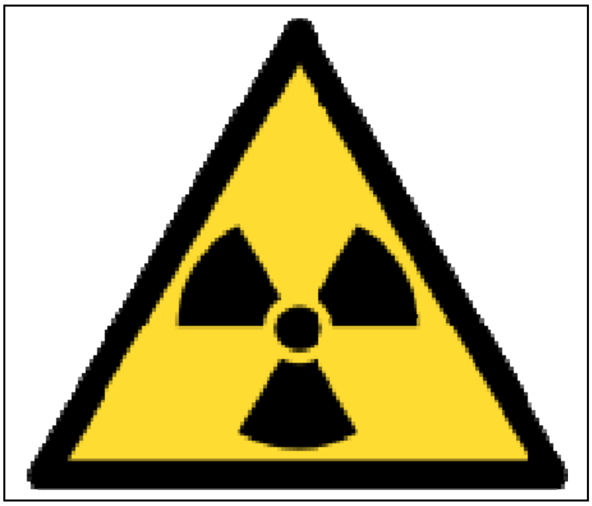
Barrhead High School
Physics Department

National Physics

Wave & Radiation
Problem Booklet



Getting Started

Success involves doing many different kinds of problems which help improve your knowledge and understanding of the ideas in the course and your ability to solve problems.

In order to get started it is a good idea to look at a general method for tackling problems and then do some calculator exercises to become familiar with the function buttons on your calculator.

General Method for Solving Problems.

Any numerical problem in physics can be solved using the following steps:

Read the question carefully.
Find out exactly what is being asked.
Extract the key data.
Select the correct equation.
Substitute the data into the equation to find the missing variable.
Remember to give your answer the correct unit.

Helpful Hint

Always watch the units in a question - they may need to be converted before being put into an equation.

e.g.	3 mA	=	0.003 A	$= 3 \times 10^{-3}$ A
	6 km	=	6 000 m	$= 6 \times 10^{3}$ m

Example

How far does a cyclist travel in 26 seconds if he is travelling at a constant speed of 8 m/s?

Solution Read the question carefully. →

Find out exactly what is being asked. → Distance

Extract the key data. → time = 26 seconds, speed = 8 m/s

Select the correct equation. → distance = speed x time

Substitute data into the equation. → d = 8 x 26

Remember to give your answer the correct unit. → = 208m

Usual layout

d	=	?	d	= v x t
v	=	8 m/s		= 8 x 26
t	=	26 s		= 208 m

Final answer d = 208 m

Use this method and layout in each of the following problems.

1. Calculate how far a car travels in 300 seconds when it is travelling at a top speed of 30 m/s.

2. How long does it take to walk to school if you walk at an average speed of 3 m/s and you live 900 metres away?

3. Find the average speed of a motor boat which takes 350 seconds to cover a 10 000 m course.

4. A runner takes 35 seconds to run round 250 metres of a track. What is his average speed?

5. A train travelling at 35 m/s takes 15 seconds to pass through a tunnel. How long is the tunnel?

6. 

Find the average speed of Sammy Snail who slithers 0·005 m in 4 seconds.

7. How long does the TGV take to travel 60 000 m given that it goes at an average speed of 120 km/h. (120 km/h = 33·3 m/s)

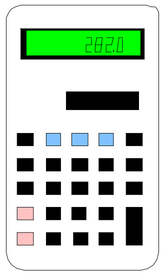
8. A school bus takes 20 minutes to travel 15 km. What is it's average speed? (Give your answer in m/s)

9. A bird maintains an average speed of 11·2 m/s for 5 minutes. How far does it travel?

10. How long does a roller blader take to travel 2 km if his average speed is 7 m/s.

Calculator Exercises.

1. Rounding answers off.



When using your calculator, answers often work out to have more than one number after the decimal point.
It is usual to round off the answer you see on the display to two numbers after the decimal point, unless stated otherwise.

Practise rounding answers off to two numbers after the decimal point by doing the following calculator exercises.

(*a*)	2 ÷ 18	(*b*)	3 ÷ 9	(*c*)	40 ÷ 82	(*d*)	23.59^2
(*e*)	6·25 x 4·21	(*f*)	3·61 x 6·54	(*g*)	7·98 x 13·24	(*h*)	2·76 x 11·3

2. Using the [EXP] button.

[EXP] or [10^x] button is one of the most useful function buttons on your calculator. It allows you to handle very small and very large numbers easily.

[EXP] or [10^x] means '**times ten to the power of**'

So, 3×10^8 can be entered into the calculator as 3 [EXP] 8 or 3 [10^x] 8

(Note: there is no need to enter 'x' before either function button.)

3×10^{-8} can be entered into the calculator as 3 [EXP] 8 [+/ -] or 3 [10^x] 8 [+/ -]

Try entering the following numbers in scientific form into your calculator and write down what you see on the display. (Use either the [EXP] [10^x] function button depending on the model of calculator you have.)

(*a*)	3×10^{8}	(*b*)	$1·4 \times 10^6$	(*c*)	$3·4 \times 10^2$
(*d*)	$1·06 \times 10^4$	(*e*)	$9·99 \times 10^9$	(*f*)	$5·67 \times 10^5$
(*g*)	3×10^{-8}	(*h*)	$1·4 \times 10^{-6}$	(*i*)	$3·4 \times 10^{-2}$
(*j*)	$1·06 \times 10^{-4}$	(*k*)	$9·99 \times 10^{-9}$	(*l*)	$5·67 \times 10^{-5}$

3. [EXP] Practice

A display like 3 08 really means 3×10^8 and 4 -06 really means 4×10^{-6} which may seem strange since the 'x 10' does not appear.

Try the following calculator exercises and write down the answers. Remember to add in the 'x 10' part yourself, don't just copy down what you see on the display.

(*a*) $3 \times 10^5 \times 5 \times 10^7$

(*b*) $4{\cdot}6 \times 10^9 \times 7{\cdot}78 \times 10^{26}$

(*c*) $4{\cdot}56 \times 10^{45} \times 5 \times 10^5$

(*d*) $0{\cdot}6 \times 10^{10} \times 0{\cdot}2 \times 10^{10}$

(*e*) $4{\cdot}98 \times 10^{21} \div 3{\cdot}23 \times 10^3$

(*f*) $9{\cdot}99 \times 10^3 \div 8{\cdot}88 \times 10^1$

(*g*) $2{\cdot}0 \times 10^{-9} \times 3{\cdot}4 \times 10^{-3}$

(*h*) $3{\cdot}45 \times 10^{-2} \times 3{\cdot}99 \times 10^{-5}$

(*i*) $0{\cdot}56 \times 10^{-4} \times 3{\cdot}23 \times 10^{-3}$

(*j*) $1{\cdot}44 \times 10^{-7} \times 7{\cdot}77 \times 10^{-4}$

(*k*) $6{\cdot}66 \times 10^{-66} \div 7{\cdot}77 \times 10^{-2}$

(*l*) $5 \times 10^{-3} \div 6 \times 10^{-6}$

(*m*) $3{\cdot}45 \times 10^{-6} \times 5{\cdot}67 \times 10^9$

(*n*) $7{\cdot}67 \times 10^{12} \div 3{\cdot}2 \times 10^{-9}$

Answers to numerical problems.

