. It was designed this way so that, once in orbit, it would be sustainable in terms of its energy needs. As an aside, the other energy requirement of satellites is fuel to allow them to be repositioned remotely as their orbit deteriorates over time; it is sometimes this that limits the lifespan of a satellite.
- The purpose of the aerial was to absorb energy transmitted by the satellite signal to pick up the information. Because the signal was very weak it needed a huge aerial to gather enough energy to detect the signal.

**Task 2**
- A low-orbiting satellite is closer to Earth, so the signal is stronger. The signal from a satellite further away will have spread out more.
- It was only in the right place to link the two continents for around 20 minutes in every two and a half hours.

**Task 3**
- Students should produce a diagram such as this to show that, while the satellite is in ‘line of sight’ with both Earth stations, they aren’t in ‘line of sight’ with each other.
- It was difficult to pick the signal up because it was weak and the satellite was moving quickly relative to the Earth. The pictures were of poor quality because of the small amount of information for each image and because of the difficulty in tracking the satellite.
P2 Evaluating and analysing evidence continued

Task 4
- It would be travelling at the same speed as all electromagnetic radiation, $3 \times 10^8$ m/s.

Task 5
There are a number of reasons, including:
- The signal was much weaker than that from a modern satellite, so huge aerials were needed.
- The satellite travelled across the sky, so the aerial had to track across from horizon to horizon in around 20 minutes.
- The satellite then disappeared for another two hours, while it orbited the Earth.

Mark scheme
For grade E, students should show that they can:
- describe how a source emits electromagnetic radiation which can be reflected, transmitted and detected by a receiver
- describe how the intensity of radiation varies with distance from the source
- understand that higher quality sound or images use more information.

For grades D, C, in addition:
- understand that electromagnetic radiation affects a receiver when it is absorbed
- understand that electromagnetic radiation spreads over an increasing surface area and is partially absorbed further from the source
- explain the implications of higher quality sound or images using more information.

For grades B, A, in addition:
- explain how the properties of waves determine the transmission and reception of signals
- explain the need for higher transmission rates to improve signal quality.
Pages 264–265 in the Student Book are exam-style questions.

**When and how to use these pages**

These questions are based on the whole of Module P2 and cover a range of different types of questions that students will meet in their written exams.

- The questions could be used as a revision test once you’ve completed the module.
- Work through the questions as a class as part of a revision lesson.
- Ask students to mark each other’s work, using the mark scheme provided.
- As a class, make a list of the questions that most students did not get right. Work through these as a class.

**Notes on the worked example**

Part c has 6 marks available and the quality of written communication is assessed. In this type of question students should structure their answer and be particularly careful that spelling and grammar are accurate. It is worthwhile for students to become familiar with the ‘banded’ mark scheme by which these questions are graded; for 6 marks the answer must not only be correct, but also well organised and well expressed.

**Assessment Objectives**

These exam-style questions cover the Assessment Objectives as described below.

<table>
<thead>
<tr>
<th>Assessment Objectives</th>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>AO1 Recall, select and communicate their knowledge and understanding of science</td>
<td>1, 2b, 3, 4, 6, worked example a, b(i), c</td>
</tr>
<tr>
<td>AO2 Apply skills, knowledge and understanding of science in practical and other contexts</td>
<td>2a, 5, 7a, 8, worked example b(ii)</td>
</tr>
<tr>
<td>AO3 Analyse and evaluate evidence, make reasoned judgements and draw conclusions based on evidence</td>
<td>5, 7b, worked example c</td>
</tr>
</tbody>
</table>

**Answers**

These answers are also supplied on the Teacher Pack CD, so students can mark their own, or their peer’s work.

<table>
<thead>
<tr>
<th>Question number</th>
<th>Answer</th>
<th>Additional notes</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>A</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>b</td>
<td>B</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>2a</td>
<td>There are fewer photons; they have longer wavelength.</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>b</td>
<td>The intensity of the radiation falls because the energy is spread over a larger area.</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>3a</td>
<td>Photons of electromagnetic radiation need to have enough energy to cause ionisation. Only radiation types with short wavelength/high frequency have this amount of photon energy.</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>b</td>
<td>A, D, E</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Ozone in the atmosphere absorbs ultraviolet radiation from the Sun and undergoes chemical reactions; less of the harmful radiation reaches us on Earth; so ozone protects us.</td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>
### P2 Exam-style questions continued

