# Waves and Optics

## 38 Wave Properties and Basic Equations

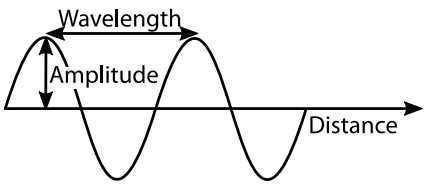
Waves can transfer energy (or information) without transferring material.

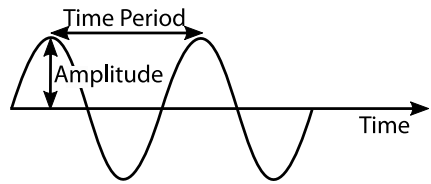
All waves involve oscillations (repeating motions back and forth).

| Longitudinal Wave | Examples |
|---|---|
| Oscillations parallel to the direction of energy transfer | Sound<br>Ultrasound<br>Seismic P wave |

| Transverse Wave | Examples |
|---|---|
| Oscillations perpendicular to the direction of energy transfer | Light<br>Other electromagnetic wave (e.g. radio)<br>Seismic S wave |

| | |
|---|---|
| Wavelength | The distance from one peak to the next |
| Time period | The time for one whole wave to go past you |
| Amplitude | The height of the wave's peaks from the midpoint |
| Frequency | The number of waves going past each second |
| Peak | The highest point on the wave |
| Trough | The lowest point on the wave |
| Speed | How fast the wave goes |



Formulae:

$$\text{wave speed} = \text{frequency} \times \text{wavelength} \qquad v = f\lambda$$

*Reason: Length of wave made each second = number of waves made each second × length of each wave.*

$$\text{frequency} = 1/\text{time Period} \qquad f = 1/T \qquad \text{so} \qquad T = 1/f$$

*Reason: the frequency tells you how many time periods there are in one second, so multiplying the time period by the frequency will always give the answer* 1.

38.1 Use the wave equations to fill in the blanks in the tables:

| Time period (s) | Frequency (Hz) |
|---|---|
| 0.10 | (a) |
| 0.050 | (b) |
| 0.0050 | (c) |
| 2.5 | (d) |
| (e) | 25 |

| Frequency (Hz) | Speed (m/s) | Wavelength (m) |
|---|---|---|
| (f) | 300 | 30 |
| (g) | 300 | 15 |
| (h) | 300 | 1.50 |
| 0.40 | (i) | 420 |
| 20 | 2.0 | (j) |

38.2 A musical note has a frequency of 440 Hz. The speed of sound in air is 330 m/s.

(a) What is the wavelength of the sound?

(b) What is the time period of the sound?

38.3 An ultrasound pulse has a wavelength of 1.0 mm. Its speed in water is 1 400 m/s.

(a) What is the frequency?

(b) What is the time period of the sound?

38.4 A lighthouse flashes once every 7.1 s. What is its frequency?

38.5 The mains power has a frequency of 50 Hz. What is its time period?

38.6 When a musical note goes up one octave in pitch, its frequency doubles. What happens to its wavelength?

38.7 What is the period of a wave whose frequency is $4.0$ Hz?

When a wave moves from one material to another, the frequency does not change. If the speed changes, the wavelength will change too.

38.8 Green light has a wavelength of $0.000\,000\,50$ m, and a speed of $300\,000\,000$ m/s.

(a) Calculate its frequency.

(b) When the green light goes into glass, it slows down. Its new speed is $200\,000\,000$ m/s. What is its frequency and wavelength in glass?

38.9 Calculate the frequency of a water wave which has a wavelength of $1.5$ m and travels a distance of $10$ metres in $5.0$ seconds. *[Hint: This question has two stages. You will have to work something out before you can calculate the quantity requested.]*

38.10 A water wave, travelling at $2.5$ m/s, has a wavelength of $50$ cm. What is the period of the wave? *[Hint: This question has two stages. You will have to work something out before you can calculate the quantity requested.]*



## Additional Wave Properties and Basic Equations

38.11 On a stormy day, a girl counts the number of wave crests breaking on the shore and finds that there are $60$ in $4.0$ minutes. Calculate the water waves' frequency in hertz (waves per second).

38.12 A tuning fork makes the musical note one octave above 'middle C' (in the 'scientific designation'). What is its frequency, if its prongs vibrate $2\,560$ times in $5.0$ s?

38.13 What is the wavelength of a $200$ Hz sound wave in the air if the speed of sound in air is $340$ m/s?

38.14 What is the speed of sound through an aluminium rod if a sound

vibration of frequency $13$ kHz has a wavelength of $40$ cm?

38.15 What is the frequency of a wave of red light in the air where its wavelength is $6.8 \times 10^{-7}$ m?

38.16 Calculate the wavelength of Radio 4 which broadcasts on a frequency of $198$ kHz.

38.17 Certain X-rays have a frequency of $1.0 \times 10^{19}$ Hz. Calculate their wavelength in the air.

38.18 What is the wavelength of a radio station which sends out radio waves of frequency $1.15$ MHz?

38.19 A certain radio station broadcasts on a frequency of $101.7$ MHz. Calculate the wavelength of the radio wave.

38.20 Calculate the frequency, in kilohertz, of a radio station which broadcasts on the Medium Wave with a wavelength of $1\,500$ m.