

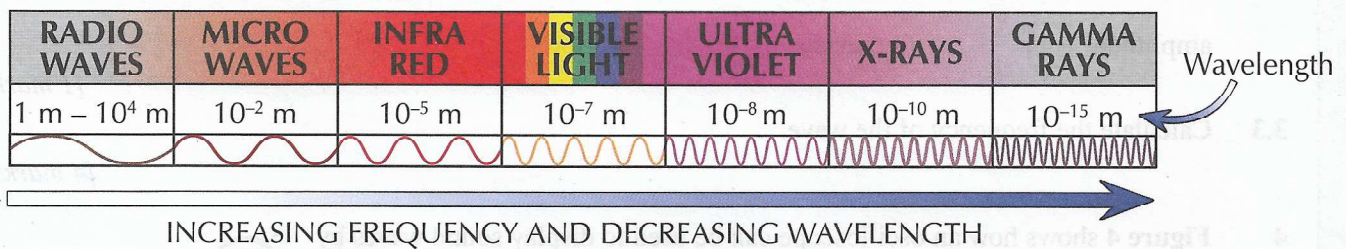
Electromagnetic Waves and Uses of EM Waves

The differences between types of electromagnetic (EM) waves make them useful to us in different ways.

There's a Continuous Spectrum of EM Waves

- 1) All EM waves are transverse waves (p.127) that transfer energy from a source to an absorber. E.g. a hot object transfers energy by emitting infrared radiation, which is absorbed by the surrounding air.
- 2) All EM waves travel at the same speed through air or a vacuum (space).
- 3) Electromagnetic waves form a continuous spectrum over a range of frequencies. They're grouped into seven basic types, based on their wavelength and frequency.

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

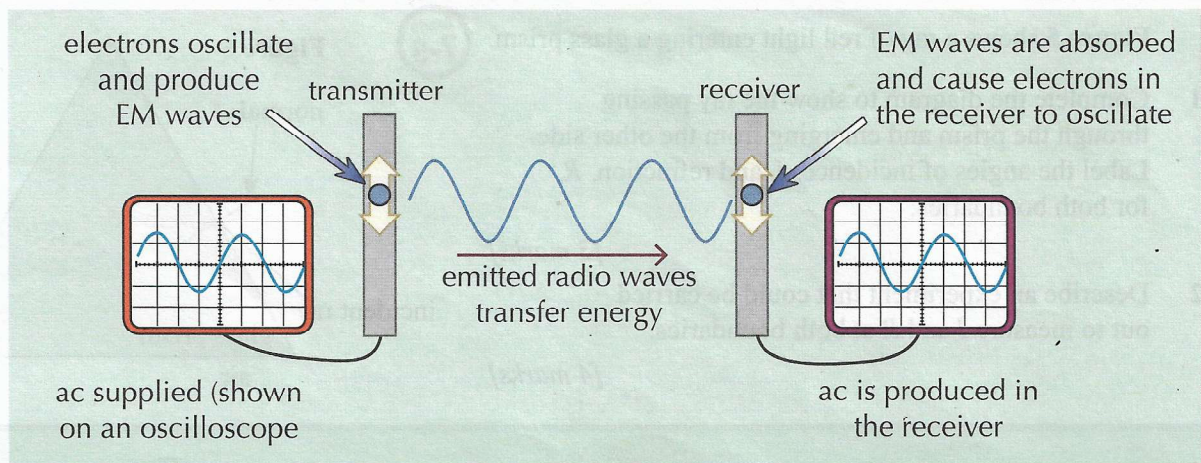


- 4) There is such a large range of frequencies because EM waves are generated by a variety of changes in atoms and their nuclei. E.g. changes in the nucleus of an atom creates gamma rays (p.75). This also explains why atoms can absorb a range of frequencies — each one causes a different change.
- 5) Because of their different properties, different EM waves are used for different purposes.

Radio Waves are Made by Oscillating Charges

- 1) EM waves are made up of oscillating electric and magnetic fields.
- 2) Alternating currents (ac) (p.52) are made up of oscillating charges. As the charges oscillate, they produce oscillating electric and magnetic fields, i.e. electromagnetic waves.
- 3) The frequency of the waves produced will be equal to the frequency of the alternating current.
- 4) You can produce radio waves using an alternating current in an electrical circuit. The object in which charges (electrons) oscillate to create the radio waves is called a transmitter.
- 5) When transmitted radio waves reach a receiver, the radio waves are absorbed.
- 6) The energy transferred by the waves is transferred to the electrons in the material of the receiver.
- 7) This energy causes the electrons to oscillate and, if the receiver is part of a complete electrical circuit, it generates an alternating current (p.52).
- 8) This current has the same frequency as the radio waves that generated it.