<table>
<thead>
<tr>
<th>5</th>
<th>Answer should include an explanation of the difference between correlation and cause, relate this to the context, and mention other factors that may contribute as a cause.</th>
<th>For 5–6 marks: Answer explains correlation fully and relates it to deforestation and rising carbon dioxide levels, but discusses other factors that may apply. All information in answer is relevant, clear, organised and presented in a structured and coherent format. Specialist terms are used appropriately. Few, if any, errors in grammar, punctuation and spelling. For 3–4 marks: Answer correctly defines correlation and relates it to deforestation and rising carbon dioxide levels. For the most part the information is relevant and presented in a structured and coherent format. Specialist terms are used for the most part appropriately. There may be occasional errors in grammar, punctuation and spelling. For 1–2 marks: Answer suggests deforestation leads to rising carbon dioxide levels. Answer may be simplistic. There may be limited use of specialist terms. Errors of grammar, punctuation and spelling may be intrusive. For 0 marks: Insufficient or irrelevant science.</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>A – false; B – true; C – false</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>7a</td>
<td>No – the space-based telescope will detect a wider range of frequencies as the atmosphere is transparent to some types of radiation but not others.</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>7b</td>
<td>A space telescope can detect more objects in space than an Earth-based telescope because it can detect all the electromagnetic frequencies – some objects in space emit types of radiation that are not detected on Earth.</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Answer should explain the higher level of X-rays at the Moon’s surface as due to the lack of atmosphere to absorb the radiation (which arrives with almost equal intensity at the Earth and at the Moon). It should explain the risk to humans, describe appropriate precautions for volunteers, and compare this with the situation for radiation workers on Earth. Precautions could include: - special training for volunteers in dealing with the hazard - wearing of radiation monitoring badges - shielding and protective clothing</td>
<td>For 5–6 marks: Answer fully explains the high intensity of radiation and the risks, takes account of the duration of exposure, presents appropriate precautions, linking these with those for radiation workers on Earth, and discusses other factors that may apply. All information is relevant, clear, organised and presented in a structured and coherent format. Specialist terms are used appropriately. Few, if any, errors in grammar, punctuation and spelling. For 3–4 marks: Answer links the presence of more X-rays with the lack of atmosphere and suggests appropriate precautions for volunteers. For the most part the information is relevant and presented in a structured and coherent format. Specialist terms are used for the most part appropriately. There may be occasional errors in grammar, punctuation and spelling. For 1–2 marks: Answer either links the presence of more X-rays with the lack of atmosphere or suggest an appropriate precaution Answer may be simplistic. There may be limited use of specialist terms. Errors of grammar, punctuation and spelling may be intrusive. For 0 marks: Insufficient or irrelevant science.</td>
<td>6</td>
</tr>
</tbody>
</table>
1 How light behaves

Here is some information from a book on photography. Use it to answer the questions below.

**Tips for taking good photos**

Don’t point your camera towards a light source like the Sun, or too much light will enter the camera and your photo will be too bright, or ‘overexposed’. Overexposure can also occur if your picture includes a shiny surface like a mirror that reflects light.

Clear windows transmit almost all light, so you can take pictures indoors in daylight. However, your photo may be very dark if it is taken in a room with very dark walls, because dark colours absorb a lot of light. Coloured objects reflect light of their colour. This means that someone wearing a blue or green top will look paler than someone wearing a red top. The coloured light reflected from the top scatters from their face, giving the person a slightly different hue.

If you want to see your pictures straight away, use a digital camera. Its image sensor detects light, converting it into an electrical signal when the light is absorbed.

1 From this information, find an example of an object that:

a) is a light source ........................................................................................................

b) reflects light ..............................................................................................................

c) absorbs light ...........................................................................................................

d) detects light ............................................................................................................

e) transmits light ...........................................................................................................

2 If you take a photograph of a building on a sunny day, why do its windows appear brighter than the rest of the building?

........................................................................................................................................

3 How does the colour of a room’s walls affect the brightness of an indoor photograph?

........................................................................................................................................

........................................................................................................................................

4 Explain why we can still see the light from the Sun through clouds, although it appears less bright. Use the words absorb and transmit in your answer.

........................................................................................................................................

........................................................................................................................................

........................................................................................................................................
The electromagnetic spectrum

When Jodie came home from school, she tuned in the radio to her favourite station and listened to music. As it got later and darker, she turned on the light. Then she heated a meal using the microwave oven. She knew her mum had taken her brother to hospital for an X-ray after he hurt his arm. She began to feel cold, so she turned on the infrared heater.

1. On the diagram below (or a larger copy of it), write in the correct boxes the different types of electromagnetic radiation mentioned in the passage above. Two types have been added for you. Use your Student Book to help you.

<table>
<thead>
<tr>
<th>Low energy</th>
<th>Ultraviolet radiation</th>
<th>High energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low frequency</td>
<td>High frequency</td>
<td></td>
</tr>
</tbody>
</table>

2. What is the link between energy and frequency for electromagnetic radiation?

3. X-rays can only be used in a controlled setting like a hospital. Suggest one reason why.

4. Find one further use for each type of electromagnetic radiation (X-ray, gamma ray, radio wave, microwave, ultraviolet, infrared and visible) and write these in a table. Remember, you can use your Student Book – or you can search on the internet (search for ‘Uses of electromagnetic spectrum GCSE’).

Light photons

We can see the effects of light being reflected and refracted, just like other waves. It transfers energy from one place to another, without transferring the material it passes through. It doesn’t even need a material to pass through.

The frequency of a light wave affects the colour of its light and the energy it carries. Red light carries less energy than blue light because red light has a lower frequency than blue light.

In 1905, Einstein described light as a stream of energy packets called photons, travelling at the speed of light. These packets carry energy even though they have no mass. The energy of each photon depends on the frequency of the light, so each photon of blue light carries more energy than a photon of red light. Finally, this enabled scientists to explain an effect first noticed in the 1890s – certain frequencies of light shone onto a metal surface could create a small electrical current; lower frequencies of light, even at higher intensity, did not create a current.

1. State three similarities between light waves and photons of light.

2. State one difference between light waves and photons of light.

3. Explain why scientists thought about light as a wave before they thought about it as a stream of photons.
Photons of light

Photons are like packets of light energy. A beam of light contains many photons, which all travel at the same speed. They transfer energy when they are absorbed.

A brighter light beam contains more photons than a dimmer light beam.

You can tell if the frequency of the light changes because its colour changes. This also changes the frequency and energy of each photon in the beam of light.

These colours of light are in order of increasing frequency, and increasing photon energy:

red yellow green blue violet

A technician controls spotlights in a theatre. Complete the table to show how he changes the type or number of photons coming from the spotlights. The first one has been done for you.

