Hazards of Electromagnetic Waves
Hazards of Electromagnetic Waves

- Ionising radiation
  - X-rays and gamma rays
  - Ultraviolet radiation
  - Other electromagnetic waves
- Summary activities
How do EM waves interact with matter?

Changes in atoms or the nuclei of atoms can result in the emission of **electromagnetic radiation** over a wide range of frequencies. Changes in the nuclei of atoms cause the emission of high frequency **gamma rays**.

The reverse of this also happens: if an atom **absorbs** EM radiation, it can result in a change in the atom or nucleus.

This means that electromagnetic waves can have hazardous effects on body cells. EM waves with high frequencies have high energies, so are able to cause the most damage. If a wave has enough energy, it can remove the outer electrons from atoms. This is called **ionisation**.
How do ionising waves affect humans?

Ionising waves have enough energy to ionise the atoms in materials. These waves can have a severe effect on living tissue by killing cells or damaging DNA.

- **Ultraviolet (UV) rays** are absorbed by the body. Skin tissues can be ionised and damaged by the shortest-wavelength ultraviolet radiation causing skin cancer.

- **X-rays** pass through soft body tissue, such as skin and muscle, without being absorbed. Denser tissue, such as bone, absorbs some X-rays and can be ionised.

- **Gamma rays** pass through the body but very high energy waves can ionise atoms in living tissue.
Ionising waves, such as gamma rays, can damage the DNA in cells and even kill cells. The risk that exposure to radiation presents can be measured using the **radiation dose**.

Radiation dose is measured in sieverts (Sv) or **millisievers** (mSv). $1000\text{mSv} = 1\text{Sv}$.

A very high dose of gamma rays in a short time can be fatal. A low dose over a long period of time will increase the risk of a person developing cancer.

The average person in the UK receives a dose of about 2.7 mSv from **background radiation**. The International Commission on Radiological Protection sets a limit of 20 mSv per year for workers in the nuclear industry.
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Hazards of X-rays and gamma rays
How are X-ray images taken safely?

Precautions must be used when X-ray images are taken.

Only the area of the body being examined is targeted with X-rays. Other areas are protected with a lead shield, which is too dense for X-rays to pass through.

One-off X-rays do not pose much risk to health. Radiographers take several X-rays each day and their potential dose is much higher.

To minimise their exposure when an X-ray image is being taken, radiographers must wear a lead apron, stand behind a screen that absorbs X-rays or even leave the room.
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How does UV radiation affect skin?

The skin uses UV radiation from the Sun to make vitamin D, which is needed for strong bones. Some exposure to UV radiation is beneficial but overexposure is generally harmful.

**Sunburn** occurs when the skin is exposed to high-intensity UV radiation, which damages skin cells. Repeated exposure leads to premature ageing of the skin and increases the risk of skin cancer.

Intense UV radiation can inflame the eyes and long-term exposure may cause cataracts.
Dark or fair skin?

Dark skin contains more **melanin** than light skin. Melanin is the body’s natural defence against UV radiation.

Melanin absorbs some of the UV before it can penetrate the top layers of the skin and damage cells underneath.

**Melanoma** is a dangerous form of skin cancer that forms in the melanin-producing cells of the skin.
Is a suntan safe?

Some people think that a suntan is safe and makes them look healthy. In fact, a **suntan** is a sign of UV damage. It is the skin’s attempt to protect cells from further damage by creating its own sunscreen.

Not all skin types can tan: skin that is easily sunburnt is most at risk from UV damage. A suntan only provides some protection, and naturally dark or tanned skin can still suffer sunburn.

Everyone, regardless of skin type, is at risk from eye damage caused by UV radiation.
Limiting exposure to UV radiation

Prolonged exposure to UV radiation carries serious health risks and so protection is important.

A combination of measures can protect skin and eyes from UV radiation:

- cover up, wear a wide-brimmed hat and sunglasses, and stay in the shade.
- apply **sunblock** or **sunscreen**. They should be applied to the skin generously and often when out in the sun.

Protection is essential for workers who are routinely exposed to UV radiation. Welders must use a head shield to protect their eyes and wear thick clothing to protect their skin.
Investigating sunscreens
SPF and safe time in the Sun

Sun Protection Factor (SPF) is a number used by sunscreen manufacturers to indicate how much longer you can stay out in the sun before getting burnt.

safe time in sun = SPF × burn time with no sunscreen

The sun index appears on weather reports, and gives a rough idea of the intensity of UV from the sun on a given day.

<table>
<thead>
<tr>
<th>sun index</th>
<th>risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>1–2</td>
<td>low</td>
</tr>
<tr>
<td>3–4</td>
<td>avoid being out for more than 1–2 hours</td>
</tr>
<tr>
<td>5–6</td>
<td>burns in 30–60 mins</td>
</tr>
<tr>
<td>7–10</td>
<td>severe burns in 20–30 mins</td>
</tr>
</tbody>
</table>
Voluntary exposure to UV radiation
UV radiation: fact or opinion?
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Radio waves are the longest-wavelength electromagnetic waves and mostly pass through the body.

They are not strongly absorbed and are thought to have no effect on the health of living tissue.

Microwaves are radio waves with short wavelengths. They are very slightly absorbed by the body and can cause a minor heating effect.

However, the microwaves produced by mobile phones have not yet been proved to cause health problems.
**How do infrared waves affect humans?**

**Infrared** (IR) waves are absorbed by skin to a limited depth. They transfer their energy to the skin tissue warming it up.

This heating effect is detected by temperature-sensitive nerve endings in the skin.

Infrared waves from this grill heat the surface of the meat. If the meat absorbs too much energy, it will become burnt.

If skin is exposed to too many high-energy infrared waves, it will become burnt.
How does visible light affect humans?

Your eyes detect visible light, which does not normally pose any health risk.

However, very bright light can damage your eyes and may even make you blind. This is why you should not look at the Sun through a telescope or binoculars.

Lasers are very intense sources of visible light. The lasers used in light shows are not powerful enough to cause harm but must be used safely.

Some very powerful lasers can cut through materials such as metal. These would also be able to burn through living tissue.
Effect of electromagnetic waves
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Multiple-choice quiz