Getting started (p2)

1.	9 000 m
2.	300 s
3.	28·57 m/s
4.	7·14 m/s
5.	525 m
6.	$1{\cdot}25 \times 10^{-3}$ m/s
7.	1801·8 s
8.	12·5 m/s
9.	3 360 m
10.	285·71 s

Rounding Off (p3)

(a)	0·11
(b)	0·33
(c)	0·49
(d)	556·49
(e)	26·31
(f)	23·61
(g)	105·66
(h)	31·19

EXP Practice (p4)

(a)	$1{\cdot}5 \times 10^{13}$
(b)	$3{\cdot}58 \times 10^{36}$
(c)	$2{\cdot}28 \times 10^{51}$
(d)	$1{\cdot}2 \times 10^{19}$
(e)	$1{\cdot}54 \times 10^{18}$
(f)	112·5
(g)	$6{\cdot}8 \times 10^{-12}$
(h)	$1{\cdot}38 \times 10^{-6}$
(i)	$1{\cdot}81 \times 10^{-7}$
(j)	$1{\cdot}12 \times 10^{-10}$
(k)	$8{\cdot}57 \times 10^{-65}$
(l)	833·33
(m)	19561·5
(n)	2·4 x 10

Speed, Distance and Time

Light and Sound

In this section you can use the equation:

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

also written as

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

where **d** = distance in metres (m)
$\bar{v}$ = average speed in metres per second (m/s)
t = time in seconds (s).

Helpful Hint
The speed of light is much faster than the speed of sound. In fact light from distant objects appears to reach us almost instantaneously.

In this section use:
speed of light = 3×10^8 m/s and speed of sound = 340 m/s.

1. Find the missing values in the following table.

	Distance (m)	*Average speed* (m/s)	*Time* (s)
(*a*)		3×10^8	5
(*b*)		340	5
(*c*)	500		1·47
(*d*)	8 600		25·3
(*e*)	6 500	3×10^8	
(*f*)	255	340	

2. Calculate how far light travels in:

   (*a*) 1 second (*b*) 3 seconds (*c*) 10 seconds.

3. Calculate how far sound travels in:

   (*a*) 1 second (*b*) 3 seconds (*c*) 10 seconds.

4. A golfer is worried about the dangers of being out on the course during a thunder and lightning storm. He suddenly sees a flash of lightning and then counts 4 seconds before he hears the clap of thunder. How far away is the storm?

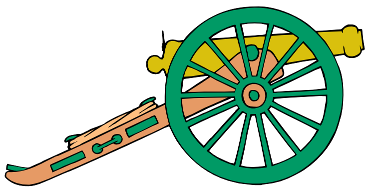
5. A group of physics students set out to measure the speed of sound. The pupils stand a distance of 200 metres from the teacher who has a flash gun and starter pistol. The pupils have to start their stopcock when they **see** the flash and stop it when they **hear** the bang. The experiment is carried out three times and the results are shown in the table below.

Distance from gun to pupils (m)	*Time recorded* (s)	*Average speed* (m/s)
200 m	0·58	
200 m	0·56	
200 m	0·59	

Calculate the speed of sound for each time recorded.

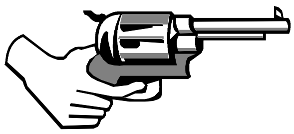
6. Spectators are told to stay behind a barrier which is 100m away from where fireworks are being set off at a display.
How long will it take spectators to hear a 'banger' after they have seen it explode?

7. During the Edinburgh Tattoo, tourists on Princes Street see the canon smoke from the castle 3 seconds before they hear the bang. How far are they from the castle?



8. A plane spotter sees a military jet and then 4·5 seconds later hears the roar from its engine. How far away is the jet?

9. In a 100m sprint race the timers start timing when they hear the starter pistol and stop timing when they see the sprinters cross the finishing line.



(*a*) Does this method overestimate or underestimate their sprint times? Explain your answer.
(*b*) How could the accuracy of the timing be improved?

10. During the demolition of the high rise flats in the Gorbals, spectators saw the explosion first and heard it 7 seconds later.

(*a*) Why was there a delay?
(*b*) How far from the explosion were they standing?

Waves and Frequency

Frequency

In this section you can use the equation:

$$\textbf{frequency} = \frac{\textbf{number of waves}}{\textbf{time taken}}$$

where **frequency** is measured in Hertz (Hz)
time is measured in seconds (s).

1. Find the missing values in the following table.

	Frequency (Hz)	*Number of Waves*	*Time* (s)
(*a*)		10	5
(*b*)		30	60
(*c*)	800	3 200	
(*d*)	12	9 600	
(*e*)	50		90
(*f*)	20 000		15

2. If a wave machine produces 5 waves each second what is the frequency of the machine?

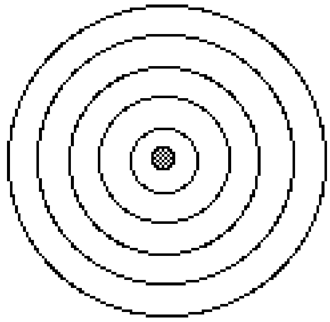
3. A man stands on a beach and counts 40 waves hitting the shore in 10 seconds. What is the frequency of these waves?

4. In 100 seconds a particular smoke alarm emits 1 000 000 sound waves. What is the frequency of the sound waves?

5. A girl is sitting on the edge of a pier. It takes 0·625 seconds for one complete wave to pass underneath her. What is the frequency of the waves?

6. A girl stands on a beach and counts 15 waves crashing onto the shore in a time of 1 minute. What is the frequency of the waves?

7. A rock is thrown into a pond and an overhead photograph is taken 2 seconds later. The photograph, as shown in the diagram below, reveals that 5 waves were produced in the 2 second period.

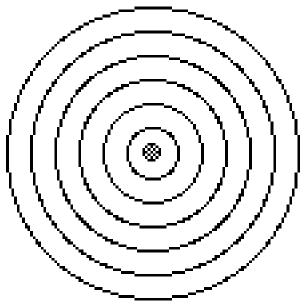


What was the frequency of these water waves?

8. In a swimming pool a wave machine creates waves with a frequency of 2 Hz. How many waves are produced in 5 minutes?

9. A smoke alarm sends out high-pitched sound waves with a frequency of 12 000 Hz. If the alarm is on for 30 seconds how many waves does it emit?

10. A pebble was thrown into a still pond and wave ripples were produced at a rate of 3 waves per second.
The diagram below represents the wave pattern in the pond a short time after the pebble was dropped.



(*a*) What was the frequency of the waves, in Hertz?

(*b*) How many waves are represented in the diagram above?

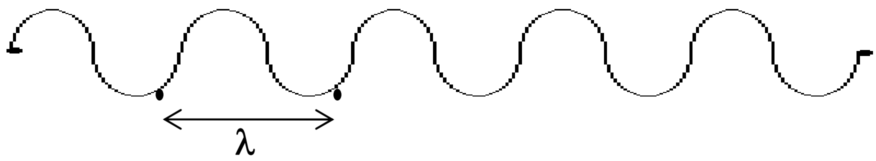
(*c*) How long did it take for this wave pattern to form?

Wavelength

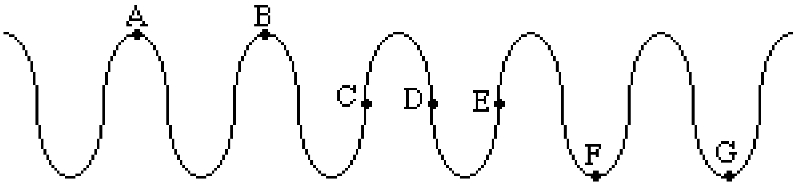
Helpful Hint

Wavelength (symbol λ) means the **length of a wave**. It is measured as the distance from one point on a wave to an identical point on the next wave.

e.g.