<table>
<thead>
<tr>
<th>Change made to the lighting</th>
<th>Change to the number of photons</th>
<th>Change to the energy of each photon</th>
</tr>
</thead>
<tbody>
<tr>
<td>A spotlight is made brighter but stays the same colour</td>
<td>More photons</td>
<td>No change</td>
</tr>
<tr>
<td>A spotlight is made dimmer but stays the same colour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A spotlight colour changes from red to green, but stays the same brightness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A spotlight colour changes from blue to green and gets dimmer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A spotlight colour changes from blue to green and gets brighter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A spotlight colour changes from yellow to red and gets dimmer</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2 Photons and the electromagnetic spectrum

Electromagnetic radiation contains photons. The Sun radiates three main forms of electromagnetic radiation. In order of increasing frequency and increasing photon energy, these are:

- infrared radiation
- visible light
- ultraviolet radiation

1 Which type of photon from the Sun has the most energy?

2 If the Sun emits equal numbers of each type of photon, which type of radiation will transfer the most energy when it reaches an absorbing surface?

Different devices capture the energy transferred by photons from the Sun:

- Solar panels absorb infrared photons – these panels are used to heat water in homes.
- Photovoltaic cells absorb visible light photons – these cells are used in solar-powered devices such as calculators, and convert visible light energy into electrical energy.

3 When Ellie shone a beam of infrared radiation at a photovoltaic cell, it did not work. Which reason explains why?
   A Not enough photons were produced by the beam
   B The photons from the beam did not have enough energy

Planets closer to the Sun than Earth receive more radiation than we do. This is because photons from the Sun spread over a larger area as they move away from the Sun. Mars is further from the Sun than Earth.

4 Explain whether more photons from the Sun will reach Mars or Earth.

5 Use your answer to question 4 to explain whether a solar panel would work better or less well on Mars.

3 Calculating energy transfer

For a beam of electromagnetic radiation:

\[
\text{energy transferred per second (J/s)} = \text{intensity (W/m}^2\text{)} \times \text{area (m}^2\text{)}
\]

1 a) The intensity of light from a lamp is 20 W/m\(^2\). The light spreads over an area of 3 m\(^2\). How much energy does the light transfer in one second?

b) Further away from the lamp, the intensity is 10 W/m\(^2\) and the light spreads over an area of 6 m\(^2\). How much energy per second does the light transfer?

c) Explain your answers to a) and b).

2 Solar panels are used to capture the Sun’s energy to provide heating and hot water in a house. The solar panel installer quoted these figures:

   - the area of one solar panel is 4 m\(^2\)
   - in winter, the Sun’s intensity is about 900 W/m\(^2\)
   - in summer, the Sun’s intensity is about 1200 W/m\(^2\)

   a) How much energy per second can the solar panel transfer in winter and in summer?

b) Explain why the householder may need to use an extra method of heating in the winter.

3 Satellites orbiting Earth use solar panels. Explain two reasons why the intensity of solar radiation reaching these panels is more than the intensity reaching a home on Earth.
### Recognising ions

1. Complete the table, saying whether the particle described is an atom, a molecule or an ion. There is more information in your Student Book on page 240 to help you.

<table>
<thead>
<tr>
<th>Name</th>
<th>Picture</th>
<th>Charge</th>
<th>Is this an atom, an ion or a molecule?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helium</td>
<td><img src="image" alt="Helium" /></td>
<td>zero</td>
<td></td>
</tr>
<tr>
<td>Iodine</td>
<td><img src="image" alt="Iodine" /></td>
<td>negative</td>
<td></td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td><img src="image" alt="Carbon dioxide" /></td>
<td>zero</td>
<td></td>
</tr>
<tr>
<td>Magnesium</td>
<td><img src="image" alt="Magnesium" /></td>
<td>positive</td>
<td></td>
</tr>
<tr>
<td>Oxygen</td>
<td><img src="image" alt="Oxygen" /></td>
<td>zero</td>
<td></td>
</tr>
</tbody>
</table>

2. Fill in the gaps below to explain how an ion is formed. Use these words:

energy gains ionisation loses photons ion

Atoms can absorb energy from ……………………… of electromagnetic waves. If the photon has enough …………………, an electron is knocked out of the atom. The atom becomes an …………………… This process is called ……………………

When a lithium atom ………………… an electron, it becomes a positively charged ion. When a chlorine atom ………………… an electron, it becomes a negatively charged ion.
2 Causing ionisation

1. Complete the sentences in the flow chart on the next page, to explain why only some photons cause ionisation. These words will help you:
   - can
   - can’t
   - electromagnetic radiation
   - electrons
   - enough positively
   - photons
   - too little

2. In the empty boxes on the next page, draw a series of simple pictures to show what happens:
   a) when radio wave photons pass through a gas, but do not ionise the gas atoms
   b) when X-ray photons pass through a gas and ionise the gas atoms.

   When you are drawing the diagrams, consider
   - the wavelength of photons
   - whether photons are absorbed by atoms or pass through the gas
   - whether the gas contains atoms, or charged ions and electrons, after the photons pass through.

3 Why does ionisation harm us?

Read this text. For each type of ionisation mentioned, state whether or not it causes ionisation, and if it does, what the effects are on living cells and/or on individual atoms and molecules, and what the importance of these effects is to us.

When gamma rays and X-rays pass through the body, some photons may be absorbed. Their photons have enough energy to ionise DNA and protein molecules inside cells, damaging them. The cells may die or mutate. The mutations are harmful because the ions take part in different chemical reactions from the original molecules. In controlled doses, gamma rays and high-energy X-rays can treat cancer if they are carefully targeted at cancerous cells.

X-rays are absorbed by bones so low doses are used to diagnose cracks and breaks in bones. However, a person who has had many X-rays may be more likely to develop leukaemia, a cancer affecting bone marrow.

