

Section 2 - Using Sound

Speed, Distance and Time

In this section you can use the equation:

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

also written as

$$\bar{v} = \frac{d}{t}$$

where \bar{v} = average speed in metres per second (m/s)

d = distance travelled in metres (m)

t = time taken in seconds (s).

1. Find the missing values in the following table:

	<i>Speed (m/s)</i>	<i>Distance (m)</i>	<i>Time (s)</i>
(a)		15 000	5
(b)		38	0.02
(c)	1 500		0.25
(d)	5 200		0.01
(e)	340	17	
(f)	330	3 465	

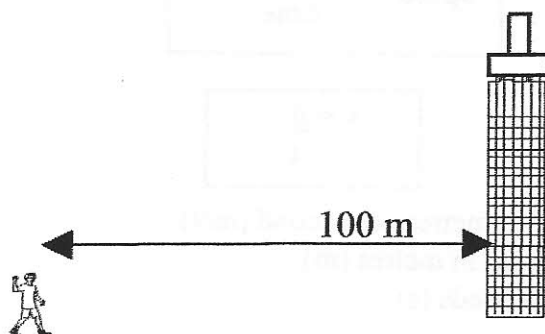
2. The speed of sound in tissue is 1 500 metres per second. How far would sound travel in tissue in a time of 0.000 2 seconds?
3. Sound in jelly can travel a distance of 0.435 metres in a time of 0.000 3 seconds. What is the speed of sound in jelly?
4. How long would it take for sound to travel 0.435 m through air if the speed of sound in air is 340 m/s?

Helpful Hint

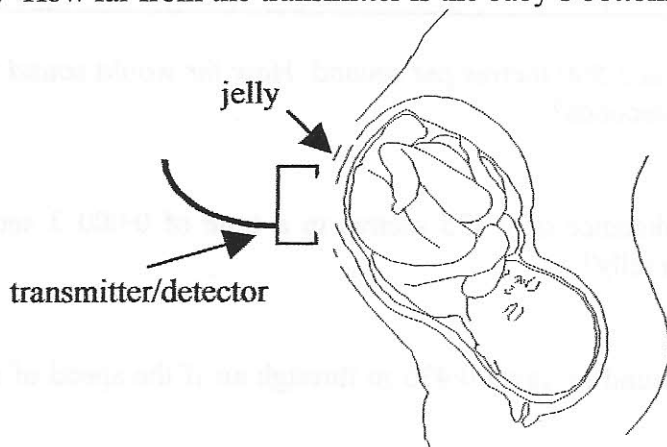
$$1 \text{ ms} = 0.001 \text{ s} = 1 \times 10^{-3} \text{ s}$$

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- The speed of sound in muscle is $1\,600\text{ m/s}$. How far would sound travel in muscle in a time of 0.5 milliseconds?
- Calculate the speed of sound in bone given that it takes 0.05 ms for sound to travel 0.15 m through bone.
- A boy is standing at a distance of 100 m from a large building. He shouts loudly and hears an echo.



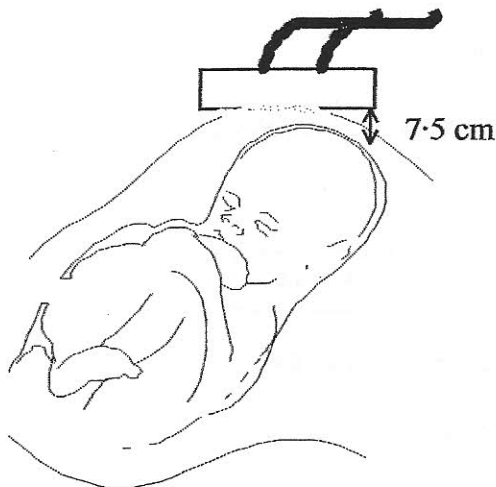
- How far did the sound travel between leaving the boy and returning to him as an echo?
 - If the speed of sound in air is 340 m/s , how long did it take for the sound to cover this distance?
- An ultrasound pulse of frequency 8 MHz is transmitted into an expectant mother's womb and reflects from baby's bottom. The pulse echo is detected 0.08 milliseconds after being transmitted. The speed of sound through the body tissue and fluid is $1\,500\text{ m/s}$.



- Another pulse is reflected from the foot of the baby. If this reflected pulse is detected 0.15 milliseconds after being transmitted, how far from the transmitter is the baby's foot?

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9. During an ultrasound scan, a baby's forehead is situated 7.5 cm from the transmitter. The ultrasound pulse travelling at 1 500 m/s is reflected from the baby's forehead.



- (a) What is the **total** distance travelled by the pulse?
- (b) What time elapses between the transmission of the pulse and the detection of the pulse echo?
10. An ultrasound pulse is transmitted into the womb of an expectant mother and the pulse echo is detected after a time of 0.38 milliseconds. The pulse was reflected by one of the baby's knees situated 28.5 cm from the transmitter. Show that the speed of sound in the womb is 1 500 m/s.