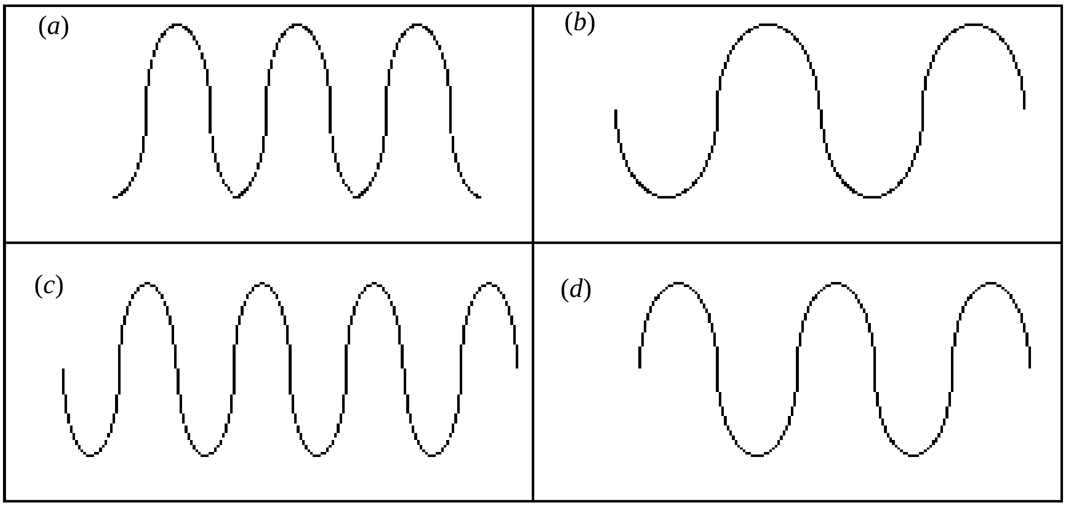


1. 'A-B' represents one wavelength in the diagram below.



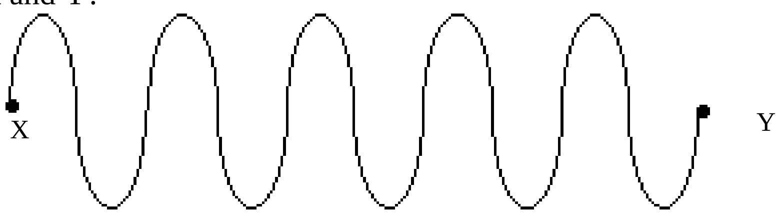
State two other pairs of letters which represent one wavelength.

2. How many waves are shown in each of the diagrams below?

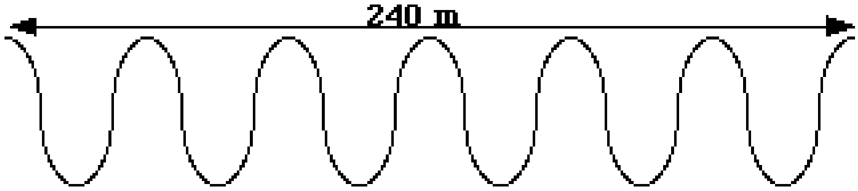


3. The wave train shown below is 20 metres long. How long is each wave?

4. The wavelength of the waves in the diagram below is 3 cm. What is the distance between X and Y?

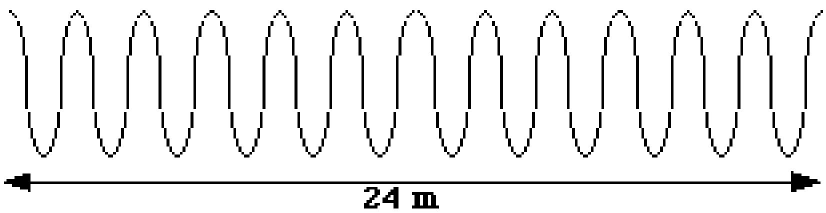


5. What is the wavelength of the waves in the diagram below?



6. Draw a wave train consisting of 2 waves. Put the labels **wavelength** and **amplitude** on your diagram in appropriate places.

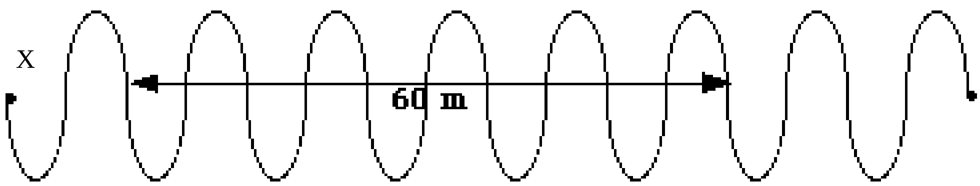
7.



(*a*) How many waves are shown in the diagram above?

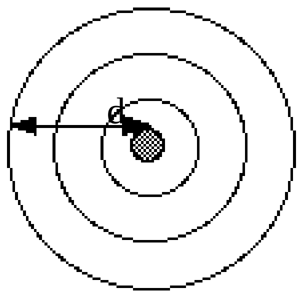
(*b*) What is the wavelength of each of these waves?

8. (*a*) Calculate the wavelength of the waves shown below.



(*b*) What is the distance from X to Y in this wave train?

9. A stone is thrown into a pond, and a wave pattern is produced as shown below. The wavelength of the waves is 6 cm.



Calculate the distance, d, travelled by the outside wave.

10. Red light from a laser has a wavelength of 4×10^{-7} m in a certain glass. How many waves, from this laser, would cover a length of 2 cm in this glass?

Speed of a Wave

In this section you can use the equation:

speed = frequency x wavelength

also written as

$$v = f\lambda$$

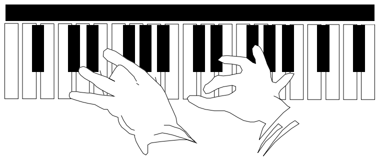
where **v** = speed of the wave in metres per second (m/s)
f = frequency in Hertz (Hz)
λ= wavelength in metres (m).

1. Find the missing values in the following table.

	Frequency (Hz)	*Wavelength* (m)	*Speed* (m/s)
(*a*)	5	3	
(*b*)	50	0·02	
(*c*)	2		0·5
(*d*)	20 000		340
(*e*)		20	600
(*f*)		$5{\cdot}5 \times 10^{-7}$	3×10^{8}

2. Water waves in a swimming pool are travelling with a speed of 2 m/s and have a wavelength of 0·8 m. What is their frequency?

3. The musical note 'E' has a frequency of 320 Hz. If sound travels with a speed of 340 m/s in air calculate the wavelength of this sound in air.



4. Sound of frequency 440 Hz has a wavelength of 3·41 m in water. Calculate the speed of sound in water.

5. What is the speed of waves which have a frequency of 50 Hz and a wavelength of 3 m?

6. A wave machine in a swimming pool produces waves with a frequency of 1 Hz. If they travel across the pool at 1·5 m/s what is their wavelength?

7. A wave generator in a ripple tank creates waves which have a wavelength of 0·02 m. If the speed of these waves is 1·2 m/s what is their frequency?

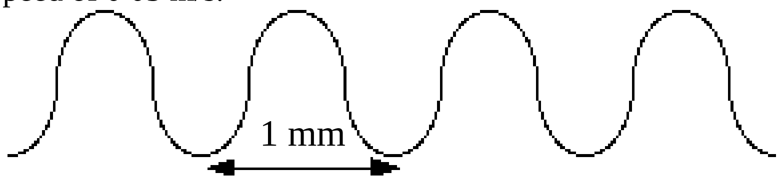
8. The speed of sound in steel is 5 200 m/s. What is the wavelength of a sound wave which has a frequency of 6 500 Hz in steel?

9. How fast will waves with a frequency of 15 000 Hz and a wavelength of 2·2cm travel?

10. What is the wavelength of waves which have a frequency of 6×10^6 Hz and a speed of 1 800 m/s?

11. Waves produced by a wave generator in a ripple tank have a wavelength of 16 mm. At what frequency is the wave generator operating if the wave speed is 0·64 m/s?

