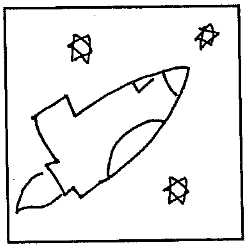
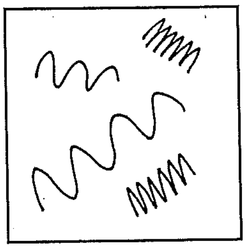
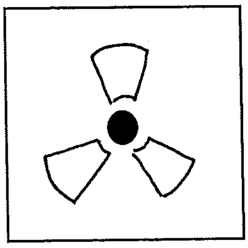
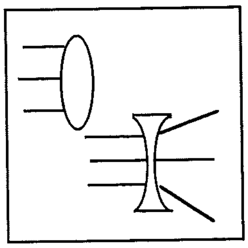
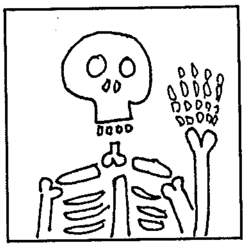
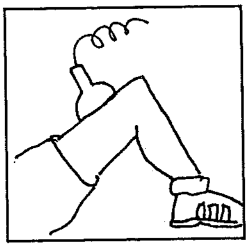
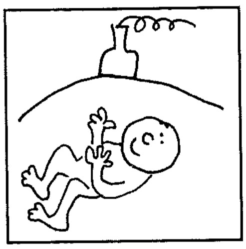
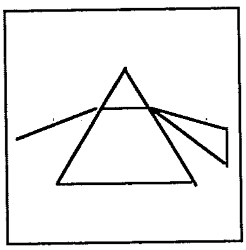
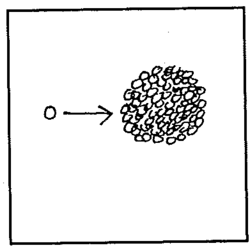
St. Maurice's High School | Physics Department

NQ 5 Physics

Unit 1

Waves and Radiation

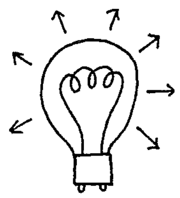










Notes and Tutorials

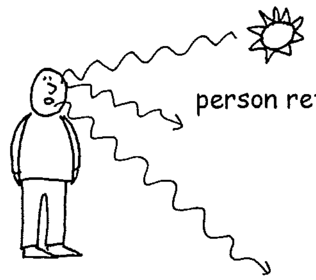
Waves and Radiation 1	Sound and Light

1. Sound and Light.

When we look at a bulb we see it because a light signal travels from the bulb to our eyes. We see a person because light from the sun or a bulb bounces off the person then travels to our eyes. We hear the person because a sound signal travels from the person to your ears.



bulb emits light



OK, they seem to be different signals - you **see** light and you **hear** the sound. But are there any other differences between **sound** signals and **light** signals.

But before we answer this question let's understand what we mean by a quantity called speed and how we measure it.

Tutorial 1	Attempt Q 1- 3

Ok let's go outside and see if we can see any other differences between sound and light.

Activity 1	Weird light and Sound

Tutorial 1	Attempt Q 4 - 8

Now as we saw, the values for the speed of sound in Activity 1 were not fantastically accurate. So how can we be more accurate?

Activity 2	Being More Accurate.

Tutorial 1	Attempt Q 9

We now know the speed of sound and light in air . Now we can work out interesting things knowing these speeds.

Activity 3 Rearranging a formula

Tutorial 1 Attempt Q 10 - 15

We have been avoiding something! - Questions involving the speed of light. That's because its such a big number, and you'll be there all day inputing it into your calculator. If only there was an easy way of dealing with big numbers like 300,000,000 or even tiny numbers like 0.0000000007?

Activity 4 Scientific notation and Weird Times

Tutorial 1 Attempt Q 16 - 25

Tutorial 1	Sound and Light 1

(1) A boy runs 30m in 5s. What is his average speed?

(2) A car travels 480m in a time of 20s. What is its average speed?

(3) A motor boat travels 700m in a time of 16s. What is its average speed?

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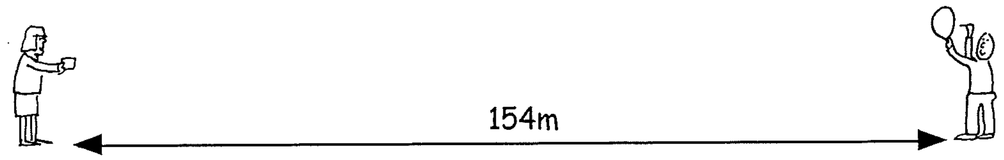
(4) What do waves carry?

(5) A girl and boy carry out an experiment to measure the speed of sound in air. The boy stands with a balloon and pin at one end of a playing field. The girl stands at the other end with a stop watch. The distance between them is 154m.



The boy bursts the balloon.

(a) Which event doses she experience first - seeing the balloon bursting or hearing the bang?

(b) Which event happens first - the balloon bursting, the sound being made or do they both happen at the same time?

(c) Why does she **see** the balloon burst before **hearing** the bang.

When she sees the balloon burst she starts the stopwatch. When she hears the bang she stops the watch. She measures a time of 0.43s

(d) Use this information to calculate the speed of sound she would obtain.

(6) In another experiment a boy stands in Princess street in Edinburgh. In the castle which is 800m away the 1 o'clock gun is fired. He sees the puff of smoke from the 1 o'clock gun then 2.3s later he hears the bang.

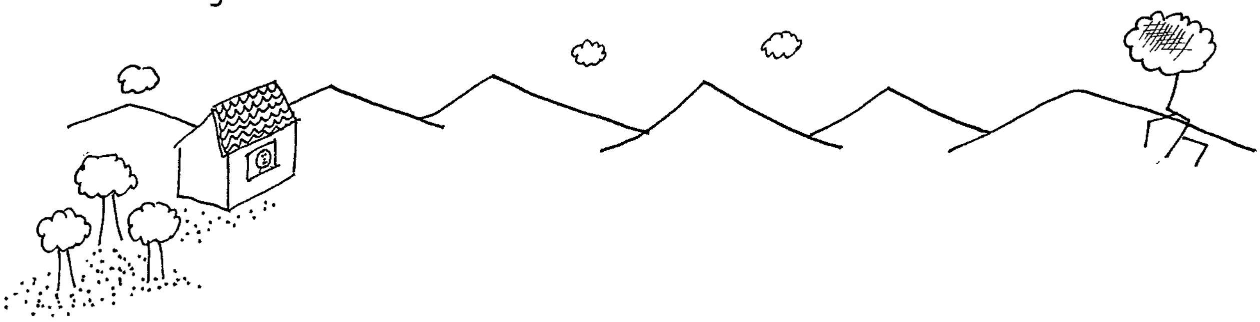
(a) Which is made first the puff of smoke, the bang or are they both made at the same time?

(b) Why does he **see** the puff of smoke before he hears the **bang?**

(c) Use the information to work out the speed of sound he would obtain.

(7) In question 4 and 5 which measurement - the distance or the time was not measured very accurately?

(8) A thunderstorm is a distance from a house. Suddenly there is a flash of lightning The girl in the house sees the flash then a few seconds later hears the thunder.



(a) Which is produced first the flash of lightning or the thunder?
(b) Why does she see the lightning before hearing the thunder?
(c) How far does the thunder travel through the air each second?
(d) The girl sees the lightning and counts 4s before hearing the bang. How far away is the storm?
(e) The time between the next flash of lightning and the thunder is only 2s What does this tell you about the storm?
(f) At one point the flash and the thunder are experienced at nearly the same time. What does this tell you about where the storm is?

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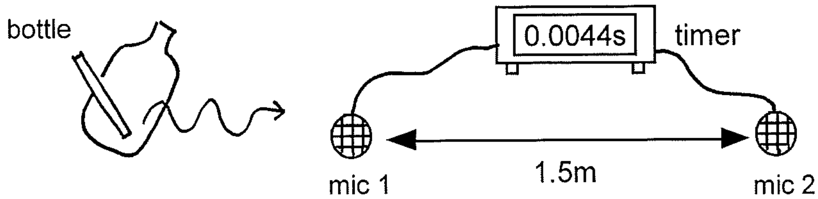
(9) This experiment was set up to measure the speed of sound more accurately. The pupil hits the bottle with a nail.



(a) Which microphone starts the stop watch?
(b) Which microphone stops the stop watch?
(c) Use the information to calculate the speed of sound.
(d) What could he do to make the results more reliable?

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(10) How far would a sound wave travel in 5s?

(11) How far would a sound wave travel in 17s?

(12) How far would a sound wave travel in 0.2s?

(13) How long would it take for a sound wave to travel 1020m?

(14) How long would it take a sound wave to travel 4080m?

(15) How long would it take a sound wave to travel 50m?

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(16) Write the following numbers in scientific notation.

(a) 400000 (b) 12000000 (c) 2340000

(17) Write the following numbers in scientific notation.

(a) 0.005 (b) 0.0000045 (c) 0.000248

(18) The speed of light is 3×10^{8} m/s. How long would it take a beam of light to travel 600,000m?