Head on over to page 52 for more on ac.



Radio Waves are Used Mainly for Communication

-
- short-wave signals reflect off the ionosphere
- ionosphere
- long-wave signals diffract (bend) around the Earth
- FM radio and TV signals must be in line of sight

Microwaves are Used by Satellites

For satellite TV, the signal from a transmitter is transmitted into space...

satellite above Earth's atmosphere

microwaves sent to satellite

microwaves sent back to Earth

cloud and water vapour

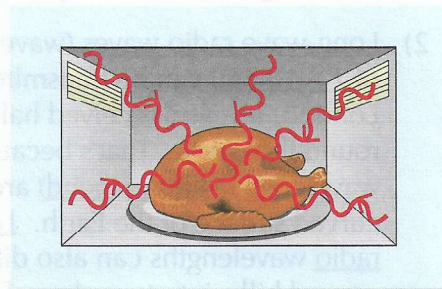
Topic 6 — Waves

Uses of EM Waves

Each type of EM wave covers a spectrum of wavelengths and frequencies itself. So the properties of, say, a microwave from one end of the range may differ from those of a microwave from the other end of the range.

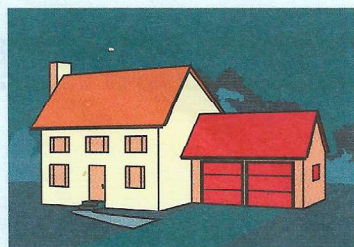
Microwave Ovens Use a Different Wavelength from Satellites

- 1) In communications, the microwaves used need to pass through the Earth's watery atmosphere.
- 2) In microwave ovens, the microwaves need to be absorbed by water molecules in food — so they use a different wavelength to those used in satellite communications.
- 3) The microwaves penetrate up to a few centimetres into the food before being absorbed and transferring the energy they are carrying to the water molecules in the food, causing the water to heat up.
- 4) The water molecules then transfer this energy to the rest of the molecules in the food by heating — which quickly cooks the food.



Infrared Radiation Can be Used to Monitor Temperature...

- 1) Infrared (IR) radiation is given out by all objects — and the hotter the object, the more IR radiation it gives out.
- 2) Infrared cameras can be used to detect infrared radiation and monitor temperature. The camera detects the IR radiation and turns it into an electrical signal, which is displayed on a screen as a picture. The hotter an object is, the brighter it appears. E.g. energy transfer from a house's thermal energy store can be detected using infrared cameras.



Different colours represent different amounts of IR radiation being detected. Here, the redder the colour, the more infrared radiation is being detected.

...Or Increase it

- 1) Absorbing IR radiation causes objects to get hotter. Food can be cooked using IR radiation — the temperature of the food increases when it absorbs IR radiation, e.g. from a toaster's heating element.
- 2) Electric heaters heat a room in the same way. Electric heaters contain a long piece of wire that heats up when a current flows through it. This wire then emits lots of infrared radiation (and a little visible light — the wire glows). The emitted IR radiation is absorbed by objects and the air in the room — energy is transferred by the IR waves to the thermal energy stores of the objects, causing their temperature to increase.

The uses of EM waves depend on their properties...

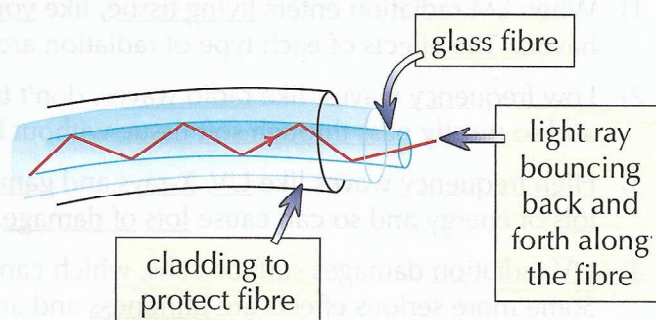
Differences in wavelength, frequency and energy between types of EM wave give them different properties. For example, some types of EM wave are very harmful (see page 140). Luckily, radio waves are considered safe to beam round the world. IR radiation is generally fairly safe, although too much of it will burn you.

Uses of EM Waves

Here are just a few more uses of EM waves — complete with the all-important reasons why they're used.

Fibre Optic Cables Use Visible Light to Transmit Data

- 1) Optical fibres are thin glass or plastic fibres that can carry data (e.g. from telephones or computers) over long distances as pulses of visible light.
- 2) They work because of reflection (p.130). The light rays are bounced back and forth until they reach the end of the fibre.
- 3) Light is not easily absorbed or scattered as it travels along a fibre.