Speed, Frequency and Wavelength

In this section you can use the equation:

$$\text{speed} = \text{frequency} \times \text{wavelength}$$

also written as

$$\bar{v} = f\lambda$$

where \bar{v} = average speed in metres per second (m/s)
 f = frequency in Hertz (Hz)
 λ = wavelength in metres (m)

1. Find the missing values in the following table:

	<i>Speed (m/s)</i>	<i>Frequency (Hz)</i>	<i>Wavelength (m)</i>
(a)		7 000 000	0.000 5
(b)		80 000	0.02
(c)	1 360	6 800 000	
(d)	330	660	
(e)	1 500		0.002 5
(f)	5 200		1.3

Helpful Hint

$$1 \text{ kHz} = 1\,000 \text{ Hz} = 1 \times 10^3 \text{ Hz}$$
$$1 \text{ MHz} = 1\,000\,000 \text{ Hz} = 1 \times 10^6 \text{ Hz}$$

- Calculate the wavelength of sound with frequency 1 000 Hz which is passing through carbon dioxide gas. (Speed of sound in carbon dioxide = 270 m/s.)
- What is the speed of ultrasound in Glycerol given that a 40 kHz ultrasound pulse has a wavelength of 4.75 cm in Glycerol?
- An 8 MHz ultrasound pulse is transmitted into water. It has a wavelength of 1.87×10^{-4} m in water. Calculate its speed.
- A buzzer emitting sound of frequency 12 kHz is switched on. What is the wavelength of the sound waves in air where the speed of sound is 340 m/s?

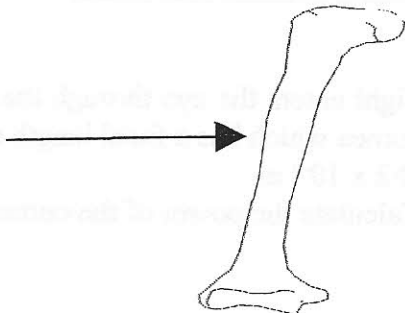
Helpful Hint

Remember ! For waves you can also use the equation

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

6. An ultrasound pulse of frequency 7 MHz is transmitted through 8 cm of muscle. The wavelength of the ultrasound in muscle is 2.29×10^{-4} m.
- (a) Calculate the speed of sound in muscle.
- (b) Calculate the time taken for the ultrasound to pass through the muscle.
7. Sound waves of frequency 4 kHz travel along a 2.6 m length of aluminium in a time of 0.5 milliseconds.
- (a) What is the speed of sound in aluminium?
- (b) Calculate the wavelength of this sound in aluminium.
8. An ultrasound pulse, of wavelength 3.75×10^{-4} m, is transmitted into the womb of an expectant mother. It is reflected by the head of her baby and the reflected pulse is detected 0.2 ms after transmission. The baby's head is positioned 15 cm from the transmitter / detector.
- (a) Show that the speed of ultrasound is 1 500 m/s inside the woman.
- (b) What frequency of ultrasound was used?

9.



It takes 0.02 milliseconds for a 15 kHz sound vibration to travel 6 cm through the humerus bone in your arm.

What is the wavelength of this sound in bone?

10. Assuming no energy losses, how far would sound travel in 1 second through a material in which a 2 kHz sound vibration has a wavelength of 95 cm?

Section 3 - Light and Sight

Power of a Lens

In this section you can use the equation:

$$\text{power} = \frac{1}{\text{focal length}}$$

where **power** is measured in dioptres (D)
focal length is measured in metres (m).

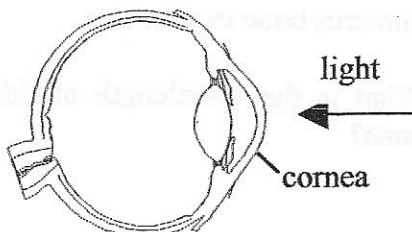
Helpful Hint

Focal length and power are both **positive for convex lenses**. e.g. +2 cm, +5 D
Focal length and power are both **negative for concave lenses**. e.g. -10 cm, -12 D
Convex lenses are used to correct **long sight**.
Concave lenses are used to correct **short sight**.

1. Find the missing values in the following table:

	Power (D)	Focal length (m)
(a)		0.6
(b)		3×10^{-2}
(c)		-0.04
(d)	16	
(e)	-46.7	
(f)	8.6	

2.

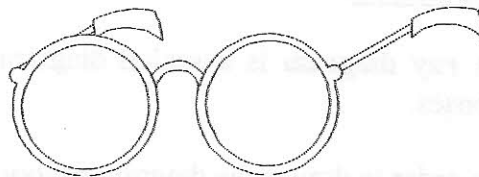


Light enters the eye through the transparent cornea which has a focal length of 2.2×10^{-2} m.
Calculate the power of the cornea.

3. The lens of the eye has a focal length of 5.5 cm when looking at a distant object. Calculate the power of the lens under these conditions.
4. The cornea and lens of the eye both focus light onto the retina. Together they act as a single lens of power +58.8 D. What is the focal length of this single lens?

