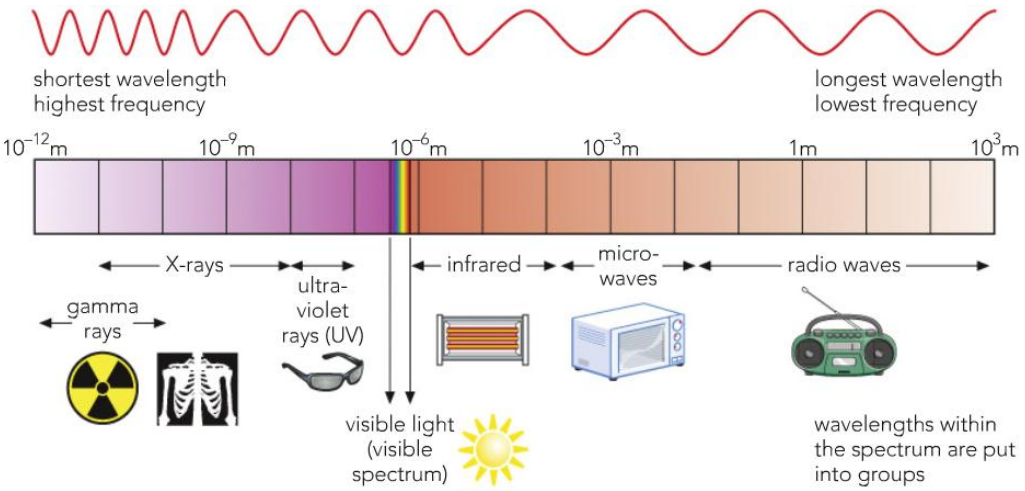
Topic 2 – The Electromagnetic Spectrum

- **BEYOND THE VISIBLE**
- Spectrum of visible light in order:
    - Red (longest wavelength, lowest frequency)→orange→yellow→green →blue→indigo→violet (shortest wavelength, highest frequency)
- **The discovery of infrared:**
- The astronomer William Herschel put coloured filters on his telescope to observe the Sun safely
- He noticed that different coloured filters heated up his telescope to different extents→he wondered whether different colours of light contained different amounts of heat:
    - To test this, Herschel used a prism to split sunlight into a spectrum and then put a thermometer in each of the colours
    - He found that as he changed the colour from violet→indigo→blue→ green→yellow→orange→red, the temperature increased
- Herschel then measured the temperature just beyond the red end of the spectrum, where there was no visible light, and found this gave the highest temperature
- This band of invisible light beyond the red spectrum is called infrared radiation (IR)
- **Going beyond violet:**
- Johann Ritter found out about Herschel's work and set about trying to find 'invisible rays' at the other end of the spectrum (i.e violet end)
- He used silver chloride, a chemical that breaks down to give a black colour when exposed to light
    - It was already known that silver chloride turned black more quickly in violet light than in red light
- Ritter showed that silver chloride turned black even faster when exposed to 'invisible rays' just beyond violet
- These 'invisible rays' were later called ultraviolet waves (ultraviolet radiation, UV)
- **Electromagnetic waves:**
- Visible light, IR and UV are all types of electromagnetic radiation
- The electromagnetic vibrations are at right angles to the direction in which the energy is being transferred by the wave→they are transverse waves
- **THE ELECTROMAGNETIC SPECTRUM**
- Electromagnetic waves can travel without any particles to vibrate→can travel through a vacuum, such as space
- All electromagnetic waves travel at 300,000 km/s in a vacuum – the fastest speed anything can move
- The full range of electromagnetic waves is called the electromagnetic spectrum
- Although continuous, the spectrum is conveniently divided into 7 major groups:
    - They are grouped according to the wavelength and frequency of the waves
    - Gamma rays (shortest wavelength, highest frequency)→x-rays→UV→ visible light (violet, indigo, blue, green, yellow, orange, red)→IR→ microwaves→radio waves (longest wavelength, lowest frequency)
    - So, compared to visible light:
        - UV: shorter wavelength, higher frequency waves
        - IR: longer wavelength, lower frequency waves