(19) How long would it take a beam of light to travel the 543,000m from Glasgow to London?

(20) How far would a beam of light travel in 5s?

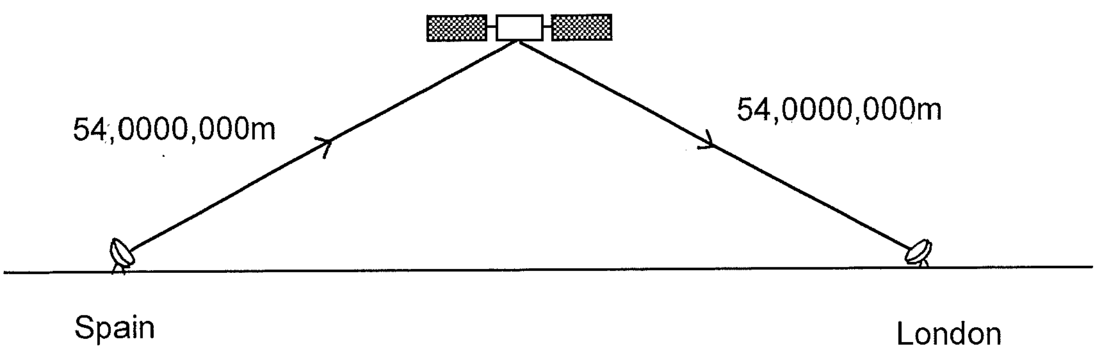
(21) How far would a beam of light travel in 0.2s?

(22) How far would a beam of light travel in 0.000004s?

(23) How long would it take a beam of light to travel 4×10^{6} m?

(24) In 1901 the first radio signal was sent from Cornwall in England to Newfoundland in Canada. The distance between the stations is 2,400,000m.
If radio waves travel at the speed of light calculate how long it took the signal to travel from Cornwall to Newfoundland.

(25) A satellite transmitter sends a signal from a football game in Spain to a satellite in space then down to the London TV studio.
The satellite signal travels at the speed of light. The distances involved are shown.



(a) Work out the distance the signal travelled. Write it in scientific notation.
(b) Calculate the time it took the signal to travel from Spain to London.

Now in the world of Science we like to measure distances in metres and time in seconds so we can compare like with like. Because what is faster? - a car travelling at 40km/hr or a train travelling at 25m/s? In many cases people rather annoyingly measure distances in cm, or mm or km, and times in minutes and hours and days. So how can we convert these annoying units into metres and seconds.

Activity 5 Conversion Poster

The great thing about studying Physics is that one minute you could be measuring huge distances like the diameter of a galaxy then the next day you could be peering down an electron microscope at tiny atoms.
It's important that we can deal with these big and small numbers.

Activity 6 Converting Big and Small Numbers

So let's now use our new conversion skill to work out trickier speed of sound and light examples.

Tutorial 2 Attempt Q 1 - 12

OK, we know that one difference between sound and light is that the speed of sound is slower than the speed of light. But are there any other differences?

Activity 7 Transverse and Longitudinal Waves

Tutorial 2 Attempt Q 13

Tutorial 2 — Sound and light 2

(1) Convert these times to seconds.

(a) 4ms (b) 2mins (c) 6hrs (d) 5days.

(2) Convert these distances to metres.

(a) 12mm (b) 8cm (c) 36cm (d) 7km
(e) 18.2km

(3) A car travels 6km in a time of 8 minutes. What is its average speed in m/s?

(4) A train travels 150km in 1 hour. What is its average speed in m/s?

(5) A worm travels 46cm across a garden slab in a time of 4 minutes.
What is its average speed in m/s?

(6) A bullet travels 90m in a time of 24ms?. What is its average speed in m/s?

(7) A jet air plane flies at 860km in 1 hour. What is its average speed in m/s?

(8) How long would it take a sound wave to travel 4.8km?

(9) How far would a sound wave travel in 9ms?

(10) How long would it take a light wave to travel 870km?

(11) How far would a light wave travel in 16ms?

(12) How long would it take a light wave to travel 8mm.

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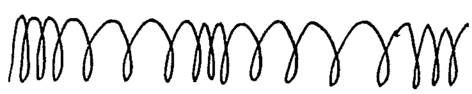
(13) Here are two waves.

A



B

(a) In which wave do particles move at right angles to the direction of energy?
(b) In which wave do particles move in the same direction as the energy?
(c) Which wave is a longitudinal wave?
(d) Which wave is a transverse wave?
(e) Are water and light waves transverse or longitudinal waves?
(f) Are sound waves transverse or longitudinal waves?

Sound can travel through gas like air. But can sound travel through liquids and solids and what about a vacuum?

Activity 8	Sound in different mediums

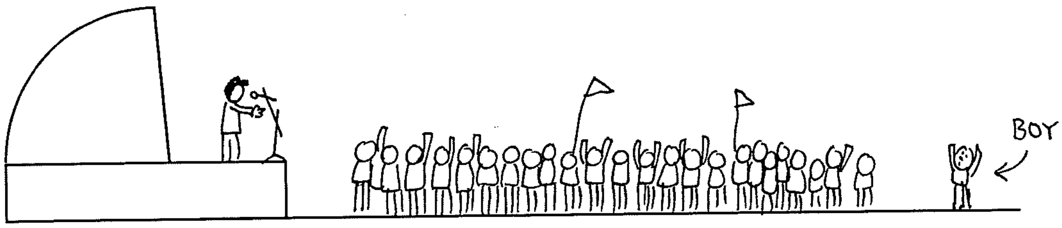
OK, so sound can travel through solids, liquids and gases. But what affects the speed at which it can travel through these mediums?

Activity 9	What affects the speed of sound

Tutorial 3	Attempt Q 1 - 2

Tutorial 3	Sound in Different mediums

(1) A boy is watching a concert on a **hot** sunny day in Spain.



(a) At night the temperature falls. Will the sound travel through the air faster or slower?

(b) Will the time taken for the sound to reach him increase or decrease?

(2) This table shows the speed of sound in different mediums.

Medium	Speed in m/s
air at 0^{o} C	331
air at 20^{o} C	343
air at 50^{o} C	361
helium	1005
water	1500
bone	4100
body tissue	1500
Granite	5000
Steel	5200

(a) Why does sound travel through helium faster than through air?

(b) How long would it take a sound wave to travel 500m in a hot desert at a temperature of 50^{o} C?

(c) Two whales are 200km apart in the ocean. How long would it take a whale whistle to travel between them?

(d) A sound wave takes 0.15s to travel through a steel pipe. How long is the pipe?

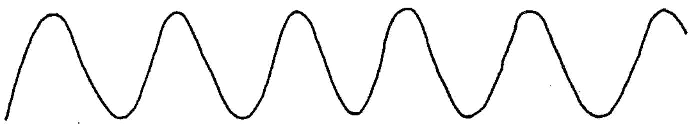
(e) A sound wave takes 1.44ms to travel through 7.2m of this material. By working out the speed name the material.

(f) A sound wave is sent through a 18cm long bone. How long would it take the sound wave to travel the length of the bone? (NB - turn cm to m)

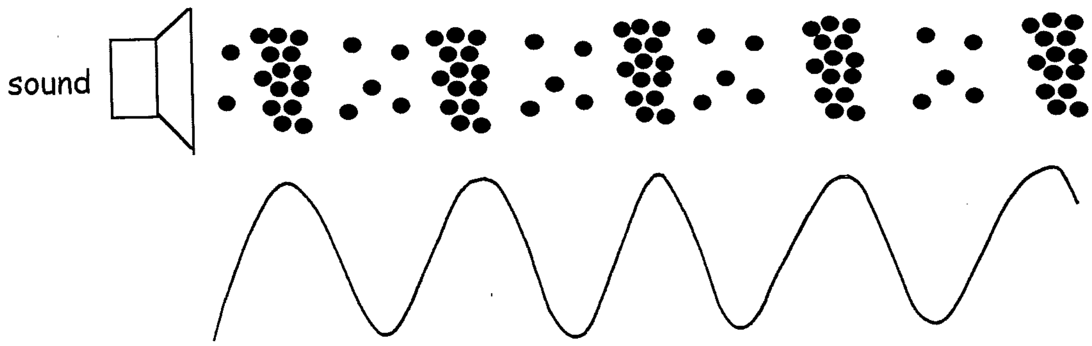
2. Wave Words

Waves are really interesting. We speak with them, we make music with them, we see with them, we surf on them, we send TV programmes around the world on them. We see inside your body with them, we can even cure cancer with them and they give us our nice tans on holiday. So let's look a bit more closely at these waves.

Now the problem with trying to study sound waves is, you can't see them, and the problem with light waves is, although you experience light, the waviness is too small to see. So to help us out here we imagine **all** waves as travelling as transverse waves like the wave shown below .



We know that sound is a longitudinal wave but for simplicity sound can also be represented by a transverse wave.
The compressions are represented by the top of the wave and the in between bits by the bottom of the wave.

