Chapter 6
Lighting and Colour

6.1 Introduction

Sight is one of the fundamental human senses and governs our much of our appreciation of the world. In computer graphics, lighting effects give a sense of realism in the form of shadows, highlights and colours. In this Chapter we will study different lighting models and how various forms of illumination contribute to the resultant image.

Light is sometimes described as an electromagnetic radiation with wavelike characteristics and at others times as a particle called a photon. Merging these ideas into a single coherent description occupies many physicists with a reawakened interest in solitary waves. Solitary waves were first observed in the 19th century in water on canals and seem to behave very much like particles. Light shows both a particle like behaviour (pressure moves satellites in orbit) and that of a wave (diffraction around edges). We shall not study the resolution of the wave-particle duality associated with the quantum mechanical descriptions of light, but will still need to understand where colour comes from and how we can mix colours to give realistic representations of artefacts. Colour is the response of the eye and the interpretation of the brain to light of different wavelengths or energies. The eye is composed of two types of cells: cones and rods. The rods do not respond to colour but work at low levels of light and give us the ability to see at night. The cones respond to colour and allow us to see different intensities of colour. Light of one particular wavelength or colour is called monochromatic light and emitted from sources such as Lasers. Light is but one part of the electro magnetic spectrum which includes radio waves, microwaves, x-rays, gamma rays and light itself. We can represent the wave like form of electromagnetic radiation as shown in Fig. 6.1.

6.2 The Electromagnetic Spectrum

The electromagnetic spectrum, which describes all radiation, is made up from components of different wavelengths $\lambda$ and frequencies $f$ related by the expression

$$c = \lambda \cdot f$$
where $c$ is the velocity of light (300,000 km sec$^{-1}$ in vacuum), $\lambda$ is measured in nanometers ($10^{-9}$ of a metre) and $f$ is measured in cycles (complete wavelengths) per second (Hertz). The time between two points on the wave where the amplitude is the same is called the period $T$ (seconds) of the wave where $T = 1/f$. The electromagnetic spectrum is summarised in the following Fig. 6.2 moving from short wavelength radiation to longer wavelengths on the right.

The shorter the wavelength the more penetrating is the radiation with $\gamma$ rays having a wavelength of $\sim 10^{-3}$ nanometers (nm) and radio waves $\sim 10^{10}$ nm. The visible spectrum lies approximately between 400 nm (blue) and 700 nm (red), a long wavelength being associated with a low frequency of radiation. We shall only be concerned with the visible part of the spectrum in this text.

### 6.2.1 Colour

The colour of an object is governed by how the atoms from which it is made respond to the light shining on the surface. The different atoms from which we are made absorb X-rays to different degrees as shown in Fig. 3.2 where the Calcium reflects (white) the radiation more strongly than the more water based soft tissue (grey-black). The differential absorption gives rise to colours depending on the composition of an object. On a clear day the sky is blue because the longer wavelengths of sunlight are more strongly absorbed while the shorter wavelength ultra violet and blue is transmitted more easily through the atmosphere and that is the colour we see.

Describing colour in a qualitative manner is usually sufficient for everyday tasks although what two people mean by ‘red’ may be quite different and depend on quantities such as age, light intensity or material surface. A few years ago we would talk about graphics systems in terms of 4 bit colour and limited resolution. We now expect 24 bit colour systems with 8 bits used for each primary colour (Red, Green, Blue) and a minimal screen resolution of 800×600 pixels. This allows 256 intensity