- Visible light waves are the only ones visible to the human eye



- Modern astronomy tries to observe stars and galaxies by detecting various parts of the electromagnetic spectrum they give off:
  - E.g the Hubble Space telescope can detect visible light, UV and IR
- **DANGERS OF ELECTROMAGNETIC WAVES**
- Microwaves:
  - The microwave frequency that can heat water is used in microwave ovens
  - Humans are mostly water→microwaves can cause internal heating of body cells - potentially dangerous. This is why microwave ovens have shields in them to stop the waves escaping
  - Mobile phones signal using microwaves, but use different frequencies→do not pose a health risk
- IR radiation:
  - Our skin absorbs IR, which we feel as heat (remember from Herschel's experiment that IR had higher temperature than visible spectrum)
  - Too much IR can damage or destroy cells→burns to skin
- All waves transfer energy. However, higher frequency waves transfer more energy (have greater <u>penetration)</u> →are potentially more dangerous…
- UV radiation:
  - Sunlight contains UV, which carries more energy than visible radiation
  - The energy transferred by UV to our cells can damage their DNA
  - Too much exposure to sunlight (UV)→skin cancer
  - UV in sunlight can also damage eyes (→cataracts…clouding of the lens, reducing vision)
  - →to protect yourself from UV radiation, you should put sun cream on and wear sunglasses
- X-rays and gamma rays:
  - These waves have higher frequency than UV, carrying even more energy
  - Excessive exposure to x-rays or gamma rays may cause genetic mutations in DNA→cancer
- **USES OF ELECTROMAGNETIC RADIATION**
- **Illumination, vision and photography:**
- Visible light is necessary for illumination, vision and photography

    - E.g the EURion pattern on banknotes (prevents digital copying) can be seen when illuminated because it reflects certain wavelengths of visible light
- **Security:**
- UV:
    - Some materials absorb UV radiation and re-emit it as visible light – this is called fluorescence
    - Fluorescence is used to check banknotes – real banknotes fluoresce when UV light is shone onto them
    - Some security lights use fluorescent lamps – these produce UV waves and use a fluorescent material on the inside of the bulb glass
- X-ray:
    - X-ray scanners are used in airports to detect objects hidden on the body as well as in luggage
    - Both x-rays and gamma rays can penetrate the body, but x-rays transfer less energy than gamma rays→are safer...
        - →x-rays are used in hospitals to detect broken bones
- IR radiation:
    - All warm objects give off some heat as IR radiation
    - CCTV cameras that detect IR are used to watch people at night – this is called thermal imaging
    - IR radiation can pass through fog→it's useful in daytime too
- **Communications:**
- Radio waves and microwaves:
    - Both radio waves and microwaves carry TV signals
    - Wi-fi wireless connections for computers use radiowaves
    - Mobile phone signals use microwaves
- IR radiation:
    - IR waves carry signals a short distance from remote controls to devices like TVs
    - IR signals are also sent down optical fibre cables for telephone and internet communications
- **Food and medicine:**
- Gamma rays:
    - 1. Gamma rays transfer a lot of energy which can kill cells (including those of bacteria/ microorganisms)→are used to sterilise food and surgical instruments
    - 2. They are also used also to kill cancer cells in radiotherapy (gamma rays are <u>aimed</u> at the cancer cells so damage to normal cells is limited)
    - 3. They can also detect cancer:
        - A chemical that emits gamma rays is injected into the blood
        - The chemical is designed to collect inside cancer cells
        - A scanner then locates the cancer by finding the source of the gamma rays
- UV radiation:
    - UV radiation can kill bacteria→used to disinfect water and sewage
- **IONISING RADIATION**
- **Gamma rays:**

- Gamma rays are ionising radiation – i.e they can remove electrons from atoms to form ions
- Ions are very reactive→if atoms in the cell are ionised, the reactions that follow can damage DNA (this is how gamma rays can cause cancer)
- Some elements naturally emit gamma radiation all the time (e.g radium) – such elements are said to be radioactive
- **Alpha and beta particles:**
- Not all substances emit gamma (γ) waves…others emit alpha (α) and beta (β) particles. Some e.g plutonium give off all three types
- Alpha and beta are particles of matter with a lot of kinetic energy
- This energy can ionise atoms→alpha and beta particles are also types of ionising radiation
- →like gamma rays, alpha and beta particles can damage DNA inside cells
- However, unlike gamma rays, they are not electromagnetic radiation