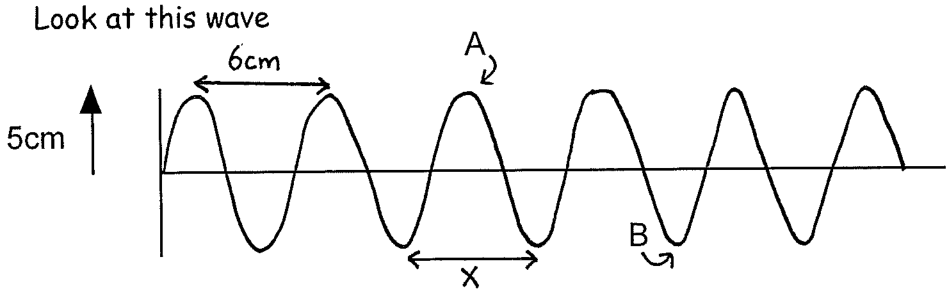


So now we have a picture of light and sound waves, let 's look at the words we use to describe them.

Activity 10	Wave words
Tutorial 4	Attempt Q 1 - 14
Activity 11	Wave pictures
Tutorial 4	Attempt Q 15 - 18

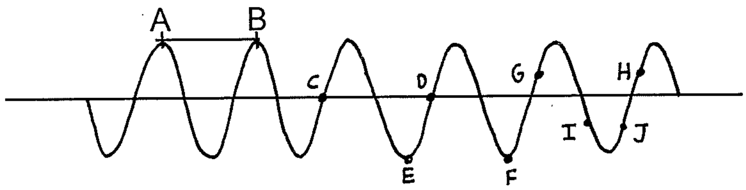
Tutorial 4	Wave Words

(1) Look at this wave



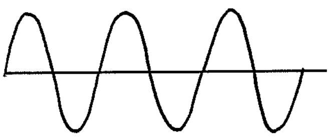
(a) What do we call part A?
(b) What do we call part B?
(c) What is the wavelength of the wave?
(d) So what is the length X?
(e) What is the amplitude of the wave?

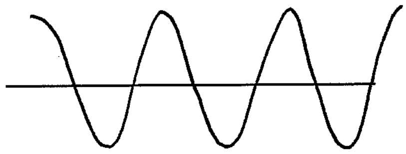
(2) Here is a picture of a wave. A-B represents one wavelength.

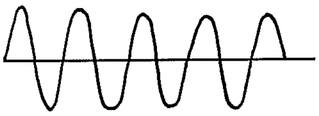


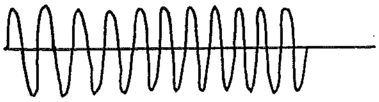
(a) State which other pairs of letters represent one wavelength.

(3) Here are 4 waves. For each wave count the number of waves shown.

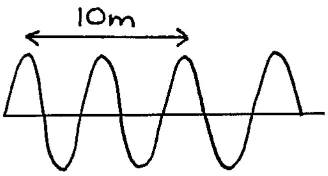
(a) 

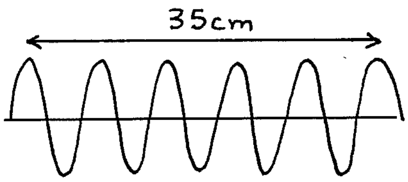
(b) 

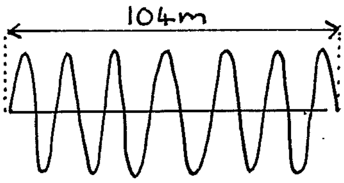
(c) 

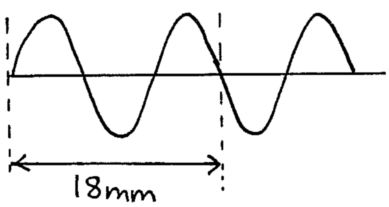
(d) 

(4) Here are a number of waves. For each wave state its wavelength.

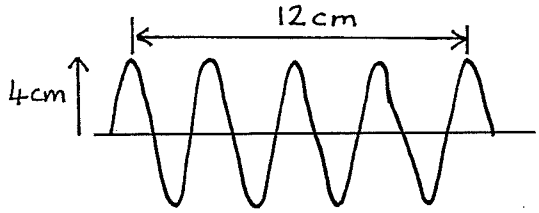
(a) 

(b) 

(c) 

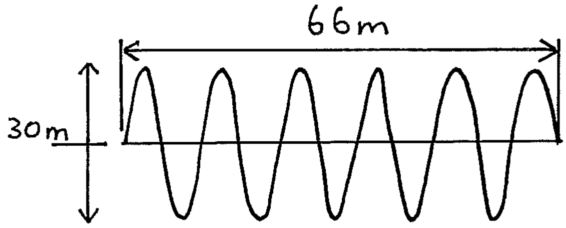
(d) 

(5) Here is a picture of a sound wave.



(a) What is its amplitude?
(b) What is its wavelength?

(6) Here is a picture of a water wave.



(a) What is its amplitude?
(b) What is its wavelength?

(7) Calculate the frequency of the waves

(a) 10 waves pass in 1s.
(b) 20 waves pass is 2s
(c) 30 waves pass in 5s
(d) 315 waves pass is 15s
(e) 48 000 waves pass in 2 minutes.
(f) 10 waves pass in 20s
(g) 12 waves pass in 90s.

(8) A sound comes off a loudspeaker as shown. The picture is taken after 2s

(a) How many waves are made in this 2s?
(b) What is the frequency of the waves?

(9) The frequency of a water wave is 2Hz. How many waves pass in 4s?

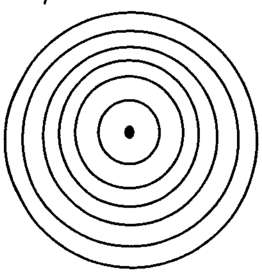
(10) The frequency of a sound wave is 200Hz. How many waves are made in 10s?

(11) The frequency of water waves lapping onto a beach is 1.5Hz. How many waves hit the beach in 20s?

(12) A smoke alarm emits a sound wave of frequency 12000Hz. How long would it take to produce 240 000 waves?

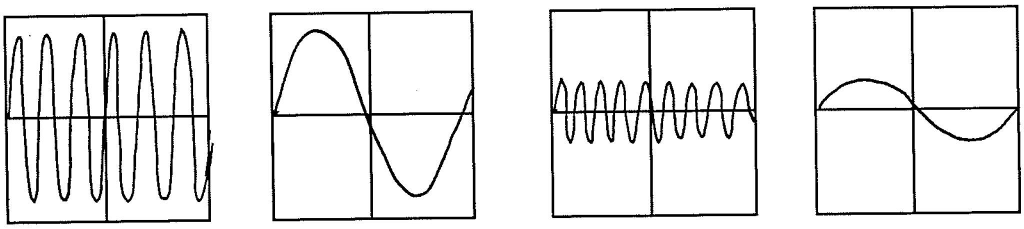
(13) A tuning fork produces a note of frequency 440Hz. How long would it take the fork to produce 2200 waves?

(14) A boy throws a stone into a pond. He takes a picture of the ripples after 2s.



(a) How many waves are made in 2s?
(b) What is the frequency of the waves?

(15) Here are 4 pictures of sound waves shown on an oscilloscope.

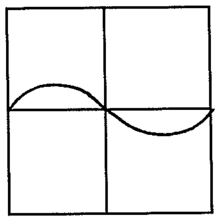


A B C D

(a) Which one shows a quiet, high freq sound?
(b) Which one shows a loud, low frequency sound?
(c) Which one shows a quiet, low frequency sound?
(d) Which one shows a loud, high frequency sound?

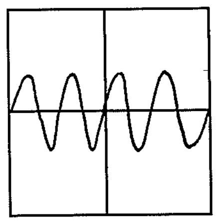
(16) A note produced by a guitar is shown on this oscilloscope.

(a) Sketch a new box and draw what would be seen on the trace if a **louder** **higher** pitched note was made.

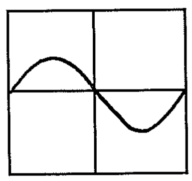


(17) This diagram shows a wave of amplitude 6cm and frequency 1000Hz.

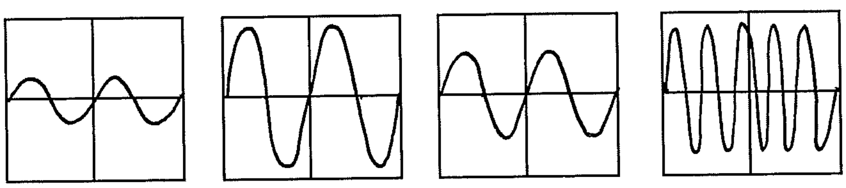
(a) Sketch a new box and draw a wave of frequency 250Hz and amplitude 12cm.



(18) Here is a picture of a sound wave.



(a) Which of these sound waves shows a sound of twice the frequency but the same volume?



A B C D

3. Diffraction

Waves like to travel in straight lines but can we make them change direction?

Activity 12	Diffraction of Sound

Activity 13	Diffraction of light.

