Electromagnetic Waves

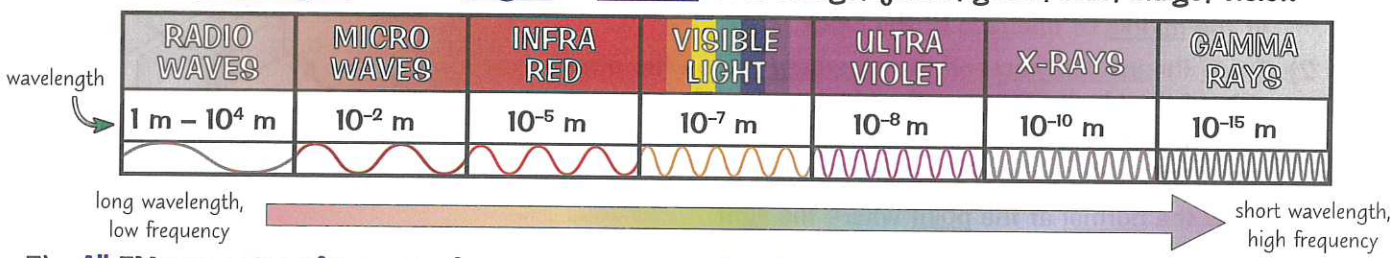
You've learned a lot about light so far, but light's just one small part of the EM spectrum...

There's a Continuous Spectrum of EM Waves

1) Electromagnetic (EM) waves are transverse waves (p.164).
2) They all travel at the same speed through a vacuum (space). But they travel at different speeds in different materials (which can lead to refraction, p.166).

Electromagnetic waves aren't vibrations of particles, they're vibrations of electric and magnetic (p.195) fields. This means they can travel through a vacuum.

3) EM waves vary in wavelength from around 10^{-15} m to more than 10^{4} m.
4) We group them based on their wavelength and frequency — there are seven basic types, but the different groups merge to form a continuous spectrum.
5) EM waves are generated by a variety of changes in atoms and their nuclei, giving a large range of frequencies. E.g. changes in the nucleus of an atom create gamma rays (p.174) and visible light is often produced by changes in an electron's energy level (p.173). This also explains why atoms can absorb a range of frequencies — each one causes a different change.
6) Our eyes can only detect a small part of this spectrum — visible light. Different colours of light have different wavelengths — from longest to shortest: red, orange, yellow, green, blue, indigo, violet.



7) All EM waves transfer energy from a source to an absorber. For example, when you warm yourself by an electric heater, infrared waves transfer energy from the thermal energy store of the heater (the source) to your thermal energy store (the absorber).
8) The higher the frequency of the EM wave, the more energy it transfers (and so the more dangerous it is for humans — see below).

Different EM Waves Have Different Properties

EM waves are sometimes called EM radiation.

As you saw on p.166, when EM waves meet a boundary they can be absorbed, transmitted, refracted or reflected. What happens depends on the materials at the boundary and the wavelength of the EM wave — e.g. some materials absorb some wavelengths of light but reflect others. This is what causes things to be a certain colour.

Differences in how EM waves are transmitted, reflected and absorbed have implications for human health:

1) Radio waves are transmitted through the body without being absorbed.
2) Some wavelengths of microwaves can be absorbed, causing heating of cells, which may be dangerous.
3) Infrared (IR) and visible light are mostly reflected or absorbed by the skin, causing some heating too. IR can cause burns if the skin gets too hot.
4) Ultraviolet (UV) is also absorbed by the skin. But it has a higher frequency, so it is potentially more dangerous. It's a type of ionising radiation (p.173) and when absorbed it can cause damage to cells on the surface of your skin, which could lead to skin cancer. It can also damage your eyes and cause a variety of eye conditions or even blindness.

Most of the UV radiation produced by the Sun that hits the Earth's atmosphere gets absorbed.

5) X-rays and gamma rays are also ionising, so they can cause mutations and damage cells too (which can lead to cancer). But they have even higher frequencies, so transfer even more energy, causing even more damage. They can also pass through the skin and be absorbed by deeper tissues.

Learn about the EM spectrum and wave goodbye to exam woe...

Here's a handy mnemonic for the order of EM waves: 'Rock Music Is Very Useful for eXperiments with Goats'.

Q1 Explain why gamma rays are more dangerous to humans than visible light. [2 marks]

Electromagnetic Waves

Warm-Up

For each sentence, circle whether it is true or false.

All electromagnetic waves are transverse. **True / False**

All electromagnetic waves travel at the same speed in a vacuum. **True / False**

Human eyes can detect a large part of the electromagnetic spectrum. **True / False**

1 **Figure 1** is an incomplete table describing the energies of different types of radiation in the electromagnetic spectrum. Grade 4-6

Figure 1

Low Energy						High Energy
Radio Waves	Microwaves	.....	Visible Light	Ultraviolet	.....	Gamma Rays

a) Complete **Figure 1** by filling in the missing types of electromagnetic radiation.

[2]

b) Draw an arrow beneath **Figure 1** that points from the type of electromagnetic radiation with the shortest wavelength towards the type with the longest wavelength.

[1]

c) The visible light section of the electromagnetic spectrum can be split further into the bands of wavelengths that make up each colour. Complete the list in **Figure 2**, which lists the colours of visible light in terms of increasing wavelength.

Figure 2

Red, Orange, ... , ... , ... , ... , Violet

[2]

d) Electromagnetic waves can be generated by changes within atoms. State which part of the atom can generate gamma rays.

.....

[1]

[Total 7 marks]

2 Some types of electromagnetic wave can be harmful to people. Grade 6-7

a) Describe how the potential danger an electromagnetic wave poses to a person varies with its frequency.

.....

[1]

b) Draw lines to match the types of electromagnetic radiation on the left to their potential side effects on the right.

Infrared	internal heating of cells
Microwaves	skin burns
X-rays	cell mutation and cancer

[1]

c) Another type of harmful electromagnetic radiation is ultraviolet radiation. Give **two** damaging effects of ultraviolet light.

1. .....

2. .....

[2]

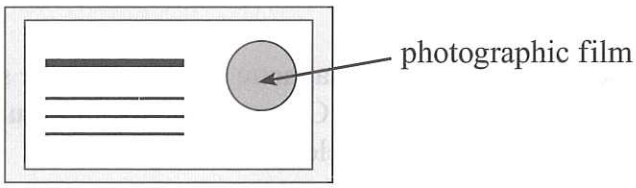
[Total 4 marks]

3 X-rays are used in hospitals to diagnose broken bones. Grade 6–7

The X-rays are generated by accelerating electrons to high speeds then firing them at a metal plate. When the electrons hit the plate, X-rays are produced.

Staff who work with X-ray machines wear badges that monitor the levels of radiation they have been exposed to, shown in **Figure 3**. These badges contain a photographic film which undergoes a chemical change when exposed to X-rays.

Figure 3



a) i) Energy is transferred when the X-rays cause the chemical reaction in the badge. State the source and observer for this energy transfer.

.....

[1]

ii) Describe the energy transfers involved in this process, from source to observer.

.....

.....

[2]

b) Give **one** other example of electromagnetic waves transferring energy from a source to an observer.

.....

.....

[1]

[Total 4 marks]