12. Calculate the frequency of the waves shown in the diagram below given that they have a speed of 0·05 m/s.



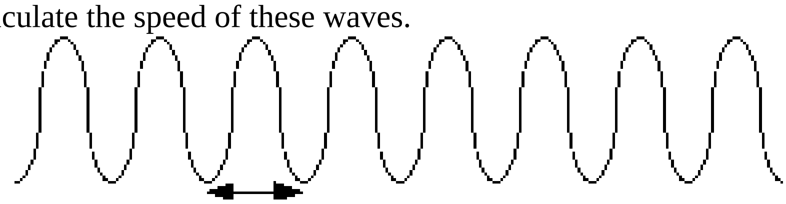
13. A boy counts 40 complete waves along the length of a swimming pool. The pool is
50 m long and the waves are travelling with a speed of 3·75 m/s. Calculate:

(*a*) the wavelength of the waves

(*b*) the frequency of the waves

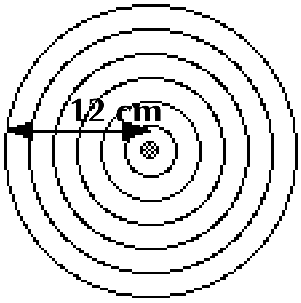
(*c*) the number of waves produced in 1 minute.

14. Waves, like the ones shown in the diagram below, are produced at a rate of 8 000 Hz. Calculate the speed of these waves.



0·3 m

15. A wave pattern formed 3 seconds after a pebble is dropped into a pond is shown below.



(*a*) How many waves were formed in 3 seconds?

(*b*) What was the frequency of the waves?

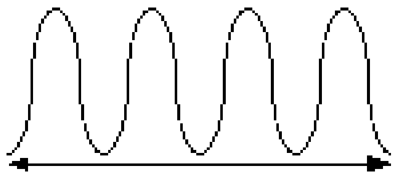
(*c*) What was the wavelength of the waves?

(*d*) Calculate the speed of the waves.

16. 30 water waves per second are created in a pool. Some of these are represented in the diagram.

(*a*) State the wavelength of the waves.

(*b*) Calculate the wave speed.

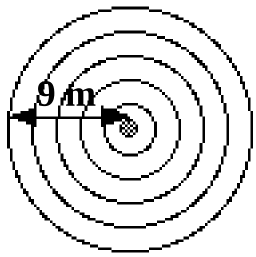


17. The waves shown in the diagram below were produced at a rate of 30 waves per minute.

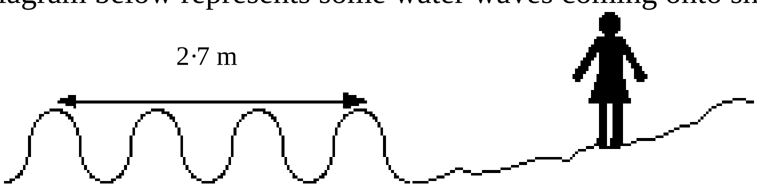
(*a*) What is their frequency?

(*b*) What is their wavelength?

(*c*) Calculate the speed of these waves.



18. The diagram below represents some water waves coming onto shore.



A girl standing on the shore counts 36 wave crests crashing onto the shore in 1 minute. Calculate the frequency, wavelength and speed of these waves.

Helpful Hint

Remember! When dealing with waves, you can also use the equation

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

19. It takes 25 seconds for a wave in a swimming pool to travel from one end of the pool to the other end. The wave has a frequency of 2·5 Hz and its wavelength is 0·4 m.

    (*a*) What is the speed of the wave?
    (*b*)
    (*b*) What is the length of the pool?

20. An alarm is set off creating sound waves of frequency 10 000 Hz. It takes 0·6 seconds for the sound to reach a man who is standing at a distance of 204 m from the alarm.

    (*a*) Calculate the speed of the sound waves.

    (*b*) Calculate the wavelength of the sound waves.

21. A wave generator in a ripple tank creates waves, which have a wavelength of 2·5 cm, at a rate of 6 waves per second. The ripple tank is 60 cm long.

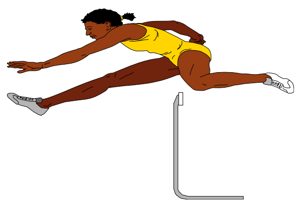
    (*a*) What is the frequency of the waves?

    (*b*) Calculate the speed of the waves.

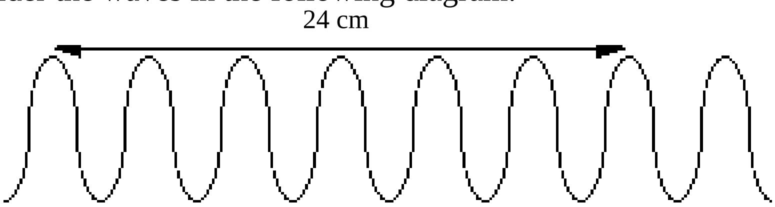
    (*c*) How long will it take for a wave to travel the length of the ripple tank?

22. Waves of frequency $8{\cdot}1 \times 10^5$ Hz can travel a distance of 27 000 m in a time of 9×10^{-5} seconds. What is the wavelength of these waves?

23. An athlete is working on her hurdling technique with her trainer.
    The trainer stands some distance up the track and blows his whistle, sending out 8 500 Hz sound waves which have a wavelength of 4 cm. It takes 0·22 seconds for the sound waves to reach the athlete.
    Calculate the starting distance between the athlete and her trainer.



24. Consider the waves in the following diagram:



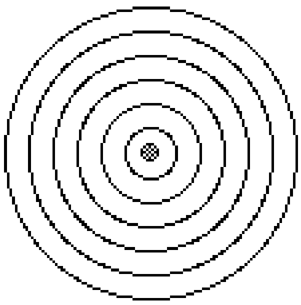
(*a*) What is the wavelength of these waves?

(*b*) Calculate the speed of the waves given that it takes 0·001 s for one complete wave to pass a point.

(*c*) Calculate the frequency of the waves.

(*d*) How many of these waves would pass a point in 1 minute?

25. The pond waves represented in the diagram below have a frequency of 24 Hz and a wavelength of 10 cm. The pattern was formed by dropping a stone into the water.



(*a*) Calculate the speed of the waves.

(*b*) How long did it take for this pattern to form from the moment the stone made contact with the water?

Speed, Distance and Time in Medicine

Speed, Distance and Time

In this section you can use the equation:

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

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:

	Speed (m/s)	*Distance* (m)	*Time* (s)
(*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?

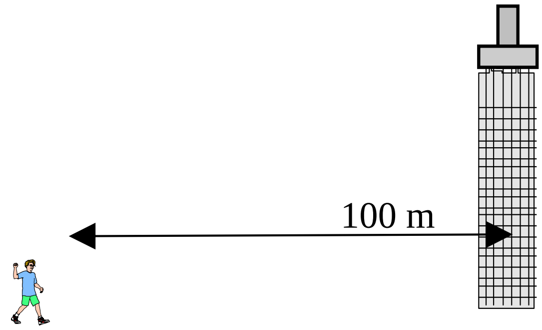
4. How long would it take for sound to travel 0·435 m through air if the speed of sound in air is 340 m/s?

Helpful Hint
1 ms = 0·001 s = 1×10^{-3} s

5. The speed of sound in muscle is 1 600 m/s. How far would sound travel in muscle in a time of 0·5 milliseconds?

6. Calculate the speed of sound in bone given that it takes 0·05 ms for sound to travel 0·15 m through bone.

7. A boy is standing at a distance of 100 m from a large building. He shouts loudly and hears an echo.



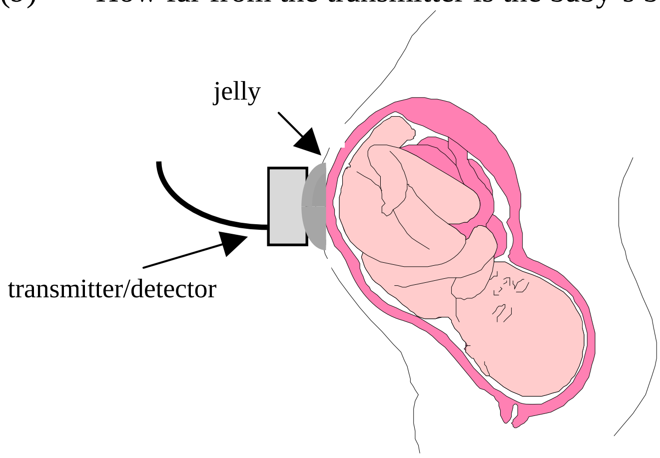
(*a*) How far did the sound travel between leaving the boy and returning to him as an echo?