Tutorial 5	Attempt Q 1 - 7

4. Sound Level

Activity 14	Sound level

Tutorial 5	Attempt Q 8 - 11

5. Ultrasound

We know that the frequency of sound can be increased, and as the frequency increases the sound gets a higher pitch.
But can humans hear all frequencies of sound?

Activity 15	Range of Human Hearing

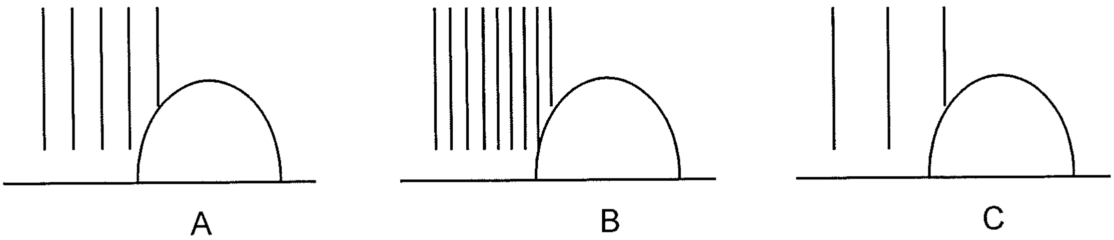
Activity 16	Ultrasound.

Tutorial 5	Attempt Q 12 - 20

Tutorial 5	Diffraction / Loudness / Ultrasound

(1) When waves meet an obstacle they bend round it. What do we call this bending effect.

(2) Here are 3 waves A,B and C meeting a hill top.



(a) Which wave will diffract the most?
(b) Which wave will diffract the least?

(3) Here are the wavelengths of 3 waves

A. 2m B. 12m C 90m.

(a) Which one will diffract the most?

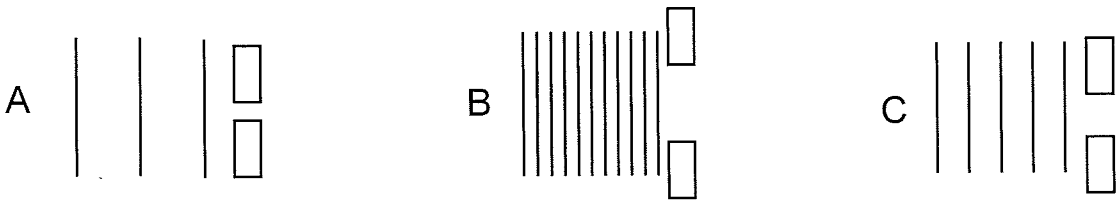
(4) (a) As the frequency of a wave increases. What happens to its wavelength?

(5) Here are the frequencies of 3 waves.

A. 1000Hz B. 50Hz C 60000kHz

(a) Which wave will diffract the most?

(6) Look at these diagrams. Which one will result in a semi circular wave pattern?



(7) A boy walks through the Scottish hills to get to a loch side music festival.

Explain why as he approaches through the hills he can only hear the bass guitar and bass drum from a band?

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(8) What is the unit for measuring loudness?

(9) Here is information about the loudness of some sounds.

Sound	Sound Level (dB)
Silence	0
Whisper at 2m	20
normal conversation	60
Lorry passing at 2m	90
Pneumatic drill at 5m	100
Disco 1m from speaker	120

(a) What is the sound level of a whisper at 2m?
(b) What produces a loudness level of 100dB?
(c) Why is it important to state the distance?
(d) Why is decibel level so important to measure?
(e) What should be worn if you are exposed to sounds above 90dB for a prolonged period of time?

(10) Noise can be called pollution. State 2 ways in which sound could ruin your environment.

(11) Give examples of where noise cancellation technology is useful to someone wearing headphones?

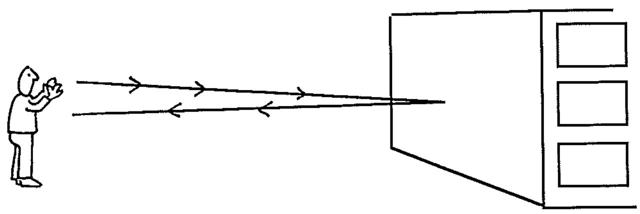
---

(12) What is the frequency range of human hearing?

(13) What is meant by ultrasound?

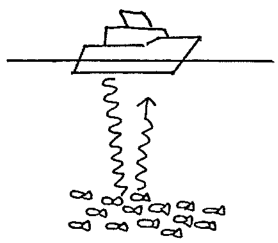
(14) Ultrasound will travel in a straight line through any material.
(a) What would make it reflect?

(15) A pupil stands a distance from the side wall of his school. He claps his hands His friend measures the time between the clap and the echo returning at 0.8s



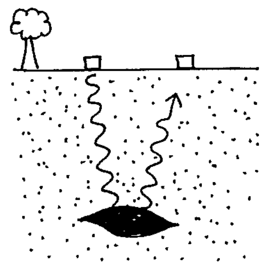
(a) How long did it take the sound to travel from the boy to the wall?
(b) Therefore work out the distance the boy is standing from the wall.

(16) Here is a fishing boat using ultrasound to find a shoal of fish.
A signal is sent out from the boat then a reflected pulse is received 1.2s later.



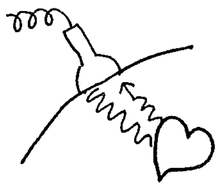
(a) What causes the reflected pulse?
(b) How long did it take the pulse to travel from the boat to the fish?
(c) Calculate the distance the fish are below the boat. (speed of sound in water = 1500m/s)

(17) An ultrasound pulse is sent down through sandstone to find a deposit of oil. The pulse takes 0.4s to return to the transmitter.
(speed of sound in sandstone = 2920 m/s)



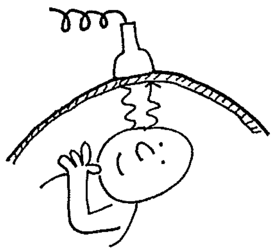
(a) How far below the ground is the oil deposit?

(18) An ultrasound scanner takes an image of a patients heart.
The time between the pulse leaving the transmitter and returning is 0.06ms. (hint - ms = $x10^{-3}$ s)
(speed of sound in muscle/tissue = 1500m/s)



(a) Calculate the depth the heart is below the scanner.

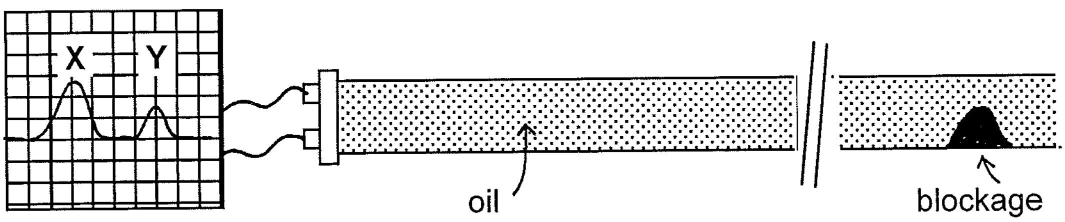
(19) A woman gets an ultrasound scan to creates picture of her unborn baby.
The baby's head is 7.5cm below the scanner as shown.



(a) What is the time elapsed between the sound being transmitted and received?
(speed of sound in fluid/tissue = 1500m/s)

(20) A blockage in an oil pipe is being located by firing a pulse of sound along the pipe. An oscilloscope is being used to record the transmitted and received pulse. The oscilloscope can be used as a timer, because each horizontal box on the screen represents 24ms in time.

X= transmitted pulse. Y= received pulse.



(a) What was the time taken by the pulse to travel from the transmitter to the receiver? (hint look at no of boxes the trace travel between X & Y)
(b) Calculate the distance the blockage is from the transmitter.
(Speed of sound in petrol oil = 1290m/s)
(c) Why is the amplitude of pulse X greater than pulse Y?

6. Speed, frequency and Wavelength.

We know that if we want to measure the speed of a wave all we need to know is how far it travels (distance) and how long it takes to travel that distance (time). Then use $\text{speed} = \frac{\text{distance}}{\text{time}}$ to calculate the speed.

I wonder, can we calculate the speed of a wave if we know the wavelength and frequency of the wave? So we are going to find an equation that links speed, frequency and wavelength.

Activity 17	Speed, wavelength and frequency.

Tutorial 6	Attempt Q 1 - 24

Tutorial 6	Speed, Wavelength and Frequency.

A. Just v = fλ for sound and water waves.

(1) A water wave has a wavelength of 4m and a frequency of 2Hz.
Calculate its speed.

(2) A wave has a wavelength of 2.5m and a frequency of 18Hz.
Calculate its speed.

(3) A wave has a frequency of 50Hz and a wavelength of 40cm.
Calculate its speed. (careful - turn cm to m)

(4) A water wave travelling at a speed of 5m/s has a frequency of 1.2Hz.
Calculate its wavelength.