High-energy ultraviolet radiation can ionise atoms including aluminium and hydrogen. Very high-frequency ultraviolet radiation can ionise DNA molecules. Ultraviolet radiation in sunlight causes photo-ionisation of oxygen and nitrogen in the atmosphere. Gamma rays and X-rays from space can ionise many different atoms and molecules. In 2005, gamma rays from a neutron star only 12 miles in diameter on the other side of the Milky Way ionised molecules in the outer layers of the Earth’s atmosphere, changing its shape briefly. This affected radio waves transmitting broadcasts, because these waves reflect off different layers in the atmosphere. The ionisation also affected the chemical reactions taking place in the atmosphere.

Photons of visible light cannot cause ionisation when absorbed, but they can cause other effects. In a laser, molecules are energised by absorbing visible light photons. These energised molecules can be triggered to release photons all at the same time, creating a very intense beam of light. This intense visible (or infrared) light from lasers is used in surgery to cut blood vessels precisely and to seal them.

When photons of microwaves and infrared radiation are absorbed, they cause a heating effect. This is why we can heat things using microwave ovens and cookers. These are not effects caused by ionisation.
Activity 2 Question 1

- Activity 2 Question 1

<table>
<thead>
<tr>
<th>Activity 2 Question 2</th>
<th>a) Radio wave photons</th>
<th>Pass through gas</th>
<th>Atoms remain unchanged</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>b) X-ray photons</td>
<td>Are absorbed by gas atoms</td>
<td>Atoms eject electrons and change into ions</td>
</tr>
</tbody>
</table>

- Activity 2 Question 2

- Activity 2 Question 1

- Activity 2 Question 2

- Activity 2 Question 1

- Activity 2 Question 2
Read this passage and then answer the questions.

Alice’s doctor sent her to the Radiology department in the local hospital after she found a lump that may have been cancerous.

The radiographer positioned Alice so that an X-ray picture would show the lump clearly. Alice was pregnant so a lead apron covered her lower stomach and pelvis, shielding the unborn baby from the X-rays. The radiographer stood behind a lead glass window to take a set of three X-ray pictures from slightly different positions.

The X-rays each lasted less than a second, exposing Alice to less radiation than she received daily from her surroundings. A few days later, the results showed that Alice’s lump was harmless, and she didn’t need treatment.

Alice was not offered a CT scan, which takes a set of X-rays over a period of about half an hour. These are combined to form a very detailed 3D image that is very helpful for doctors in planning treatment. But the dose from a CT scan may be 500 times higher than for a normal X-ray picture. The X-rays carry more energy, and the exposure time is much longer. This increases a patient’s risk of developing cancer.

1 Write down one advantage and one disadvantage of using X-rays in medical diagnosis.

..........................................................................................................................
..........................................................................................................................

2 Describe two precautions that the radiographer took to protect Alice.

..........................................................................................................................
..........................................................................................................................

3 The radiation from the X-rays was at a safe level for Alice. Why did the radiographer need to stand behind the lead glass screen?

..........................................................................................................................
..........................................................................................................................

4 Write down one advantage and one disadvantage of using a CT scan.

..........................................................................................................................
..........................................................................................................................

5 Why do CT scans increase the risk of a person developing cancer?

..........................................................................................................................
..........................................................................................................................
2 Protection from ionising radiation

Radiographers use X-rays and gamma rays as part of their job. Their exposure to radiation needs to be controlled because it occurs over long time periods, and the effects add up.

To control the risk, radiographers follow safe procedures when handling equipment. They also wear badges to monitor the amount and type of radiation they are exposed to.

Write an introductory information sheet for new radiographers in a hospital. The sheet should mention some or all of these things:

- why the radiographer is at risk from X-rays or gamma rays
- when they are likely to be exposed to X-rays or gamma rays
- some simple rules to limit their radiation exposure (think about time, distance and shielding)
- whether or not the extra risk they face is likely to be harmful.

You may need to find information on the internet. Useful search terms are:

- safety X-ray
- safety gamma rays
- radiographer

3 Assessing risks

Many people get confused between hazards and risks.

A hazard is something that can cause harm, such as a poison or a radioactive source.

A risk is the likelihood that the harm will occur, and how serious the harm may be.

Different factors affect how large a risk really is, for example:

- whether someone is exposed to the hazard frequently or occasionally
- whether the effects of the hazard are very serious
- whether the person is trained or has equipment to cope with the risk.

Different factors affect how large we think a risk is, for example:

- whether it takes place in a familiar or unfamiliar setting
- whether a person can control what happens
- whether the impact of things going wrong might involve death or serious injury.

Patients who have cancer may be offered a CT scan. This type of diagnosis increases the cancer risk for a patient, especially for a child or if repeated scans are carried out. However, a professional will recommend a CT scan if they feel that the benefits outweigh the risks.

Prepare a leaflet for a patient who has been told they will need a CT scan. The leaflet should:

- explain simply what a CT scan is and why it is needed
- explain why there is a risk from the exposure to radiation
- explain simply how this risk will be controlled
- compare this risk with other everyday risks (in a way that eases the patient’s worries).
1 Heating with microwaves

A mobile phone and a microwave oven both use microwaves. Choose the correct words to complete these sentences.

- A person absorbs **less/more** microwave energy using a mobile phone compared with a meal being cooked in a microwave oven.
- Mobile phones can't cook food because they emit **more/less** microwave energy compared with a microwave oven.
- Mobile phone microwaves are less harmful than those from a microwave oven because they are much **less/more** intense.
- Mobile phone microwaves are less harmful than those from a microwave oven because their frequency is much **smaller/greater**.
- More energy is needed to cook a large amount of food than a small amount, so the large amount needs a **longer/shorter** cooking time in the microwave oven.