(*b*) If the speed of sound in air is 340 m/s, how long did it take for the sound to cover this distance?

8. 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 m/s.

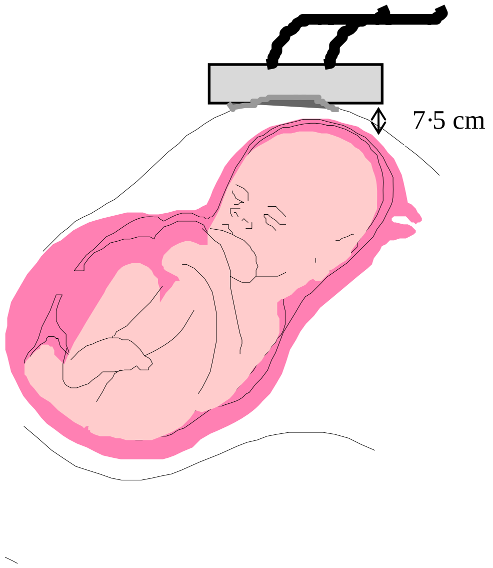
(*a*) How far does the pulse travel?

(*b*) How far from the transmitter is the baby's bottom?



(*c*) 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?

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:

speed = frequency x 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:

	Speed (m/s)	*Frequency* (Hz)	*Wavelength* (m)
(*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 kHz = 1 000 Hz = 1×10^3 Hz
1 MHz = 1 000 000 Hz = 1×10^6 Hz

2. 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.)

3. What is the speed of ultrasound in Glycerol given that a 40 kHz ultrasound pulse has a wavelength of 4·75 cm in Glycerol?

4. An 8 MHz ultrasound pulse is transmitted into water. It has a wavelength of $1{\cdot}87 \times 10^{-4}$ m in water. Calculate its speed.

5. 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

$$\textbf{Speed} = \frac{\textbf{distance}}{\textbf{time}}$$

6. An ultrasound pulse of frequency 7 MHz is transmitted through 8 cm of muscle. The wavelength of the ultrasound in muscle is $2{\cdot}29 \times 10^{-4}$ 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?

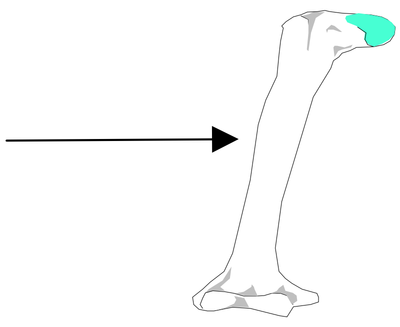
   (*b*) Calculate the wavelength of this sound in aluminium.

8. An ultrasound pulse, of wavelength $3{\cdot}75 \times 10^{-4}$ 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.



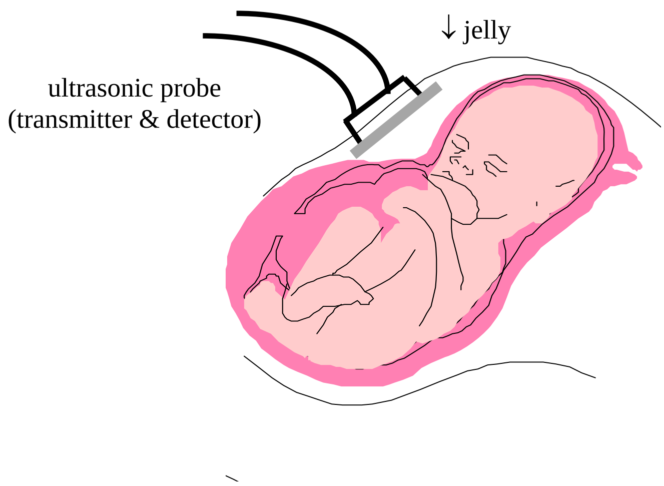
It takes 0·02 milliseconds for a 15 kHz sound vibration to travel 6 cm through the humerus bone in your arm.

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?

Nat 5 Questions : Medical uses.

1. Ultrasound can be used in medicine to monitor the growth of unborn babies.



On a visit to hospital an expectant mother is scanned with ultrasound of frequency 8 MHz, which has a wavelength of 0·19 mm in the body.
One pulse of ultrasound leaves the transmitter, is reflected by the baby's hand and returns to the detector in a time of 0·15 milliseconds.

(*a*) What is meant by ultrasound?

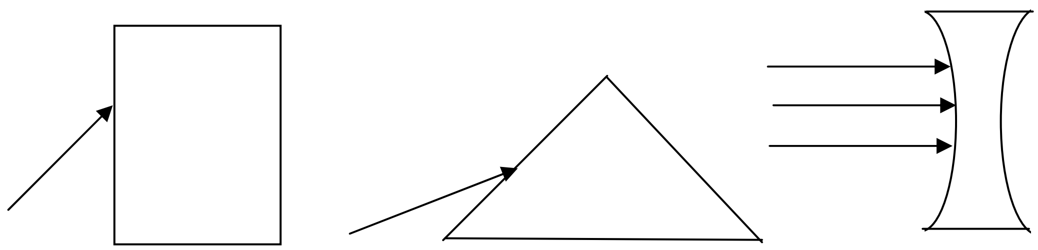
(*b*) Why is a layer of jelly placed between the mother and the transmitter / detector?

(*c*) How far from the transmitter / detector is the baby's hand positioned?

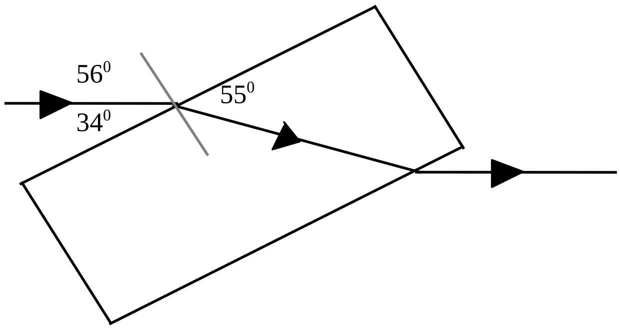
(*d*) Explain how the image of a baby is produced during an ultrasound scan.

2. Four pupils were asked to find out as much as they could about the refraction of light and the use of lenses.

(*a*)Jane shone rays of light through different perspex shapes. Copy and complete the diagrams below to show her results.



(*b*) Robert shone a ray of light through a rectangular glass block. He sketched the path of the ray through the block and measured three angles. The diagram below shows the measurements he made.

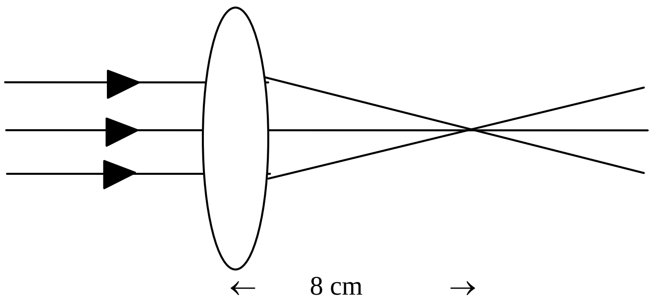


(i) What is the line drawn at right angles to the surface of the glass block called?