5. Louise measures the focal length of the convex lenses in her glasses. They each have a focal length of 6.4 cm.

- (a) Calculate the power of these lenses.
(b) Is Louise long sighted or short sighted?



6. An optician is looking for a convex lens of focal length 6 cm to make up a pair of reading glasses for Mrs Mow. The first drawer he looks in contains the following lenses: +12.7 D, -16.7 D, +14.8 D, +16.7 D and -12.7 D

Which of these lenses would be most suitable for Mrs Mow's glasses?

7. The spectacles that John wears for watching the television have lenses which have a power of -11 D.

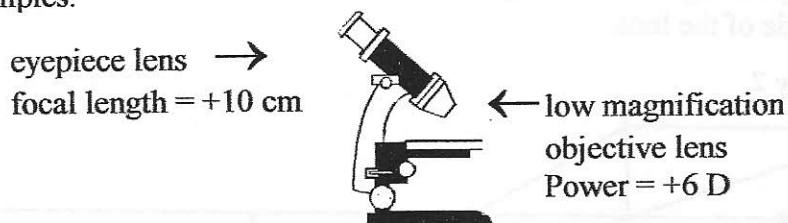
- (a) Calculate the focal length of these lenses.
(b) Is John long sighted or short sighted?

8. Jane and Gary measure the focal length of two convex lenses by using them to form an image of the window on the white wall of the laboratory. Jane finds the focal length of her lens to be +13 cm. Gary's lens has a focal length of +24 cm. Who has the more powerful lens?

9. Endoscopes are used in hospitals to allow doctors to see inside patients without cutting them open. The eyepiece lens at the end of the image guide in an endoscope has a power of +10 D.

- (a) Calculate the focal length of this lens.
(b) Is the eyepiece lens convex or concave?

10. A doctor in the pathology department of a hospital uses a microscope to study some tissue samples.



- (a) Calculate the power of the eyepiece lens.
(b) Calculate the focal length of the objective lens.
(c) Are these lenses convex or concave?

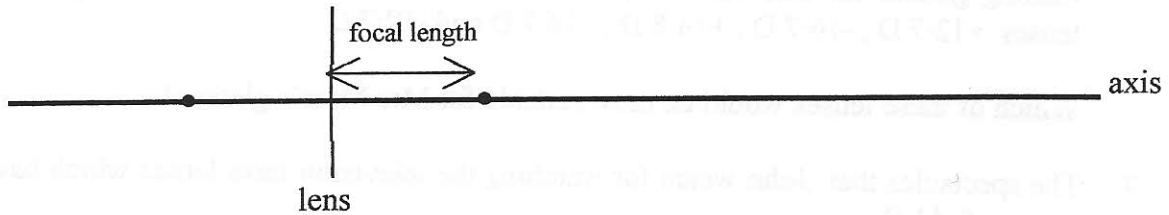
Ray Diagrams

Helpful Hint.

A **ray diagram** is a scaled diagram which allows us to describe images produced by lenses.

In order to draw a ray diagram follow these 4 simple steps:

1. Draw a vertical line to represent your lens and then a long horizontal line (axis) through the centre of the lens.



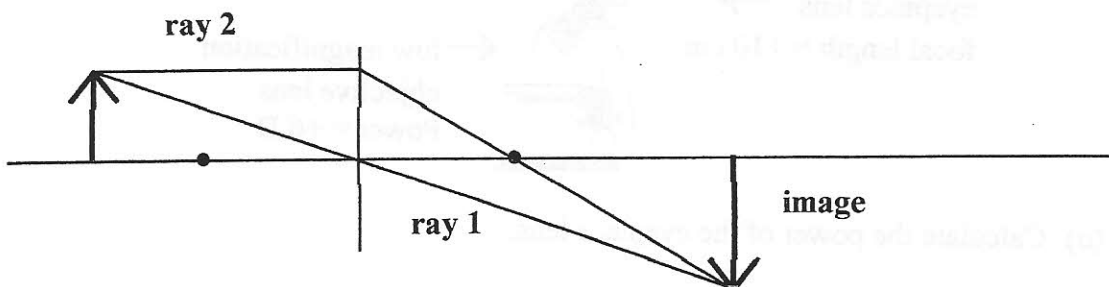
Mark the focal points either side of the lens at the correct distance from it.

2. An arrow can be used to represent your object. Draw it, pointing upwards, on the horizontal axis.



You must draw the arrow either to the exact height of your object or select an appropriate vertical scale. Position the arrow at the correct distance from the lens - again you may have to select an appropriate horizontal scale!

3. Draw **ray 1** from the tip of your arrow straight through the centre of the lens. Draw **ray 2** from the tip of your arrow to the lens so that the ray is parallel to the axis. After passing through the lens ray 2 is directed down through the focal point on the right hand side of the lens.



4. At the point where rays 1 and 2 meet, the sharpest image of the object (arrow tip) will be formed. The image is drawn from the horizontal axis to this point as shown in the diagram above.