2 Cooking safely with microwaves

Use information from the internet to prepare a short advice sheet that could be included with a new microwave oven. The advice sheet should cover these points:

- Why food containers should be made of non-metal materials.
- Why the power of the microwave oven affects the heating time.
- Why different quantities of food need different heating times.
- Why you need to add water before cooking dry food like rice or pasta.
- Why you should be careful removing food from a microwave oven.
- Why you should not use a microwave oven if the door is damaged.
Could your mobile phone harm you?

Read this text and then answer the questions.

In 2009, 4.3 billion people used mobile phones worldwide. Despite the advantages, there are long- and short-term problems associated with the use of mobile phones. This year, people are more likely to be killed or injured while using their mobile phone, as a result of crime or accident, than they are to develop ill health such as cancer due to long-term use. However, people are happier to accept risks that they are familiar with, or that they feel they can control.

Mobile phones emit low levels of microwave radiation. Several long-term international studies have suggested that this radiation causes no significant cancer risk. However, there may be an increased risk of benign (non-cancerous) tumours in people who use their phones a lot. Other concerns include reduced fertility in some men, although there is no definite evidence.

People living near a mobile phone base station are exposed to constant, very low levels of microwave radiation. Scientists are confident that these levels of radiation are so low that they are extremely unlikely to cause any health effects.

Mobile phones have become popular during the last 20 years and long-term problems may take many years to become apparent. Internationally, governments spend millions of pounds researching the possible cancer risks caused by mobile phones, while mobile phone companies are developing versions of their mobiles which emit less microwave radiation, to reduce any possible risk.

There are other risks: it is now illegal in many countries to drive while using a hand-held mobile phone, as this has been linked with an increased risk of causing accidents. Drivers who are distracted while texting or calling from a mobile have directly caused many deaths worldwide.

The police also warn of the increased risk of being mugged for your mobile phone. Some statistics suggest up to 300,000 people have been attacked on the street for their mobile. Statistically, 14–17 year olds are the most likely victims of street crime. You are more likely to be mugged if you use your mobile phone on the street without being fully aware of your surroundings and the risks.

Other concerns include cyber-bullying and ‘happy-slapping’ (when a crime against a person is recorded with a phone camera).

1 Using your own ideas as well as those in the text above, make three lists:
   - Advantages of using a mobile phone
   - Short-term disadvantages of using a mobile phone
   - Long-term disadvantages of using a mobile phone

2 ‘People are more likely to be killed or injured while using their mobile phone, as a result of crime or accident, than they are to develop ill health such as cancer due to long-term use.’ Explain why many users are happy to take this risk.

3 The risk of harm being caused by signals from mobile phone masts is tiny but many people living near phone masts campaign for their removal. Explain why the risk is less acceptable for them than for the general population.

4 The government and mobile phone companies are spending millions of pounds on research into a possible cancer risk even though many studies have already shown that there is no clear link. Explain why they feel this action is necessary.
When you have completed these activities, combine all your answers into one information sheet.

1 Ozone in the atmosphere

Cut out and stick these labels in suitable places on or around the diagram, adding arrows if necessary.

<table>
<thead>
<tr>
<th>Radiation from the Sun includes ultraviolet radiation.</th>
<th>Ozone formed at ground level is damaging to health.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ozone in the atmosphere’s outer layers absorbs ultraviolet radiation.</td>
<td>Some man-made chemicals released into the atmosphere can damage the ozone layer.</td>
</tr>
</tbody>
</table>
2 Effects of ultraviolet radiation

Use the internet, your Student Book and other resources to find out how exposure to different strengths of ultraviolet radiation affects humans.

For each of these headings, describe the effect of the exposure on the body and how to control the risks involved:

- Health benefit of exposure to a small amount of ultraviolet radiation.
- Harm caused by exposure to strong ultraviolet radiation for a few hours.
- Harm caused by exposure to strong ultraviolet radiation over many years.

3 Could your mobile phone harm you?

Read on page 247 in your Student Book about how high-frequency ultraviolet radiation affects ozone differently from low-frequency ultraviolet radiation.

Remember ‘high frequency’ means high photon energy; ‘low frequency’ means low photon energy.

1 For each of high-frequency and low-frequency ultraviolet radiation, answer these questions:
   - Which molecules absorb the radiation?
   - What is produced after the reaction?

2 Find out more information about ozone and ultraviolet radiation to add to your information sheet. For example, find out about:
   - other chemical reactions that occur in the ozone layer, and explain one or more of these reactions in more detail
   - different types of ultraviolet radiation (UV-A, UV-B and UV-C) and their interactions with ozone.
The greenhouse effect: Technician sheet

Equipment and materials

- Two identical sheets of paper or thin card (A5 size is suitable)
- Thin sheet of insulation such as foam or cotton wool (no more than 5 mm thick) to cover one sheet of paper
- Two identical lamps (12 V 24 W SBC bulbs)
- Temperature probe or thermochromic paper

Method

Place the cotton wool over one sheet of paper – this represents the Earth and its atmosphere.

The other sheet of paper represents the Moon.

If you are using temperature probes, set these up to monitor the temperature on the surface of each piece of paper (i.e. under the insulation).

If you are using thermochromic paper, stick a square in the middle of each sheet of paper.

Arrange the lamps so they are the same distance (approximately 10 cm) from the Earth and the Moon.

Leave the lamps on for about 5 minutes, then turn them off and remove them.

Immediately begin monitoring the temperature of the two sheets of paper for a few minutes, leaving the insulation in place.

Either take regular readings from the temperature probes, or check the colour of the thermochromic paper (you will need to remove the insulation briefly).

Health and Safety notes

Beware of the hot lamp bulbs.