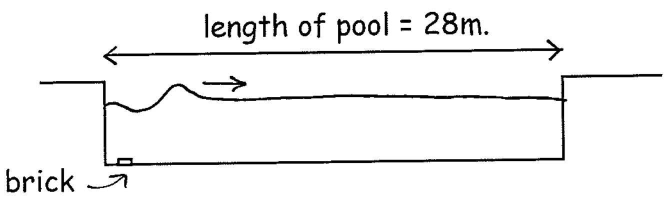
(5) The wavelength of a sound wave travelling at 340m/s is 4.2m.
Calculate its frequency.

(6) A wave machine at a swimming pool produces waves with a speed of 0.86m/s. If the wavelength of the waves is 1.5m calculate its frequency.

(7) A wave has a frequency of 550Hz. If its speed is 45m/s.
(a) Calculate its wavelength.
(b) If you doubled its frequency what would happen to its wavelength.

B. v=fλ and v = d/t for sound and water waves

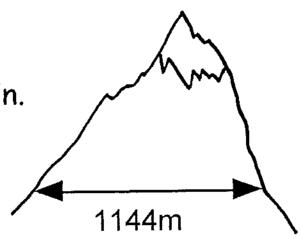
(8) A girl measures the length of a swimming pool . She drops a brick in at one end and measures the time it takes a wave to travel the 28m



Time to travel the 28m = 20s

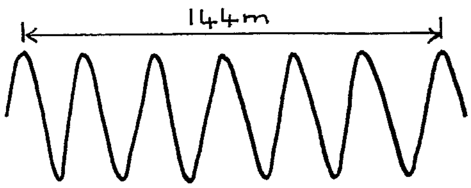
(a) Calculate the speed of the waves.
(b) If the distance between peaks was 1.2m calculate the frequency of the waves?

(9) A sound wave takes 0.22s to travel through a granite mountain.
The mountain has a width of 1144m.



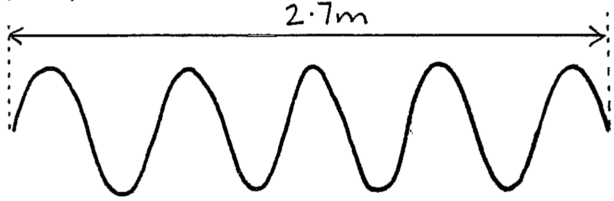
(a) Calculate the speed of the sound waves in granite.
(b) If the frequency of the waves in the granite was 45000Hz calculate the wavelength of the waves in the ganite.

(10) Here is a picture of a sound wave travelling through air.



(a) What is the speed of a sound wave travelling through air?
(b) What is the wavelength of the wave?
(c) Calculate the frequency of the waves?

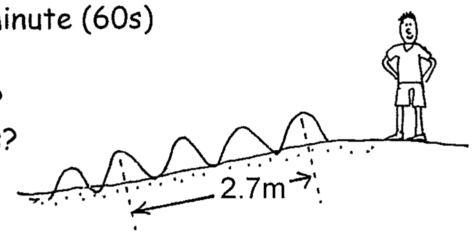
(11) Here is a picture of a water wave.



(b) What is the wavelength of the wave?
(c) If 40 waves pass you in 5s what is the frequency of the waves?
(d) Calculate the speed of the wave.

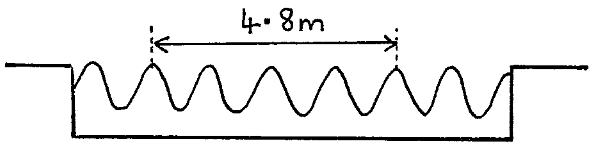
(12) Billy is studying water waves breaking onto a beach as shown.
He counts 20 waves hitting the shore in 1minute (60s)

(a) What is the frequency of the waves?
(b) What is the wavelength of the waves?
(c) What is the speed of the waves?



(13) 30 water waves shown in the diagram are created in a University research tank in 2s

(a) Calculate its frequency.
(b) Calculate its wavelength.
(c) Calculate its speed.

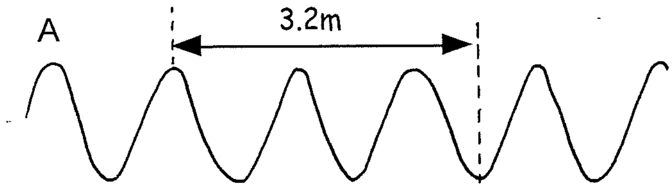


(14) The frequency of a sound wave is 12kHz. What is its wavelength?

(15) The wavelength of a sound wave is 4cm. What is its frequency?

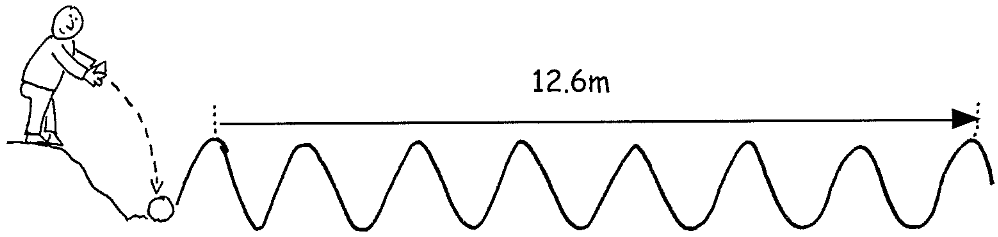
(16) A wave of frequency 680kHz has a wavelength of 15cm.
Calculate its speed.

(17) The peak A of this wave travels 4.8m is a time of 1.2s.



(a) Calculate its speed.
(b) Calculate its frequency. (hint - can you find its wavelength)

(18) A boy drops a stone into the water and takes a picture of the ripples after 5s.



(a) How far did the first peak travel in the 5s?
(b) Calculate the speed of the wave.
(c) From the diagram can you work out the wavelength?
(d) Therefore calculate the frequency of the wave.

<u>C</u> <u>$v=f\lambda$ and $v=d/t$ for light waves</u>

(19) A beam of red light has a wavelength of 7×10^{-7} m. Calculate its wavelength

(20) Light waves leave a fluorescent material with a frequency of 7.8×10^{15} Hz. What is the wavelength of the light waves?

(21) A wave travels 27000m in a time of 9×10^{-2} s. Its frequency is 8.1×10^{4} Hz

(a) Calculate the speed of the wave.
(b) Calculate the wavelength of the waves.

(22) A light wave has a frequency of 36MHz. What is its wavelength?

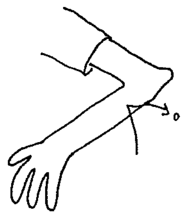
(23) A light wave has a wavelength of 0.04m. Calculate its frequency

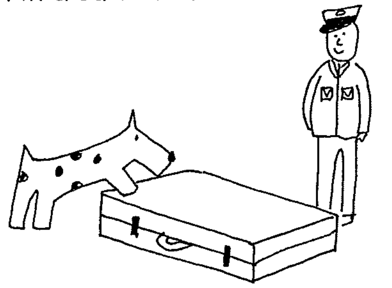
(24) What is the frequency of light wave with a wavelength of 0.24mm?

Waves and Radiation 2	Electromagnetic Spectrum.

1. Electromagnetic Radiation

Our senses are fairly limited. We can only hear frequencies of sound between 20 and 20 000Hz. Our skin can't feel bits of dust banging into it. Our noses can't smell a pair of pongy socks hidden in a suitcase.





What about our eyes? Are there light waves whizzing about the room just now that our eyes are not sensitive enough to pick up? Well the answer is yes. The air around us is choc a bloc with billions of light waves whizzing around that we can't see.

Sometimes calling all these waves LIGHT waves is a bit confusing because we can't see most of them. So we will give them their scientific name - ELECTROMAGNETIC waves or radiation. Visible light is just a very small part of this big electromagnetic family.

Activity 18	Meet the Electromagnetic Waves family
Tutorial 7	Attempt Q 1 - 6
Activity 19	Radio and TV
Activity 20	Microwaves
Activity 21	Infra Red
Tutorial 7	Attempt Q 7 - 13

Activity 22 Visible Light

Activity 23 Ultra Violet

Activity 24 X Rays

Activity 25 Gamma Rays

Tutorial 7 Attempt Q 14 - 19

We now know lots about the family of electromagnetic waves from radio waves with there long wavelengths way down to gamma rays with their tiny, microscopic wavelengths. Let's see if we can apply our understanding

Activity 26 Mobile Electromagnetic Radiation Bus

Tutorial 7	Electromagnetic Radiation

(1) Here is the electromagnetic radiation family or spectrum.

Radio & TV	A	Infra Red	Visible light	B	X rays	Gamma Rays

(a) Name the missing parts of the spectrum A and B?
(b) What is the only part of the spectrum that you can see?
(c) What happens to the frequency as you travel from radio to gamma waves?
(d) Therefore what happens to the wavelength of the waves?
(e) Waves in which part of the spectrum have the most energy?
(f) Which has a higher frequency X- rays or infra red radiation?
(g) Which has the longer wavelength radio waves or visible light?

(2) What is the speed of every wave in the electromagnetic spectrum?

(3) Which has the higher frequency red or blue light?

(4) An infra red wave and an X ray meet a building. Which one will diffract the most round the building? Explain.

(5) The wavelength of an X ray is 7.2×10^{-11} m. Calculate its frequency.