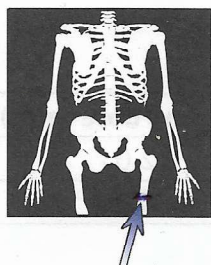


Ultraviolet Radiation Gives You a Suntan

- 1) Fluorescence is a property of certain chemicals, where ultra-violet (UV) radiation is absorbed and then visible light is emitted. That's why fluorescent colours look so bright — they actually emit light.
- 2) Fluorescent lights generate UV radiation, which is absorbed and re-emitted as visible light by a layer of phosphorus on the inside of the bulb. They're energy-efficient (p.28) so they're good to use when light is needed for long periods (like in your classroom).
- 3) Security pens can be used to mark property with your name (e.g. laptops). Under UV light the ink will glow (fluoresce), but it's invisible otherwise. This can help the police identify your property if it's stolen.
- 4) Ultraviolet radiation (UV) is produced by the Sun, and exposure to it is what gives people a suntan.
- 5) When it's not sunny, some people go to tanning salons where UV lamps are used to give them an artificial suntan. However, overexposure to UV radiation can be dangerous (fluorescent lights emit very little UV — they're totally safe).

There's more on the dangers of UV on p.140.

X-rays and Gamma Rays are Used in Medicine



The brighter bits are where fewer X-rays get through.
This is a negative image.
The plate starts off all white.

There's more on gamma rays on p.75.

- 1) Radiographers in hospitals take X-ray 'photographs' of people to see if they have any broken bones.
- 2) X-rays pass easily through flesh but not so easily through denser material like bones or metal. So it's the amount of radiation that's absorbed (or not absorbed) that gives you an X-ray image.
- 3) Radiographers use X-rays and gamma rays to treat people with cancer (radiotherapy). This is because high doses of these rays kill all living cells — so they are carefully directed towards cancer cells, to avoid killing too many normal, healthy cells.
- 4) Gamma radiation can also be used as a medical tracer (p.83) — this is where a gamma-emitting source is injected into the patient, and its progress is followed around the body. Gamma radiation is well suited to this because it can pass out through the body to be detected.
- 5) Both X-rays and gamma rays can be harmful to people (p.140), so radiographers wear lead aprons and stand behind a lead screen or leave the room to keep their exposure to them to a minimum.

Dangers of Electromagnetic Waves

Okay, so you know how useful electromagnetic radiation can be — well, it can also be pretty dangerous.

Some EM Radiation Can be Harmful to People

- 1) When EM radiation enters living tissue, like you, it's often harmless, but sometimes it creates havoc. The effects of each type of radiation are based on how much energy the wave transfers.
- 2) Low frequency waves, like radio waves, don't transfer much energy and so mostly pass through soft tissue without being absorbed.
- 3) High frequency waves like UV, X-rays and gamma rays all transfer lots of energy and so can cause lots of damage.
- 4) UV radiation damages surface cells, which can lead to sunburn and cause skin to age prematurely. Some more serious effects are blindness and an increased risk of skin cancer.
- 5) X-rays and gamma rays are types of ionising radiation. (They carry enough energy to knock electrons off of atoms.) This can cause gene mutation or cell destruction, and cancer.

You Can Measure Risk Using the Radiation Dose in Sieverts

- 1) Whilst UV radiation, X-rays and gamma rays can all be harmful, they are also very useful (see pages 83 and 139). Before any of these types of EM radiation are used, people look at whether the benefits outweigh the health risks.
- 2) For example, the risk of a person involved in a car accident then developing cancer from having an X-ray photograph taken, is much smaller than the potential health risk of not finding and treating their injuries.
- 3) Radiation dose (measured in sieverts) is a measure of the risk of harm from the body being exposed to radiation.
- 4) This is not a measure of the total amount of radiation that has been absorbed.
- 5) The risk depends on the total amount of radiation absorbed and how harmful the type of radiation is.
- 6) A sievert is pretty big, so you'll often see doses in millisieverts (mSv), where $1000 \text{ mSv} = 1 \text{ Sv}$.

Radiation doses can be calculated for all types of radiation, not just UV, X-rays and gamma rays.

Risk can be Different for Different Parts of the Body

A CT scan uses X-rays and a computer to build up a picture of the inside of a patient's body. The table shows the radiation dose received by two different parts of a patient's body when having CT scans.

	Radiation dose (mSv)
Head	2.0
Chest	8.0

If a patient has a CT scan on their chest, they are four times more likely to suffer damage to their genes (and their added risk of harm is four times higher) than if they had a head scan.

The risks and benefits of radiation exposure must be balanced...

Ionising radiation can be dangerous, but the risk can be worth taking. From 1920-1970, X-ray machines were installed in shoe shops for use in shoe fittings. But when people realised radiation was harmful, they were phased out. The risks far outweighed the benefits of using X-rays rather than tape measures...