Mains electrical equipment must be inspected and tested in accordance with regulations.
Absorbing radiation and warming up

All objects emit electromagnetic radiation. The warmer they are, the more radiation they emit. Objects can also absorb, transmit, or reflect radiation.

The Sun emits different frequencies of electromagnetic radiation. This radiation reaches the Earth's atmosphere.

Complete the sentences below using these words:

absorbs  transmits  reflects

a) The Earth's atmosphere ................. some of this radiation back to space.

b) The Earth's atmosphere ................. some of this radiation to the Earth's surface.

c) The Earth's surface ................. radiation that reaches it, and it warms up. Because the Earth's surface is warmer it emits more electromagnetic radiation.

d) The Earth's atmosphere ................. some radiation back to the Earth's surface.

e) The Earth's atmosphere ................. some radiation and re-radiates it back to Earth.

The Earth and its atmosphere become warmer if more radiation is absorbed than emitted.
The Moon's surface temperature reaches 123 °C when the surface is facing the Sun, and falls to −233 °C when facing away from the Sun.

The highest temperature recorded on the Earth’s surface is 70 °C (in Iran) and the lowest is −89 °C (in Antarctica).

Choose at least two of the clues below to explain each of these ideas:

a) The Earth and the Moon receive similar amounts of radiation.
b) The Earth doesn't gain heat as quickly as the Moon.
c) The Earth doesn’t lose heat as quickly as the Moon.
d) Increasing the levels of greenhouse gases in our atmosphere will increase the average temperature on Earth.

**Clue 1:** The Moon and the Earth are similar distances from the Sun.

**Clue 2:** The Earth’s atmosphere reflects some radiation from the Sun.

**Clue 3:** Radiation from the Earth’s surface is absorbed and re-radiated back by greenhouse gases in the atmosphere.

**Clue 4:** The Moon has a negligible atmosphere.

**Clue 5:** The Moon takes about a month to turn on its axis but Earth only takes 24 hours.

**Clue 6:** The Sun radiates more energy at a higher frequency than the Earth and the Moon.

**Clue 7:** The Earth’s surface emits more radiation, at a higher frequency, as it warms up.

**Clue 8:** The atmosphere warms up if it absorbs more radiation than it emits.
Can we prove the effects of greenhouse gases?

Look at these graphs.

1. Explain whether or not the graphs show a correlation between carbon dioxide levels in the atmosphere and:
   a) the use of fossil fuels
   b) economic growth (when countries become wealthier)
   c) world population.

2. Suggest one possible way that a change in carbon dioxide levels could be *caused* by changes in:
   a) the use of fossil fuels
   b) economic growth
   c) world population.

3. Suggest other factors that could affect changes in carbon dioxide levels in the atmosphere.
Carbon sources and stores

The processes in the boxes below either release carbon (as carbon dioxide) into the atmosphere or remove carbon it by storing it.

Cut out the boxes and stick each one in the table to show which processes release carbon and which remove and store it.

<table>
<thead>
<tr>
<th>Releases carbon into the atmosphere</th>
<th>Removes carbon from the atmosphere</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Respiration by animals</th>
<th>Forest fires</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photosynthesis by plants on land</td>
<td>Respiration by plants</td>
</tr>
<tr>
<td>Volcanic eruptions</td>
<td>Diffusion of carbon dioxide into the surface of oceans</td>
</tr>
<tr>
<td>Gases absorbed by oceans</td>
<td>Burning fossil fuels</td>
</tr>
<tr>
<td>Fossilisation of animal and plant remains</td>
<td>Photosynthesis by phytoplankton in oceans</td>
</tr>
</tbody>
</table>
2 Carbon dioxide in the atmosphere

In this activity, you will investigate how processes change the concentration of carbon dioxide in the atmosphere.

- Draw a carbon cycle diagram to show the natural carbon cycle that would have been taking place 500 years ago.
- Alter this diagram using different colours, adding or removing processes so that it shows the carbon cycle taking place today.

Use your diagrams to answer these questions.

1. a) List processes that take place to a greater extent now, compared with 500 years ago.
   b) List processes that take place to a lesser extent now, compared with 500 years ago.

2. Put the processes you have listed in question 1 into two groups:
   a) processes releasing carbon dioxide into the atmosphere
   b) processes removing carbon dioxide from the atmosphere.

3. Use your answers to these questions to explain how recent changes in the carbon cycle affect the proportions of carbon in different stages of the carbon cycle.

3 Finding a correlation

In this activity you will investigate whether or not human activity has affected the concentration of carbon dioxide in the atmosphere.

Find graphs on the internet that show changes during the last 100 years in:
- worldwide population
- fossil fuel usage
- rates of deforestation
- carbon dioxide emissions
- global temperature

If trends are correlated, then increasing one trend will make the other trend increase or decrease. This may happen if there is another factor that affects both trends.

1. a) Use the graphs you have found to decide if any of these changes can be correlated. How did you decide?
   b) What might be the reasons for any correlation?

Correlation is not the same as one thing causing a change in another. This only happens if a process directly links the two.

2. Explain why it may be easy to say that trends are correlated, but may be much harder to claim that one trend causes a change in another trend.
Effects of global warming

All these statements contain mistakes. Write out the correct version, adding more information if needed.

1. Scientists believe global warming is causing the increase in levels of greenhouse gases in the atmosphere.
   Correct statement:
   ……………………………………………………………………………………………………….
   ……………………………………………………………………………………………………….
   ……………………………………………………………………………………………………….

2. The effects of global warming include larger glaciers, falling sea levels and steadier weather patterns.
   Correct statement:
   ……………………………………………………………………………………………………….
   ……………………………………………………………………………………………………….
   ……………………………………………………………………………………………………….