(ii) What size is the angle of incidence?

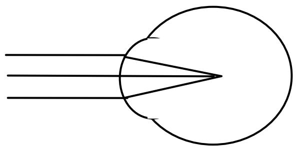
(iii) What size is the angle of refraction?

(*c*) Anne decided to investigate a convex lens. She traced the path of 3 parallel rays of light through the lens. Her result is shown below.



What was the power of the lens that Anne was using?

(*d*) Paul found a diagram in a text book showing a common eye sight problem.



Name this eye defect and draw a diagram showing how it can be corrected using a suitable lens placed in front of the eye.

3. Read the passage below and use it to answer the questions that follow.

The sun is a star 150 x10^6 km from Earth which produces enormous amounts of energy in the form of electromagnetic waves. We can detect the visible light from the sun with our eyes but we cannot detect the invisible ultraviolet light which also reaches Earth. Exposure to the ultraviolet light from the sun can produce a change in the colouring of the skin which we call a sun tan.

There are three types of ultraviolet radiation. We are constantly exposed to UVA and we need this for healthy growth and to make vitamin D in our bodies. UVA light has wavelengths in the range 315 to 400 nm. UVB light has wavelengths in the range 280 to 315 nm.
Most of the UVB light from the sun is removed by the layer of ozone in the atmosphere around the Earth. Scientists have found that there is a hole in the ozone layer which is allowing more UVB to reach us on the surface of the earth. UVB can cause a skin cancer called melanoma. The third type of UV light, with wavelengths in the range 200 to 280 nm, is called UVC .

People who are going to be exposed to the sun for any length of time should protect their skin with sun tan cream. An extract from the back of a bottle of sun tan cream is given below.

Bronzage cream protects the skin from sun burn, premature skin ageing and long term damage to the internal structure of the skin by filtering out the harmful UVA/UVB rays from sunlight.

Bronzage is water resistant even after a swim of 30 minutes.

(*a*) Calculate how long it takes for ultraviolet light to travel from the sun to Earth.

(*b*) Construct a table giving the wavelengths of UVA, UVB and UVC light.

(*c*) Calculate the frequency of the shortest wavelength UVC light.

(*d*) What type of UV light has a frequency of 7·5 x 10^{14} Hz?

(*e*) What range of wavelengths does Bronzage sun tan cream block?

The Electromagnetic Spectrum

In this section you can use the two equations which you met earlier:

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

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

Where $\bar{v}$ = average speed in metres per second (m/s)
f = frequency in hertz (Hz)
λ = wavelength in metres (m)
d = distance in metres (m)
t = time in seconds (s).

Helpful Hint
All Electromagnetic waves travel at a speed of 3×10^8 m/s (300 000 000 m/s) through space.
A useful unit of distance is the **nanometre**
1 **nm** = 0·000 000 001 m = 1×10^{-9} m

1. Electromagnetic waves with frequencies close to the frequency of visible light have very short wavelengths often measured in nanometres (nm).

   Convert the following wavelengths into metres:

   (*a*) 5 nm (*b*) 400 nm (*c*) 700 nm (*d*) 1 500 nm.

2. Our eyes can detect visible light with wavelengths ranging from 400 nm to 700 nm. Light with a wavelength of around 400 nm is violet in colour. Red light has a wavelength of around 700 nm.

   Calculate the frequencies of violet light and red light.

3. A doctor examines a patients stomach using a fibrescope. White light is shone down a bundle of optical fibres called the light guide and reaches the end of the fibrescope in $1{\cdot}75 \times 10^{-9}$ seconds. If the light guide is 35 cm long calculate the speed of the light as it travels down the fibres.

4. Peter sprained his ankle playing football. The physiotherapist uses infra red radiation of wavelength $1{\cdot}2 \times 10^{-4}$ metres to heat the tissue in his ankle and help it heal. Calculate the frequency of this radiation.

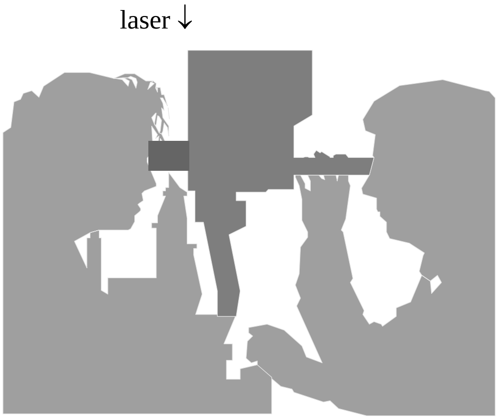
5. An elderly patient is suffering from pains in his knees. The doctor in the hospital takes a ‘heat picture’ called a thermogram of the knees and detects an inflammation of the joints caused by arthritis. The infra red radiation being given out by the knees is of frequency 5×10^{12} Hz. Calculate the wavelength of this radiation.

6. The ancient Egyptians used ultraviolet radiation from the sun’s rays to treat the skin complaint acne. Ultraviolet light is still used today in hospital to treat acne. Calculate the wavelength of UV light of frequency $8{\cdot}8 \times 10^{16}$ Hz.

7. Microwaves are part of the electromagnetic spectrum and have many uses from telecommunications to cooking. Microwaves of wavelength 12 cm are used in ovens to cook food. The human body gives out microwaves of wavelength 9 cm which can be detected by a small aerial placed in contact with the skin. These microwaves allow doctors to measure the temperature of organs inside the body.

   Calculate the frequency of microwaves emitted from the body.

8. An argon laser which produces blue/green light of wavelength 500 nm is being used to treat Mrs Doig who suffers from diabetes. The laser is used to seal blood vessels which have been bleeding into the eye and damaging her sight. Calculate the frequency of the light produced by the laser.

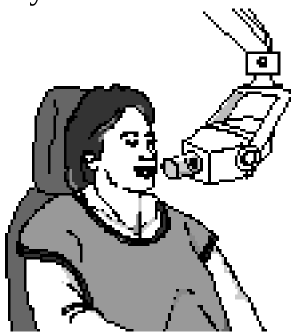


9. A low power red argon laser (700 nm) is directed through an optical fibre to a cancerous tumour in a patients throat. The laser light activates a drug injected into the patient which will kill the cancerous cells.

   (*a*) What is the frequency of the red light produced by the laser?

   (*b*)Calculate how long it will take for the light to travel 95 cm down the optical fibre if it travels at a speed of $2{\cdot}2 \times 10^{8}$ m/s.

10. X - rays were discovered in 1895 by Wilhelm Rontgen. X - rays are now widely used in medicine and dentistry.



John is having an X-ray taken of one of his molars which is giving him pain. The dentist sets up the X-ray apparatus and goes to stand behind a lead screen. The X - rays used have a frequency of 2×10^{17} Hz.

(*a*) Calculate the wavelength of these X-rays.

(*b*)How long will it take for these X -rays to travel 10 cm from the X- ray machine to John's tooth?

Nuclear Radiation-Humans and Medicine

Half Life

Helpful Hint
Half life is defined as the **time taken** for the activity of a radioactive source to fall to **half** its original value.

e.g. half life = 2 days **means** that every 2 days the activity of the source will half.

1. The initial activity of a radioactive isotope is 400 Bq. The sample has a half life of
   2 minutes and is allowed to decay for 8 minutes. Calculate the final activity of the isotope.

2. A radioactive tracer has an activity of 160 Bq. The tracer has a half life of 5 hours and decays for 15 hours. What is its final activity?

3. A radioactive source with a half life of 2.5 minutes decays for 10 minutes. The source has an initial activity of 64 kBq. Calculate the final activity of the source.

4. Radioactive paint is left decaying in a room for 3 hours. The initial activity of the paint is 320 Bq and it has a half life of 1 hour. Find the final activity of the paint.