(6) The following table shows the wavelength bands associated with the electromagnetic families.

Family	Wavelength range (m)
Radio & TV	over 0.1m
Microwaves	0.1 to 1×10^{-3}
Infra red	1×10^{-3} to 7×10^{-7}
Visible light	7×10^{-7} to 4×10^{-7}
ultraviolet	4×10^{-7} to 1×10^{-9}
X rays	1×10^{-9} to 1×10^{-12}
gamma rays	1×10^{-12} to 1×10^{-13}

(a) What is the wavelength range of ultraviolet light?
(b) A wave has a wavelength of 5×10^{-7} m . Which family does it belong to?
(c) A wave has a wavelength of 4×10^{-10} m. Which family does it belong to?
(d) A wave has a frequency of 1.2×10^{13} Hz Which family does it belong to? (hint - a calculation is involved)

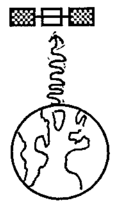
(7) State the type of electromagnetic radiation you would use in each of the following applications.

(a) Heat treating damaged muscle tissue.
(b) Carrying TV programmes up to a satellite in space.
(c) For taking a picture of an old persons hands to diagnose arthritis.
(d) Carrying football commentaries from Edinburgh to Glasgow.
(e) Carrying the pictures of the game from Glasgow to Edinburgh.
(f) Finding people in dark or smoke filled rooms during a house fire.

(8) A TV signal uses a carrier wave of frequency 450MHz and a radio station uses a radio wave of frequency 810kHz.

(a) Which station - the radio or TV uses the highest frequency wave?
(b) Therefore which uses the wave with the longest wavelength?

(9) A geostationary satellite is positioned 36 000km above the Earth. A microwave is sent up to the satellite. The wavelength of the microwave is 2cm.



(a) Calculate the frequency of the microwave.
(b) How long would it take the microwave to reach the satellite?

(10) A microwave of frequency 8GHz carries signals to a satellite in space. What is its wavelength?

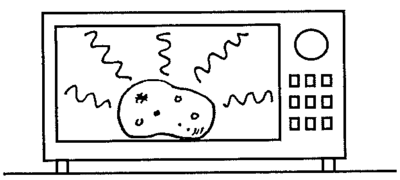
(11) Tony sprains his ankle when playing rugby. A physiotherapist uses infra red radiation of wavelength 1.2×10^{-4} m to help the ankle heal.

(a) What is the frequency of the infra red radiation?
(b) To heal tissue which is deeper under the skin she has to use infra red radiation with a shorter wavelength. Without doing a calculation should she use a beam of frequency 6000MHz or 3000MHz?

(12) A radio station sends a signal 152km from an aerial outside Inverness to Aberdeen. The frequency of the radio wave is 99.5MHz.

(a) Calculate the wavelength of the radio wave
(b) How long (time) would it take the signal to travel the 152km?

(13) Microwaves have been used for many years to cook food. The wavelength of microwaves is about 12cm. Calculate their frequency.



(14) For each application state the type of electromagnetic radiation used.

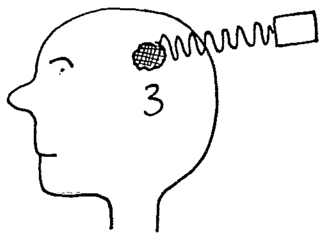
(a) To help clear up severe skin conditions like acne.
(b) Removing a birth mark or tattoo.
(c) To create a picture of dense body material like bone.
(d) To kill cancer cells lying deep inside the body without surgery.
(e) As an invisible security marker on equipment.
(f) To kill bacteria on surgical equipment (Could be two)
(g) For cutting and welding metal

(15) Our eyes can see a range of wavelengths of electromagnetic radiation from red light with a wavelength of 700nm down to violet light with a wavelength of 400nm (nano means $\times 10^{-9}$ m).

(a) Without doing a calculation state which colour has the highest frequency.
(b) Calculate the frequency of violet light.
(c) What would the violet light turn into if its wavelength was shortened further?

(16) The ancient Egyptians knew that sunlight was good for the skin.
A ray of UV light has a frequency of 8.8×10^{16} Hz. Calculate its wavelength.

(17) A gamma ray is used to kill cancer cells in a patients brain. If the wavelength of these gamma rays is 1.2×10^{-19} m calculate their frequency.



(18) An X ray has a frequency of 6.8×10^{17} Hz
Calculate its wavelength.

(19) Typical wavelengths in air of light of different colours are given in the following table.

Colour	Wavelength in air (m)
red	6.5×10^{-7}
green	5.2×10^{-7}
blue	4.0×10^{-7}

(a) What is the speed of light in air?
(b) The frequency of a certain colour of light is 4.6×10^{14} Hz.
What colour is this light?

2. Visible Light

Because visible light is the family of radiation we experience all the time because we can see it, we are going to take a closer look at how we can control it.

Activity 27	Refraction.

Tutorial 8	Attempt Q 1 - 8

Activity 28	Uses of Refraction.

Tutorial 8	Attempt Q 9 - 13

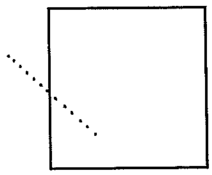
Tutorial 8 — Refraction

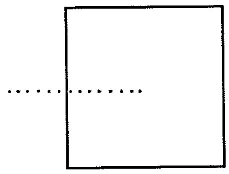
(1) (a) What happens to the speed of a wave when it travels from one medium into another?

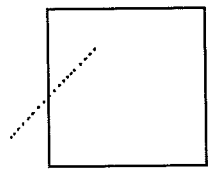
(b) What do we call this change in speed?

(c) When a wave travels from one medium into another at an angle to the normal what else about the wave changes?

(2) Look at these 3 diagrams. Three pupils have tried to draw the normal to the side of a glass block


X

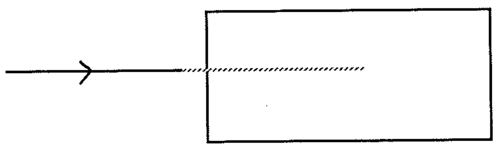

Y

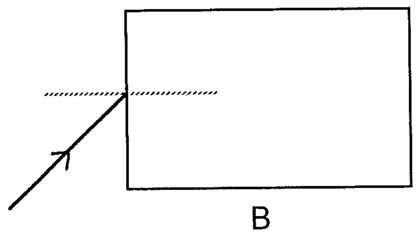

Z

(a) Which is the only normal which has been drawn properly?

(b) What is the angle between a boundary and the normal?

(3) Look at these two diagrams of a beam of light travelling from air into 2 glass prisms.


A

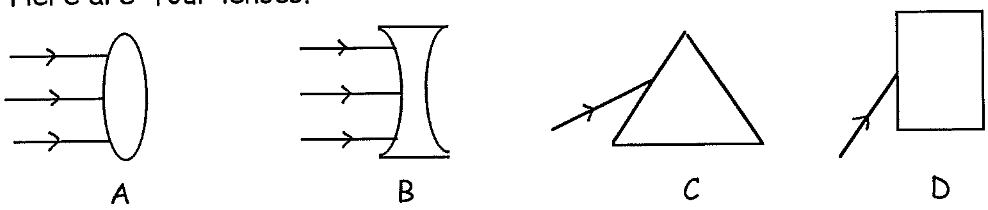

B

(a) In diagram A why will only the speed of the light change as the light travels from air into the glass?

(b) Will the speed of the light increase or decrease?

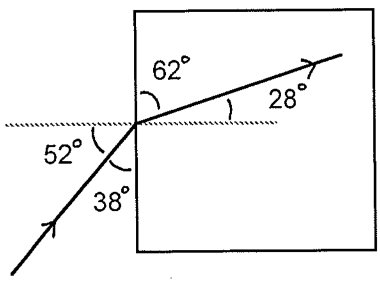
(c) In diagram B why will the speed and direction of the light both change?

(4) Here are four lenses.



(a) Sketch each lens and complete the diagram to show what happens to the rays of light.
(b) What is the name given to lens A?
(c) What name is given to lens B?

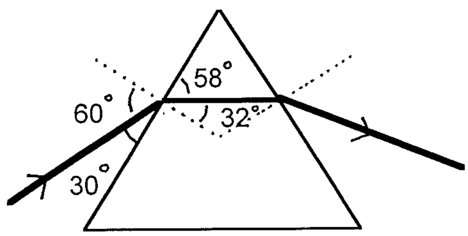
(5) This diagram shows a beam of light travelling through a prism.



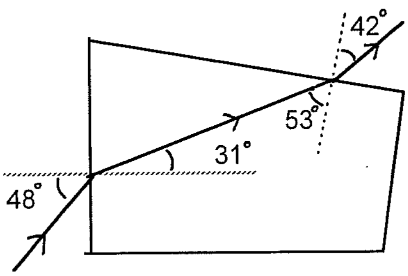
(a) What do we call the dotted line?
(b) What do we measure **from** this line?
(c) Name the angle of incidence.
(d) Name the angle of refraction.

(6) Look at this beam of light being refracted through this glass prism.