3. Sea levels will rise because icebergs already in the sea will melt.
   Correct statement:
   ……………………………………………………………………………………………………….
   ……………………………………………………………………………………………………….
   ……………………………………………………………………………………………………….

4. A cold winter in the UK shows us that global warming is not happening.
   Correct statement:
   ……………………………………………………………………………………………………….
   ……………………………………………………………………………………………………….
   ……………………………………………………………………………………………………….

5. Global warming only happens on Earth and is totally caused by the actions of humans.
   Correct statement:
   ……………………………………………………………………………………………………….
   ……………………………………………………………………………………………………….
   ……………………………………………………………………………………………………….
2 The impact of global warming

Use the internet, the Student Book and other resources to find out about how the effects of global warming impact on different people around the world.

Give an example of a vulnerable group of people or area of the world, and explain the impact on the people, for each of the following effects:

a) difficulties growing crops in some regions due to climate change
b) extreme weather
c) flooding.

You could use a labelled map to help your answers.

3 Working together to tackle the problems

The impact of global warming could be catastrophic for people living in some countries, but have a limited impact on others. However, many countries are responsible for contributing to the causes of climate change and global warming.

Before politicians decide how to respond to global warming, they must take account of the risks and the benefits of different possible actions to people affected in different ways. One way is to use computer climate models to calculate the chance of certain forms of climate change happening, and to show how different scenarios lead to different consequences, and hence different impacts on groups of people.

In a small group, research more fully the impact of one effect of climate change from activity 2. Use data from computer models if available.

Find out:
- how different groups of people will be affected (include both damaging and beneficial effects, if any)
- what steps can be taken by governments of different countries to reduce the impact of climate change (include both short-term and long-term steps)
- how these actions taken to reduce the impact of climate change will affect different groups of people in these different countries.

Use your research to make a recommendation about which action should be taken.

Websites with useful information about climate change include:
- The Met Office
- NASA
- FCO

Search for ‘climate change’ on these websites.
Then plug in a microphone and talk into it. Show that the signal is very irregular. Now explain that what happens in a radio broadcast is that the sound signal is used to modulate the carrier wave, and that it is this modulation that is detected and turned back into sound in the radio receiver. (You may choose to add that the modulation can either be of the wave amplitude, as shown in the Student Book (AM) or of the wave frequency (FM).)

**Plenary suggestions**
Students summarise three key points from the lesson and share them with their partners.

**Student Book answers**
Q1 Radio waves; microwaves; infrared radiation; visible light.
Q2 Carry infrared or visible light signals very long distances without the radiation being absorbed.
Q3 Cannot travel long distances in air so would not reach the satellite.
Q4 The carrier wave frequency.
Q5 So they can broadcast at the same time without interfering with one another.
Q6 Still match the shape of the sound signal it is transmitting; the carrier waves (shown in blue) would have a longer wavelength.

**Worksheet answers**

**Activity 1 (Low demand)**
Q1 Radio waves; microwaves; infrared; visible.
Q2 Lower frequency and energy.

**Activity 2 (Standard demand)**
Q1 *Radio waves*: radio, terrestrial TV  
   *Microwaves*: mobile phone, satnav, satellite TV  
   *Infrared*: remote control, cable TV, land line telephone, automatic sensor  
   *Visible*: warning light
Q2 Radio waves and microwaves.

**Activity 3 (High demand)**
Student’s diagrams should show the waves before modulation, after modulation and after decoding (along the lines of Figure 3 on Student Book p. 255) and with clear annotation.

**Practical sheet answers**
Independent variable – thickness of material; dependent variable – if the infrared is absorbed or not; control variables – type of material; distance from TV; the remote controller used; how the readings are taken.
Possible method: Point the remote control straight at the TV from a distance of 2 m. Check that the TV can receive the signal. Put a 2 cm thick sample of the material directly in front of the remote control. The two should be very close and the signal must travel through the material. Check if the TV receives the signal. Increase the sample thickness by 2 cm each time until the signal is no longer received. Repeat with another material.
1 Waves and communication

1 Tick the types of electromagnetic radiation that are used for communication.

<table>
<thead>
<tr>
<th>Low frequency and energy</th>
<th>radio waves</th>
<th>microwaves</th>
<th>infrared</th>
<th>visible</th>
<th>ultraviolet</th>
<th>X-rays</th>
<th>gamma rays</th>
</tr>
</thead>
<tbody>
<tr>
<td>High frequency and energy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2 Do forms of electromagnetic radiation used for communication have higher or lower frequency and energy than other forms of electromagnetic radiation?

………………………………………………………………………………………………………………..

2 Using waves for communicating

1 For each form of electromagnetic radiation that you ticked in activity 1, write in the right-hand column the types of communication that use it. Choose from the list below or from the items your teacher displays.

- mobile phone
- remote control
- cable TV
- radio
- satellite TV
- landline phone
- automatic sensor
- terrestrial TV
- satnav
- warning light

2 Which forms of electromagnetic of radiation are used to transfer signals very large distances without using cables?

………………………………………………………………………………………………………………..

3 Radio broadcasts

Imagine that a friend missed the lesson on radio communications and told you that they didn’t understand about carrier waves and modulation. Design a diagram that shows:

- how the sound signal coming from a radio newsreader’s microphone is combined with a carrier wave
- how when broadcast this combined signal is decoded by the radio so the news can be heard.

Your diagram should be easily understood and show clearly where the waves are combined and separated.
1 State whether each picture shows an analogue signal or a digital signal.