5. Radioactive rocks emit radiation, which can be harmful, if exposure to them is not controlled.
   Some rocks have an activity of 160 Bq and emit radiation over a 3 day period. What is the final activity of these rocks given that their half life is 12 hours.

6. An isotope of indium which emits alpha radiation is left decaying for 4 hours. The half life of the source is 60 minutes and the initial activity is 200 counts per minute. Calculate the final activity of the isotope.

7. A sample of radioactive uranium has an initial activity of 600 kBq. After 10 days its activity has dropped to 150 kBq.
   Use this information to calculate the half life of the source.

8. A sample of radioactive caesium has an initial activity of 1 400 kBq. After 9 minutes its activity has dropped to 175 kBq.
   Use this information to calculate the half life of the source.

9. Calculate the half life of a radioactive sample which has an initial activity of 2 000 Bq that drops to 125 Bq in a period of 16 hours.

10. Calculate the half life of a radium spray source, which emits alpha radiation, given that it takes 45 minutes for the activity to drop from 2 400 counts per minute to 75 counts per minute.

11. A beta radiation source has an activity of 3 kBq and this drops to 750 Bq in a period of 24 days. What value does this give for the half life of the source?

12. An isotope of indium has a half life of 75 minutes. After a period of 5 hours it is found to have an activity of 5·75 counts per minute. Use this information to calculate the activity of the source at the start of the 5 hour period.

13. Calculate the initial activity of a radioactive source whose activity falls to 20 kBq in 16 minutes given that it has a half life of 2 minutes.

14. A radioactive rock decays for 48 hours and has a final activity of 480 kBq. What was its initial activity if its half life was 12 hours?

15. A radioactive source has a half life of 2 days. What fraction of the sample is left after:

    (a) 2 days   (*b*) 6 days   (*c*) 20 days?

16. Radioactive caesium has a half life of 16 minutes. What fraction of the sample is left after:

    (a) 16 mins   (*b*) 32 mins   (*c*) 80 mins?

17. A radioactive sample has a half life of 20 seconds. How long has the sample been decaying if the fraction left is:

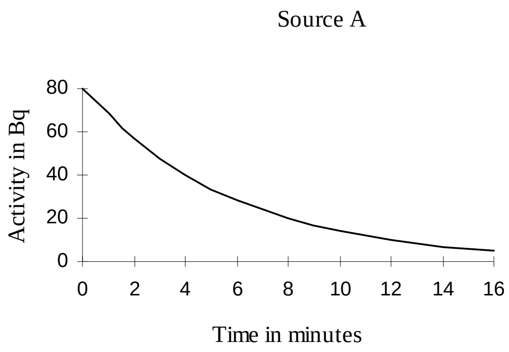
    (a) 1/4   (*b*) 1/16   (*c*) 1/64?

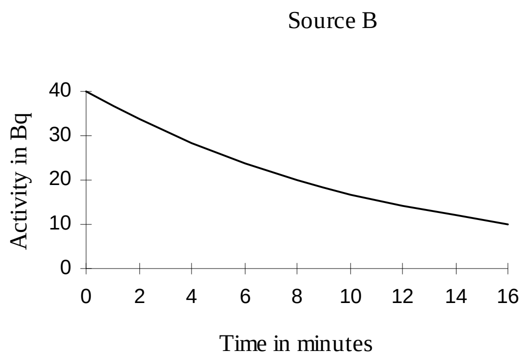
18. How many half lives have occurred if:

    (a) 1/8 of a sample remains   (*b*) 1/32 of a sample remains?

19. A radioactive sample has a half life of 30 seconds. How long has it been decaying if 1/16th of the original sample is left?

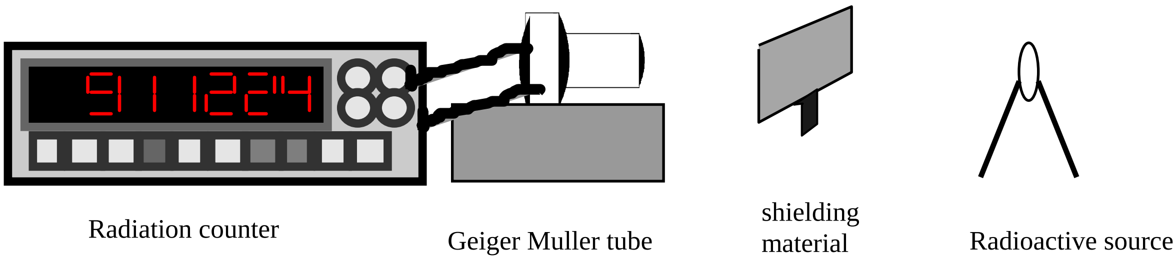
20. A medical physicist set up an experiment to check the half life of some radioactive samples to be used as radioactive tracers in kidneys.
He plotted the results from each experiment on graphs shown below.





Use the graphs to estimate the half life of each radioactive source.

21. A student sets up the following apparatus to measure the half life of a radioactive sample of cobalt 60. Since the experiment is carried out in a sealed container we can assume background radiation is negligible.

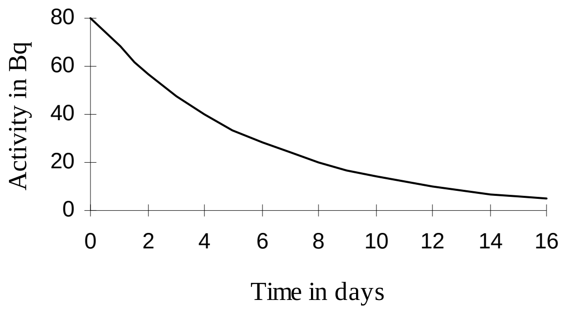


She obtained the following results.

Activity (Counts per minute)	800	600	410	310	200	150	100	75
Time (mins)	0	10	20	30	40	50	60	70

Use these results to plot a graph of activity against time and use it to find the half life of the radioactive source.

22. Use the graph below to answer the following questions.
(graph is corrected for background radiation)



(*a*)What is the half life of the source?

(*b*)What would the activity of the source be after 12 days?

> *Helpful Hint*
> **Background radiation** does not come from the actual radioactive source but from other sources such as cosmic rays etc. It must therefore be **subtracted** from any **uncorrected** activity readings before calculations can be done or graphs plotted.

23. Background radiation in a science lab is 14 counts per minute. When Alan and David set about calculating the half life of a radioactive source they found that its activity fell from 94 counts per minute to 24 counts per minute in 3 hours. Use their results to calculate the half life of the source.

24. A radioactive source has an activity of 375 Bq and this drops to 60 Bq in 9 days. If background radiation is 15 Bq , calculate the half life of the source.

25. The activity of an isotope varies with time as shown below. The count rate is **uncorrected** for background radiation.

Count rate (*per minute*)	230	190	160	130	110	95	80	70
Time (*hours*)	0	1	2	3	4	5	6	7

The background count is 30 counts per minute.

(*a*)Plot a corrected graph of activity against time **for the isotope**.

(*b*)Calculate the half life of the isotope.

