Chapter 4 Ionising Radiation

The spectrum of radiation

So what exactly is radiation? The simplest answer is that it is energy on the move – and there are many kinds. Sunshine, music and waves on the surface of water are examples. At low levels many are quite harmless and even beneficial to life. Extreme levels can cause damage in almost every case – very loud music can damage hearing, and too much sun causes sunburn. However, a little sunshine is positively good for the skin by promoting the production of important vitamins. Similarly music that is not too loud may be positive and uplifting.

There is an important point here. It is not that gentle music causes only a little damage, but that it causes no damage to hearing whatever. When compared with the damage due to excessively loud sounds, the effect is not proportionate. Technically such a relationship is termed *non-linear* and this will be an important idea in subsequent chapters. In the case of music and damage to hearing the non-linearity may be obvious, but for other forms of radiation the distinction between proportionate and non-proportionate response will need to be looked at using both experimental data and an understanding of what is happening.

Most of the radiation from the Sun comes in the form of electromagnetic waves – this includes light and other parts of a wide spectrum. Each such wave involves entwined electric and magnetic fields. It has a frequency and an intensity just as a sound wave has a pitch and a volume. Our understanding of electromagnetic waves dates from the work of James Clerk-Maxwell in the 19th century, who built on the work of Michael Faraday and others. As for any wave, the speed at which it moves is equal to the frequency times the wavelength. Since the speed is essentially constant, the wave may be labelled by its wavelength instead of its frequency, but either will do. On a radio receiver, for example, some stations are labelled by their frequency in MHz (mega-hertz, millions of waves per second), while for others the wavelength in metres is used. The product of the two is the speed of radio-waves, 300 million metres per second, the same as that of light.

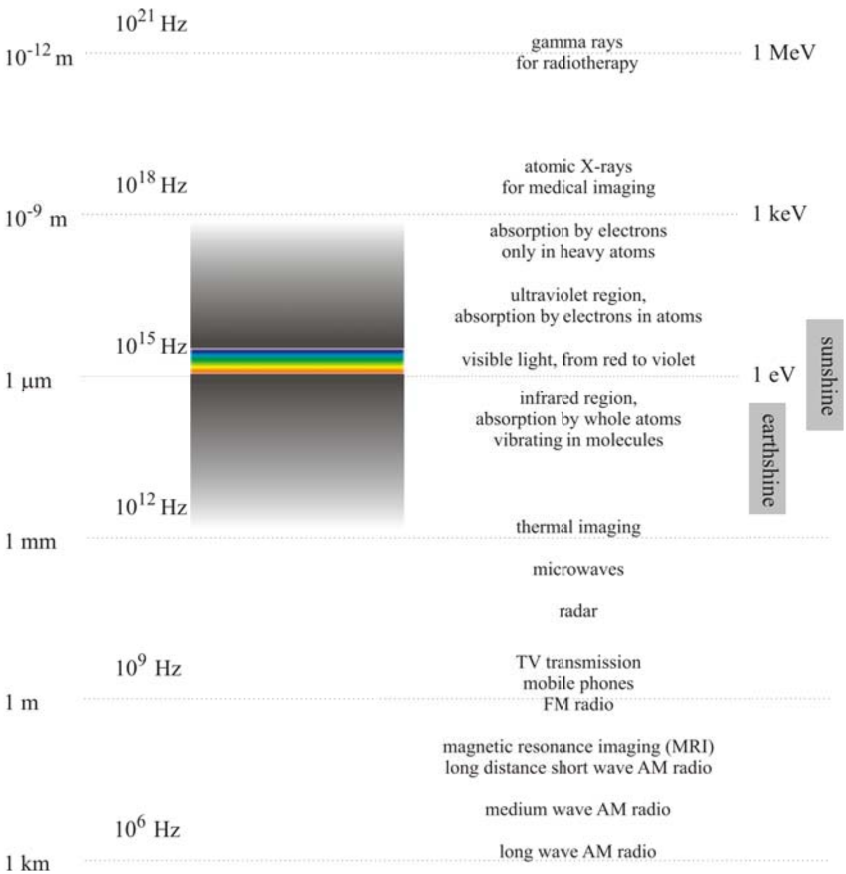

Figure 3 The frequency spectrum of electromagnetic waves.

How a wave is received is determined largely by the frequency not the intensity. For example, a radio receiver selects a station by choosing its frequency rather than its loudness. In the same way that for sound there are frequencies that cannot be heard by the ear, so for light there are frequencies that are invisible to the eye. In fact only a tiny range of frequencies of electromagnetic waves is visible. The whole spectrum is represented in Figure 3 with a logarithmic frequency scale running up the page and covering more than 15 powers of 10, as shown in the second column in oscillations per second (Hz). The first column gives the corresponding wavelength. Visible light with its characteristic spectrum of rainbow colours is the narrow band half way up the diagram. The point is that there really is no fundamental difference between these waves, from radio through light to X-rays, except the frequency. At the highest frequencies (and shortest wavelengths) the powers of 10 become harder to cope with and a third scale based on the electron volt (eV) is often used.[11] This is shown on the right of Figure 3 with the usual prefixes for powers of 10.[12]

Much benefit has been brought to everyday life through enabling mankind effectively to see using these other frequencies [4]. Lower in the diagram are radio-waves up to 10^9 Hz, used for example in MRI to see inside the human body and in radar to see ships and planes in fog and darkness. Slightly higher is thermal imaging, used to see warm bodies accidentally buried or concealed. Just below the visible frequencies is a region called the *infrared absorption band*, shown as shaded in the diagram. At these frequencies many materials are opaque because the rotation and vibration of molecules are in tune and resonate with electromagnetic waves. Above the visible there is another band, the *ultraviolet absorption band*. Here it is the more nimble atomic electrons that are in tune and the cause of the absorption. So here too materials are opaque, as marked by the shading.

Heavier elements with their more tightly bound electrons have an ultraviolet absorption band that extends to much higher

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[11] The electron volt is 1.6×10^{-19} joules. This is a useful scale in the atom. The electron in the hydrogen atom has an energy of 13.6 eV while typical nuclear energies are in MeV.

[12] μ or micro, one millionth. m or milli, one thousandth.
k or kilo, one thousand. M or mega, one million. G or giga, one billion.