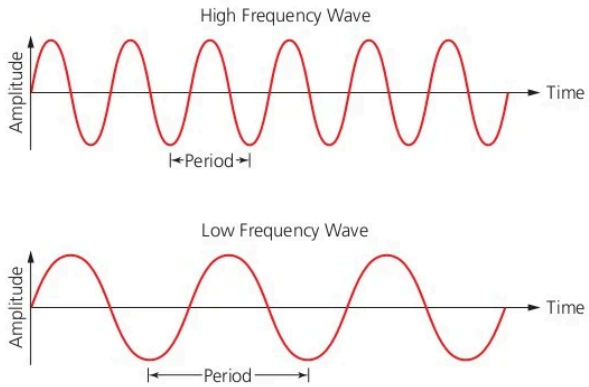
1.2.2 Representation of sound

Soundwaves are vibrations in the air. The human ear senses these vibrations and interprets them as sound.

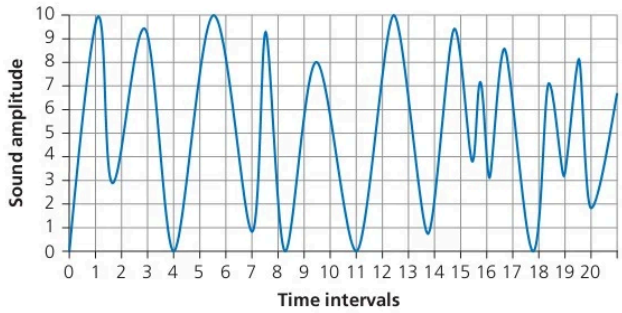
Each sound wave has a frequency, wavelength and amplitude. The amplitude specifies the loudness of the sound.



▲ **Figure 1.8** High and low frequency wave signals

Sound waves vary continuously. This means that sound is analogue. Computers cannot work with analogue data, so sound waves need to be sampled in order to be stored in a computer. Sampling means measuring the amplitude of the sound wave. This is done using an analogue to digital converter (ADC).

To convert the analogue data to digital, the sound waves are sampled at regular time intervals. The amplitude of the sound cannot be measured precisely, so approximate values are stored.



▲ **Figure 1.9** A sound wave being sampled

Figure 1.9 shows a sound wave. The x-axis shows the time intervals when the sound was sampled (1 to 21), and the y-axis shows the amplitude of the sampled sound to 10.

At time interval 1, the approximate amplitude is 10; at time interval 2, the approximate amplitude is 4, and so on for all 20 time intervals. Because the amplitude range in Figure 1.9 is 0 to 10, then 4 binary bits can be used to represent each amplitude value (for example, 9 would be represented by the

binary value 1001). Increasing the number of possible values used to represent sound amplitude also increases the accuracy of the sampled sound (for example, using a range of 0 to 127 gives a much more accurate representation of the sound sample than using a range of, for example, 0 to 10). The number of bits per sample is known as the **sampling resolution** (also known as the **bit depth**). So, in our example, the sampling resolution is 4 bits.

Sampling rate is the number of sound samples taken per second. This is measured in hertz (Hz), where 1 Hz means 'one sample per second'.

So how is sampling used to record a sound clip?

- the amplitude of the sound wave is first determined at set time intervals (the sampling rate)
- this gives an approximate representation of the sound wave
- each sample of the sound wave is then encoded as a series of binary digits.

Using a higher sampling rate or larger resolution will result in a more faithful representation of the original sound source. However, the higher the sampling rate and/or sampling resolution, the greater the file size.

▼ **Table 1.3** The benefits and drawbacks of using a larger sampling resolution when recording sound

Benefits	Drawbacks
larger dynamic range	produces larger file size
better sound quality	takes longer to transmit/download music files
less sound distortion	requires greater processing power

Link

See Section 1.3 for a calculation of file sizes.

CDs have a 16-bit sampling resolution and a 44.1 kHz sample rate – that is 44 100 samples every second. This gives high-quality sound reproduction.

1.2.3 Representation of (bitmap) images

Bitmap images are made up of **pixels** (picture elements); an image is made up of a two-dimensional matrix of pixels. Pixels can take different shapes such as:

▲ **Figure 1.10**

Each pixel can be represented as a binary number, and so a bitmap image is stored in a computer as a series of binary numbers, so that:

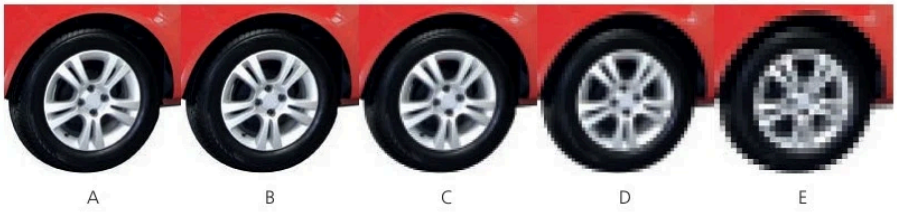
- a black and white image only requires 1 bit per pixel – this means that each pixel can be one of two colours, corresponding to either 1 or 0
- if each pixel is represented by 2 bits, then each pixel can be one of four colours ($2^2 = 4$), corresponding to 00, 01, 10, or 11
- if each pixel is represented by 3 bits then each pixel can be one of eight colours ($2^3 = 8$), corresponding to 000, 001, 010, 011, 100, 101, 110, 111.

The number of bits used to represent each colour is called the **colour depth**. An 8 bit colour depth means that each pixel can be one of 256 colours (because

$2^8 = 256$). Modern computers have a 24 bit colour depth, which means over 16 million different colours can be represented With x pixels, 2^x colours can be represented as a generalisation. Increasing colour depth also increases the size of the file when storing an image.

Image resolution refers to the number of pixels that make up an image; for example, an image could contain 4096 × 3072 pixels (12 582 912 pixels in total).

The resolution can be varied on many cameras before taking, for example, a digital photograph. Photographs with a lower resolution have less detail than those with a higher resolution. For example, look at Figure 1.11:



▲ **Figure 1.11** Five images of the same car wheel using different resolutions

Image 'A' has the highest resolution and 'E' has the lowest resolution. 'E' has become pixelated ('fuzzy'). This is because there are fewer pixels in 'E' to represent the image.

The main drawback of using high resolution images is the increase in file size. As the number of pixels used to represent the image is increased, the size of the file will also increase. This impacts on how many images can be stored on, for example, a hard drive. It also impacts on the time to download an image from the internet or the time to transfer images from device to device. A certain amount of reduction in resolution of an image is possible before the loss of quality becomes noticeable.

Activity 1.15

1 Explain each of the following terms:
   - i colour depth
   - ii ASCII code and Extended ASCII code
   - iii Unicode
   - iv sampling rate
   - v bitmap image

2 A colour image is made up of red, green and blue colour combinations. 8 bits are used to represent each of the colour components.
   - i How many possible variations of red are there?
   - ii How many possible variations of green are there?
   - iii How many possible variations of blue are there?
   - iv How many different colours can be made by varying the red, green and blue values?

3 Describe the effect of increasing resolution and sampling rate on the size of a file being stored in a computer.