Appendix (i) Data Sheet

Speed of light in materials	
Material	*Speed in m/s*
Air	3×10^8
Carbon dioxide	3×10^8
Diamond	$1{\cdot}2 \times 10^8$
Glass	$2{\cdot}0 \times 10^8$
Glycerol	2.1×10^8
Water	$2{\cdot}3 \times 10^8$

Speed of sound in materials	
Material	*Speed in m/s*
Aluminium	5 200
Air	340
Bone	4 100
Carbon dioxide	270
Glycerol	1 900
Muscle	1 600
Steel	5 200
Tissue	1 500
Water	1 500

Gravitational field strengths	
	Gravitational field strength on the surface in N/kg
Earth	10
Jupiter	26
Mars	4
Mercury	4
Moon	1·6
Neptune	12
Saturn	11
Sun	270
Venus	9
Uranus	11·7
Pluto	4·2

Specific heat capacity of materials	
Material	*Specific heat capacity in J/kg°C*
Alcohol	2 350
Aluminium	902
Copper	386
Glass	500
Glycerol	2 400
Ice	2 100
Lead	128
Silica	1 033
Water	4 180
Steel	500

Specific latent heat of fusion of materials	
Material	*Specific latent heat of fusion in J/kg*
Alcohol	$0{\cdot}99 \times 10^5$
Aluminium	$3{\cdot}95 \times 10^5$
Carbon dioxide	$1{\cdot}80 \times 10^5$
Copper	$2{\cdot}05 \times 10^5$
Glycerol	$1{\cdot}81 \times 10^5$
Lead	$0{\cdot}25 \times 10^5$
Water	$3{\cdot}34 \times 10^5$

Melting and boiling points of materials		
Material	*Melting point in °C*	*Boiling point in °C*
Alcohol	-98	65
Aluminium	660	2470
Copper	1 077	2 567
Glycerol	18	290
Lead	328	1 737
Turpentine	-10	156

Specific latent heat of vaporisation of materials	
|*Material*	*Sp.l.ht vap(J/kg)*
Alcohol	$11{\cdot}2 \times 10^5$
Carbon dioxide	$3{\cdot}77 \times 10^5$
Glycerol	$8{\cdot}30 \times 10^5$
Turpentine	$2{\cdot}90 \times 10^5$
Water	$22{\cdot}6 \times 10^5$

SI Prefixes and Multiplication Factors		
Prefix	*Symbol*	*Factor*
giga	G	$1\,000\,000\,000 = 10^9$
mega	M	$1\,000\,000 = 10^6$
kilo	k	$1\,000 = 10^3$
milli	m	$0{\cdot}001 = 10^{-3}$
micro	μ	$0{\cdot}000\,001 = 10^{-6}$
nano	n	$0{\cdot}000\,000\,001 = 10^{-9}$

Speed, Distance and Time Light and Sound (p.5)

1.
(a) 1·5 x 10^9 m
(b) 1 700 m
(c) 340·14 m/s
(d) 339·92 m/s
(e) 2·17 x 10^{-5} s
(f) 0·75 s
2.
(a) 3 x 10^8 m
(b) 9 x 10^8 m
(c) 3 x 10^9 m
3.
(a) 340 m
(b) 1 020 m
(c) 3 400 m
4. 1 360 m
5. 344·83m/s, 357·14 m/s, 338·98 m/s.
6. 0·29 s
7. 1 020 m
8. 1 530 m
10.
(b) 2 380 m

Waves, Frequency (p.7)

1.
(a) 2 Hz
(b) 0·5 Hz
(c) 4 s
(d) 800 s
(e) 4 500
(f) 300 000
2. 5 Hz
3. 4 Hz
4. 10 000 Hz
5. 1·6 Hz
6. 0·25 Hz
7. 2·5 Hz
8. 600
9. 360 000
10.
(a) 3 Hz
(b) 6
(c) 2 s

Wavelength(p.9)

1. CE, FG
2.
(a) 3
(b) 2
(c) 4
(d) 2·5
3. 5 m
4. 15 cm
5. 40 m
7.
(a) 12
(b) 2 m
8.
(a) 12 m
(b) 96 m
9. 18 cm

10. 50 000

<u>Speed of a Wave</u>(p.11)

1.
(a) 15 m/s
(b) 1 m/s
(c) 0·25 m
(d) 0·017 m
(e) 30 Hz
(f) 5·45 x 10^{14} Hz
2. 2·5 Hz
3. 1·06 m
4. 1500 m/s
5. 150 m/s
6. 1·5 m
7. 60 Hz
8. 0·8 m
9. 330 m/s
10. 3 x 10^{-4} m
11. 40 Hz
12. 50 Hz
13.
(a) 1·25 m
(b) 3 Hz
(c) 180
14. 2 400 m/s
15.
(a) 6
(b) 2 Hz
(c) 2 cm
(d) 0·04 m/s
16.
(a) 7 cm
(b) 2·1 m/s
17.
(a) 0·5 Hz
(b) 1·8 m
(c) 0·9 m/s
18. 0·6 Hz, 0·9 m, 0·54 m/s.
19.
(a) 1 m/s
(b) 25 m
20.
(a) 340 m/s
(b) 0·034 m
21.
(a) 6 Hz
(b) 0·15 m/s
(c) 4 s
22. 370·37 m
23. 74·8 m
24.
(a) 4 cm
(b) 40 m/s
(c) 1 000 Hz
(d) 60 000
25.
(a) 2·4 m/s
(b) 0·25 s

Speed, Distance and Time in Medicine(p.16)
1.
(a) 3 000 m/s
(b) 1 900 m/s
(c) 375 m
(d) 52 m
(e) 0·05 s
(f) 10·5 s
2. 0·3 m
3. 1 450 m/s
4. 1·28 x 10^{-3} s
5 0·8 m
6. 3 000 m/s
7.
(a) 200 m
(b) 0·59 s
8.
(a) 0·12 m
(b) 0·06 m
(c) 0·11 m
9.
(a) 15 cm
(b) 1 x 10^{-4} s

Speed, Frequency and Wavelength(p.19)
1.
(a) 3 500 m/s
(b) 1 600 m/s
(c) 2 x 10^{-4} m
(d) 0·5 m
(e) 600 000 Hz
(f) 4 000 Hz
2. 0·27 m
3. 1 900 m/s
4. 1 496 m/s
5. 0·03 m
6.
(a) 1 603 m/s
(b) 4·99 x 10^{-5} s
7.
(a) 5 200 m/s
(b) 1·3 m
8.
(b) 4 x 10^{6} Hz
9. 0·2 m
10. 1 900 m

Nat5 Questions : Medical Uses(p.21)
1.
(c) 0·11 m
2.
(b) (i) 56^{0}
(ii) 35^{0}
(c) +12·5 D
3.
(a) 500 s
(b) 1·5 x 10^{15} Hz
(d) UVA

(e) 280 nm - 400 nm

The Electromagnetic Spectrum(p.24)

1.
(a) 5×10^{-9} m
(b) 4×10^{-7} m
(c) 7×10^{-7} m
(d) $1{\cdot}5 \times 10^{-6}$ m
2. violet - $7{\cdot}5 \times 10^{14}$ Hz
red - $4{\cdot}3 \times 10^{14}$ Hz
3. 2×10^{8} m/s
4. $2{\cdot}5 \times 10^{12}$ Hz
5. 6×10^{-5} m
6. $3{\cdot}41 \times 10^{-9}$ m
7. $3{\cdot}33 \times 10^{9}$ Hz
8. 6×10^{14} Hz
9.
(a) $4{\cdot}27 \times 10^{14}$ Hz
(b) $4{\cdot}32 \times 10^{-9}$ s
10.
(a) $1{\cdot}5 \times 10^{-9}$ m
(b) $3{\cdot}33 \times 10^{-10}$ s

Nuclear Radiation(p.27)

1. 25 Bq
2. 20 Bq
3. 4 kBq
4. 40 Bq
5. 2·5 Bq
6. 12·5 counts per minute
7. 5 days
8. 3 minutes
9. 4 hours
10. 9 minutes
11. 12 days
12. 92 counts per minute
13. 5 120 kBq
14. 7 680 kBq
15.
(a) 1/2
(b) 1/8
(c) 1/1024
16.
(a) 1/2
(b) 1/4
(c) 1/32
17.
(a) 40 s
(b) 80 s
(c) 120 s
18.
(a) 3
(b) 5
19. 120 s
20. A - 4 minutes
B - 8 minutes
21. half life=20 min
22.
(a) 8 days
(b) 12 Bq or 13 Bq

23. 1 hour
24. 3 days
25.
(b) 4 hours