(a) Name the angle of incidence.
(b) Name the angle of refraction.



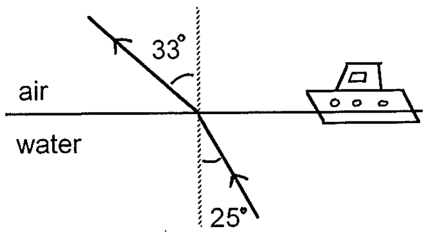
(7) This diagram shows a beam of light travelling through a prism.



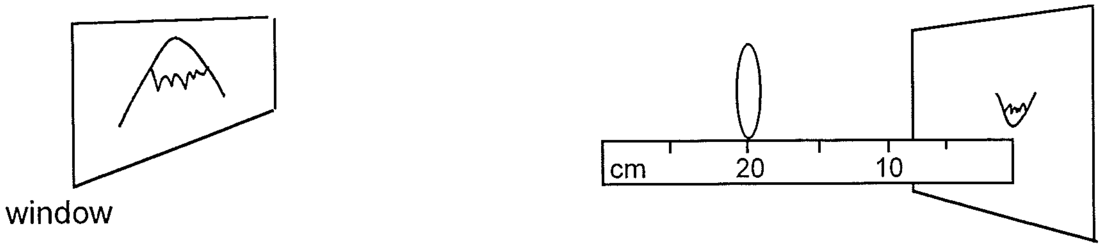
(a) State two angles of incidence.
(b) State two angles of refraction.

(8) This diagram shows a beam of light travelling from water back into air.

(a) State the angle of incidence.
(b) State the angle of refraction.



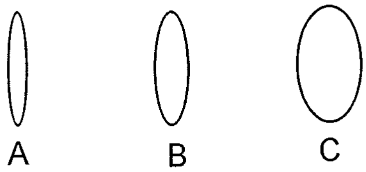
(9) The following apparatus was used to measure the focal length of a convex lens.



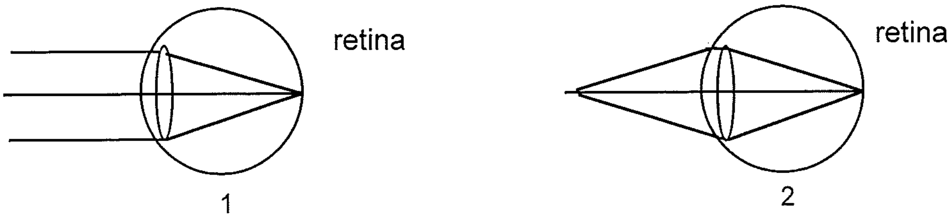
(a) Describe how the image of the hill created on the paper compares with the actual hill?

(b) Use the information on the diagram to state the focal length of the lens.

(10) Which lens has the shortest focal length?



(11) Look at these diagrams of a person with perfect vision.



(a) How can you tell from the diagrams that the person has perfect vision?

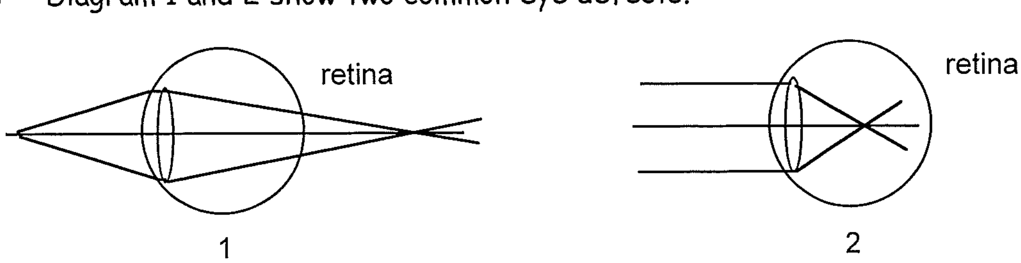
(b) In diagram 1 is she looking at a nearby or distant object?

(c) In diagram 2 is she looking at a nearby or distant object?

(12) A woman can read her book but struggles to see a distant car registration plate.

(a) Which eye defect is she suffering from?

(13) Diagram 1 and 2 show two common eye defects.



(a) Which eye defect is shown in diagram 1.

(b) Which lens would correct this defect?

(c) Which eye defect is shown in diagram 2.

(d) Which lens would correct this defect?

Waves and Radiation 3	Nuclear Radiation

1. What is Nuclear Radiation?

OK, we have looked at Electromagnetic radiation, but what is nuclear radiation? Well the clue is in the title. But before we look at what nuclear radiation is, let's look at the tiny, tiny wee particles which make up the whole universe. Yes the atom.

Activity 29	The atom

Activity 30	Unstable Atoms and Nuclear Radiation.

Tutorial 9	Attempt Q 1- 4

We mentioned back in the last section that gamma radiation was dangerous because it caused ionisation. But do alpha and beta radiation cause ionisation as well and if so do they cause more or less than gamma rays?

Activity 31	Ionisation

Now, because all radiation causes ionisation, it is dangerous. So how can we stop it getting near to us?

Activity 32	Absorption

Tutorial 9	Attempt Q 5 - 8

Because Gamma radiation is a type of electromagnetic radiation we have looked at some of its applications in the last section. let's see if we can find some more applications for all 3 types of nuclear radiation.

Activity 33	Applications of Nuclear Radiation.

Tutorial 9	Attempt Q 9 - 11

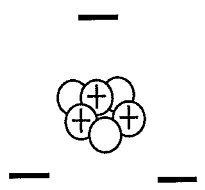
We tend to think that nuclear radiation comes from leaks from nuclear power plants or nuclear bomb testing. But is this the only source?

Activity 34	Background Radiation

Tutorial 9	Attempt Q 12 - 15

Tutorial 9 — The Atom and Nuclear Radiation

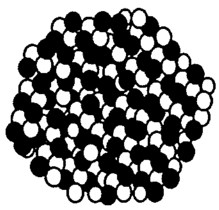
(1) Look at this picture of an atom.



(a) Name the two particles in the nucleus.
(b) Which particle has a positive charge?
(c) Which particle has no charge?
(d) What is the name of the particles which circle the nucleus?
(e) What is their charge?

(2) Most atoms around us are electrically neutral. What does this tell you about the number of protons and electrons in an electrically neutral the atom?

(3) This diagram shows an unstable Uranium nucleus.



(a) Why is this diagram described as a uranium nucleus and not a uranium atom?
(b) What is it about the nucleus that makes it unstable?
(c) Name the 3 types of nuclear radiation that an unstable nucleus emits to try and become stable.
(d) Why are these 3 types called NUCLEAR radiation?

(4) (a) Which type of nuclear radiation is a particle made from two protons and two neutrons?
(b) Which type of nuclear radiation is an electromagnetic wave?
(c) Which type of nuclear radiation is a fast moving electron?

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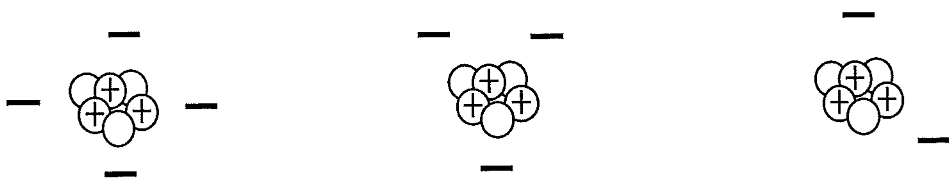
(5) Here are 3 atoms.



A B C

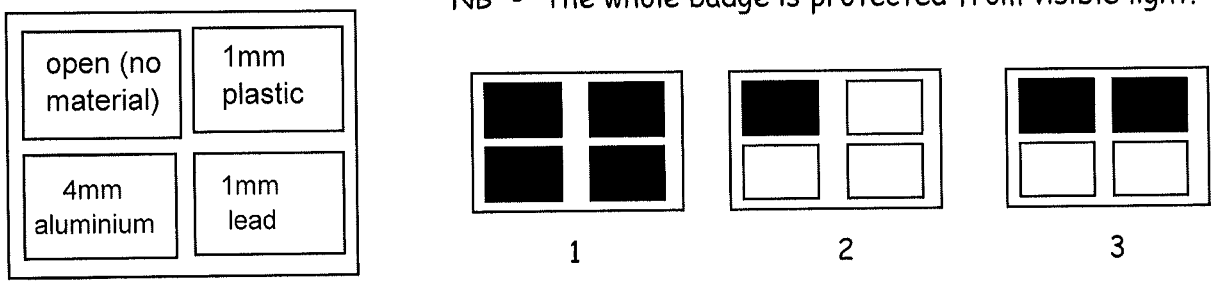
(a) Which one is neutral?
(b) Which one is a positive ion?
(c) Which one is a negative ion?
(d) What do we call the process were electrons are added or removed from an atom?

(6) (a) Which type of nuclear radiation causes the most ionisation?
(b) Give two reasons why this type of radiation causes the most ionisation.

(7) (a) Which type of nuclear radiation is stopped by a thick block of lead?
(b) Which type of nuclear radiation is stopped by a piece of paper or 5cm of air?
(c) Which type of nuclear radiation is stopped by 2m of air or 3mm of aluminium?