<table>
<thead>
<tr>
<th>Signal</th>
<th>Digital or analogue?</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Signal 1" /></td>
<td></td>
</tr>
<tr>
<td><img src="image2.png" alt="Signal 2" /></td>
<td></td>
</tr>
<tr>
<td><img src="image3.png" alt="Signal 3" /></td>
<td></td>
</tr>
<tr>
<td><img src="image4.png" alt="Signal 4" /></td>
<td></td>
</tr>
<tr>
<td><img src="image5.png" alt="Signal 5" /></td>
<td></td>
</tr>
</tbody>
</table>

2 Explain how you can tell if a signal is digital.

3 Explain why the information in a digital signal is easier to interpret accurately than an analogue signal.
2 Changing analogue signals to digital signals

A person singing creates a continuously changing analogue signal. When the song is recorded and broadcast as a digital file:

- the analogue signal is measured at equal time intervals
- these measurements are recorded as a series of numbers
- these numbers are changed into codes – strings of 1s and 0s
- these digital codes are transmitted using electromagnetic waves that turn on and off, matching this sequence (1 is on, 0 is off)
- when these pulses are received, a decoder converts the digital numbers into the original numbers
- the original music is recreated using these numbers.

1. Why must the analogue signal be measured many, many times during the song?
2. Why are measurements changed into codes before transmitting the signal with electromagnetic waves?
3. What is the job of the decoder?
4. Why isn't the broadcast song exactly like the original song?

3 Comparing analogue and digital signals

Unwanted signals that get mixed in with the original signal are called ‘noise’.

The quality of analogue signals is worse after copying or transmission because the noise is copied or transmitted along with the original information. The whole signal is amplified, including the noise, because it is hard to clean up the noise.

The quality of digital signals stays the same after copying or transmission because noise is easier to recognise and remove during the process.

Investigate and compare some analogue signals/data and some digital signals/data. Listen to some recordings and look at some images. Think about which part of the signal or image matches the original, and which is due to noise.

Suggestions:

- Compare a cassette/vinyl recording with a CD/MP3 recording.
- Compare a photocopied image with the original image.
- Compare a computer printout with the original image.
- Are the methods of reproduction analogue or digital? Describe the quality.
- Amplify the sound / enlarge the image. Describe the quality now.

1. Explain what ‘noise’ is.
2. Describe how the noise affects analogue recording(s) and image(s).
3. Use your ideas about analogue and digital signals to explain why digital signals can have noise removed but analogue signals cannot.
disadvantages and give their opinion on whether the decision is the right one or not. The main broadcasters (e.g. BBC, ITV, Channel 4) all provide information about the switchover. Also, local and national news reports from the time of the switchover contain useful facts that will still be available after the switchover is complete.

**Plenary suggestions**

Students think of an answer to this question (they could discuss in small groups): how important has the development of digital data storage and processing been?

**Student Book answers**

- Q1 The amount of digital information in the form of binary digits (1 byte = 8 digits).
- Q2 7 bytes; one byte per letter).
- Q3 When more data is stored, the quality of an image improves.
- Q4 We can store more data on devices than previously.
- Q5 Can be processed by computer and changed into different forms, e.g. sound, text; it can be stored and sent between different devices.
- Q6 Can be shared by users and transmitted (e.g. by email) and used on different computers for different purposes.

**Worksheet answers**

**Activity 1 (Low demand)**

- Q1 A: 384; B: 96
- Q2 A: 384; B: 96
- Q3 A; the picture on the smallest grid size
- Q4 Higher-quality images use more pixels.

**Activity 2 (Standard demand)**

- Generally the software can edit files in these formats – MP3, WMA, WAV, OGG, Windows Media.
- The software can record new files from different input devices such as microphone, sound card etc; it can edit the file (cut, paste, copy, delete, mix, etc.) and can apply different effects (e.g. delay, fade, etc.); it can save files onto different devices (e.g. CDs).
- People who could use this include DJs, radio and TV sound engineers, music technicians, etc.

**Activity 3 (High demand)**

The report should include points like these:

- Viewers – bigger range of programmes; better quality; more interactivity; but may need to upgrade equipment and retune; may not receive a strong signal.
- Broadcasters – opportunity to broadcast more programmes; can broadcast several simultaneous events, e.g. sports events.
- Manufacturers and retailers – more sales as people need to upgrade; some stock becomes obsolete.
- The country as a whole – enables the UK to compete internationally in the field.
- Overall – beneficial for the majority of people, but some people will be forced to invest in costly new equipment and some may have a weaker signal than before.
1 Pixels

Colour in each picture, but colour the whole of each grid square just one colour.

For each picture, count how many squares the image and its background occupy.

A: .......... squares  B: .......... squares

1 Information is stored on computers in bytes. If each square in the pictures needs one byte of data to record its colour, how many bytes of data would be used to store each picture?

A: .......... bytes  B: .......... bytes

2 Which picture is more detailed? ........

3 Each square on your picture corresponds to one pixel of a digital image. For a better quality of image, what can you say about the number of pixels needed?

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2 Storing and editing sound

Sound-editing software can be used on a computer to process sound files. The software allows sections of the recording to be removed, reordered, altered and saved in different file formats.

Investigate one sound-editing package and prepare an information sheet suitable for a new user.

Describe:
- the types of file it can be used with
- key functions of the software (how it can modify the sound file)
- who may find these features useful.

Include at least one image to explain a feature – and if you are producing your information on a computer, try to include a sound track as an example.

3 Advantages of digital TV

The ‘big switchover’ to digital TV means that all TV broadcasts will be digital.

Research the reasons for the switchover, and prepare a short report that explains the advantages and possible disadvantages for different groups of people.

Include a decision on whether, in your opinion, changing to digital TV is a good thing.

You should consider the impact on:
- viewers in different parts of the country
- broadcasters
- manufacturers and retailers of TV equipment
- the country as a whole, for example its status in the world, its economy, etc.