(8) The left hand diagram shows a badge worn by nuclear workers. The right hand diagrams show the developed photographic film from the badges of 3 workers

NB - The whole badge is protected from visible light.



Each badge was exposed to one type of radiation

(a) Which type of radiation was badge 1 exposed to?
(b) Which type of radiation was badge 2 exposed to?
(c) Which type of radiation was badge 3 exposed to?

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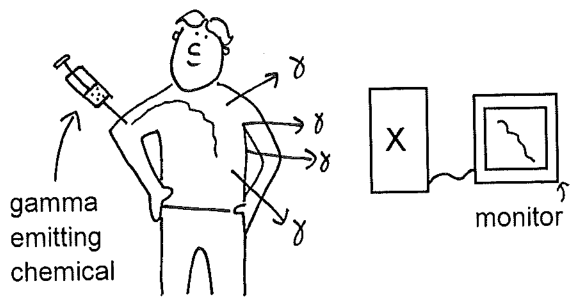
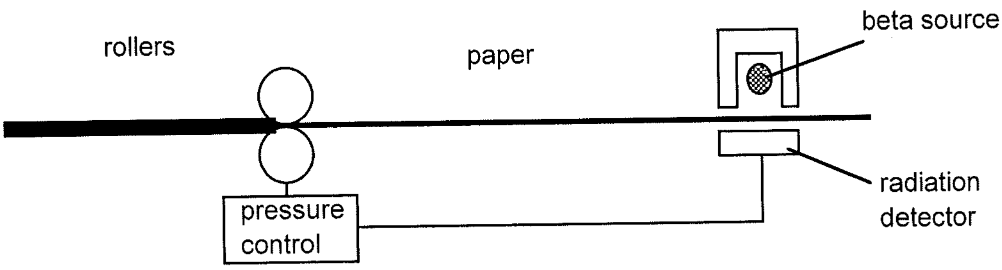
(9) Gamma rays can be used as a tracer to study the flow of fluid around the body.

(a) State 2 reasons why the chemical injected into the patient emits gamma rays and not alpha or beta particles?
(b) What is device X called?

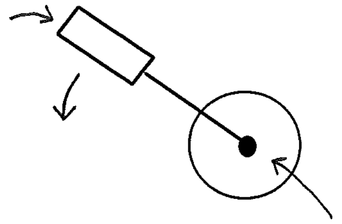


(10) A paper mill uses a beta emitting radioactive source to monitor the thickness of paper. The detector picks up the amount of beta particles passing through the paper.



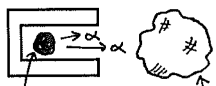
(a) Why would it not be a good idea to use an alpha source?
(b) Why would it not be a good idea to use a gamma source?
(c) One day the reading on the radiation detector increases rapidly. Does this indicate the paper is too thick or too thin.
(d) Should more or less pressure be exerted on the paper?

(11) Gamma rays can be fired directly at a tumour in the middle of a brain as shown The gamma emitter circles the patient's head.



(a) Why would gamma rays be a better option than alpha or beta radiation
(b) Why does the gamma emitter circle round the skull as it fires at the tumour

For a person who cannot get to hospital regularly the doctors can place an alpha source in a container very close to the tumour as shown.



(c) Why would an alpha source be more effective in this situation than a gamma source?
(d) Why is the alpha source placed in a container?

---

(12) What do we call the radiation which is around us all the time?

(13) This table gives information about different sources of background radiation. However the writer has forgotten to add the headings for each column.

A	B
Radon gas from the rocks and soil	Leaks from nuclear power station
Cosmic rays from space	Hospital treatments.
Carbon and Potassium in the human body.	Fall out from nuclear testing
	Aeroplane trips

(a) What is the heading A?
(b) What is the heading B?

(14) Why are you only permitted a certain number of X-rays per year?

(15) (a) Why are pilots only allowed to fly a certain number of flights per year?
(b) Why would an astronaut be more concerned with background radiation than a pilot?

2. Measuring Radiation.

So we know that there is radiation around us all the time and if you work with radiation you are more likely to be exposed to more radiation than most people. This is dangerous because the radiation can ionise the atoms in our healthy cells and therefore damage the cell.
So what we are looking for in this section, is a quantity that will tell us the biological harm radiation can do to us. If we can measure how dangerous the radiation is, we can take steps to reduce our exposure to it.

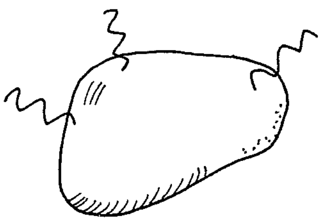
So on our route to this final useful quantity we will look at some other ways of measuring radiation.

Activity 35	Activity (A)

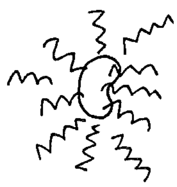
Tutorial 10	Attempt Q 1 - 6

OK, Activity is a start. It tells us how much radiation the source is emitting each second. But it does not tell us about the number of particles that actually hit a person's body, how fast they are going or just how big this body or organ is.

Look at this diagram. In the diagram, 6 bits of radiation are being absorbed by a big 1kg liver. In diagram 2 400 bits of radiation are hitting a wee 0.3kg kidney.



liver



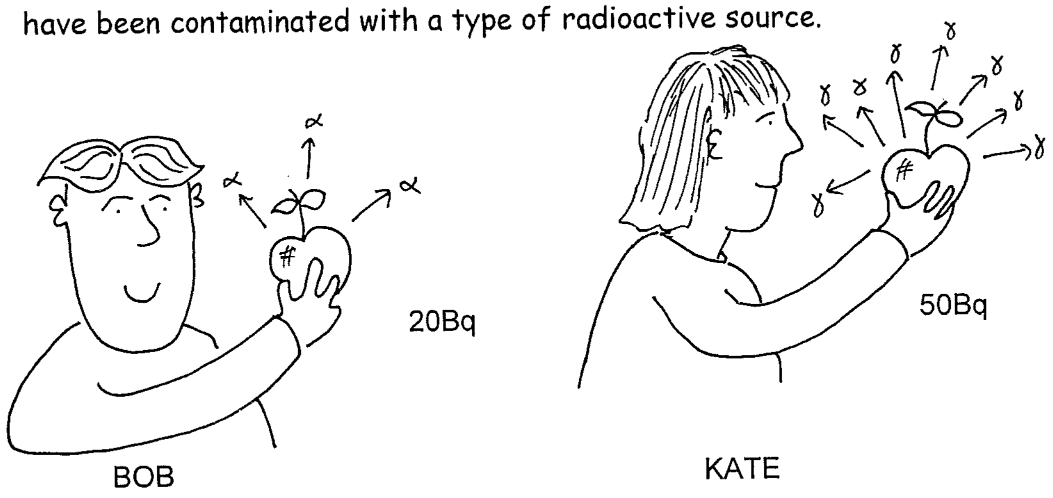
kidney

Which organ will undergo the greatest harm? It looks like the kidney will suffer more damage because it has a smaller mass and is absorbing more energy.
So we have to take into account the total **energy** of the particles hitting the organ and also the organ's **mass**.

Activity 36 Absorbed Dose (D)

Tutorial 10 Attempt Q 7 - 10

look at these two nuclear workers. Bob and Kate have just eaten apples which have been contaminated with a type of radioactive source.



Bob is not bothered because the activity of his apple was only 20Bq. But why **<u>should</u>** Bob be more worried than Kate?

What other thing do we need to take into account when we are trying to measure the biological harm radiation will do

Activity 37 Equivalent Dose (H)

Tutorial 10 Attempt Q 11 - 27

Tutorial 10	Dosimetry - Measuring Radiation

Activity

(1) In a radioactive source 240 decays occur in 6s. What is the activity?

(2) A radioactive source emits 8×10^5 alpha particles in 40s. What is the activity of the source?

(3) The activity of a source is 7 000Bq. How many nuclear decays take place in 20s?

(4) The activity of a source is 8.4kBq. How many decays take place in 2minutes?

(5) The activity of a source is 52MBq. How long would it take for 2.6×10^8 beta particles to be emitted?

(6) In a radioactive source 78 000 decays take place in 6mins 20s. Calculate the activity.

Absorbed Dose

(7) An industrial worker of mass 78kg absorbs 250J of radiation. Calculate the absorbed dose he receives.

(8) A nuclear workers hand which has a mass of 0.8kg receives 68mJ of radiation. What is the absorbed dose received by his hand?

(9) A hospital worker 64kg receives and absorbed dose of 120μGy of radiation. How much energy did the eye receive?

(10) A patient's thyroid gland receives 500Gy of radiation from a source. If the gland receives 15J of energy calculate the mass of the gland.

Equivalent Dose

(11) The absorbed dose does not give very accurate idea of the biological harm the radiation can do. For this we need another Quantity.

(a) Which quantity gives us an accurate idea of the biological harm radiation can do to a human body?

(b) What two important things does this quantity take into account?

(12) We know that alpha particles would cause more ionisation in the human body than beta and gamma rays. So which particle will have the largest weighting factor?

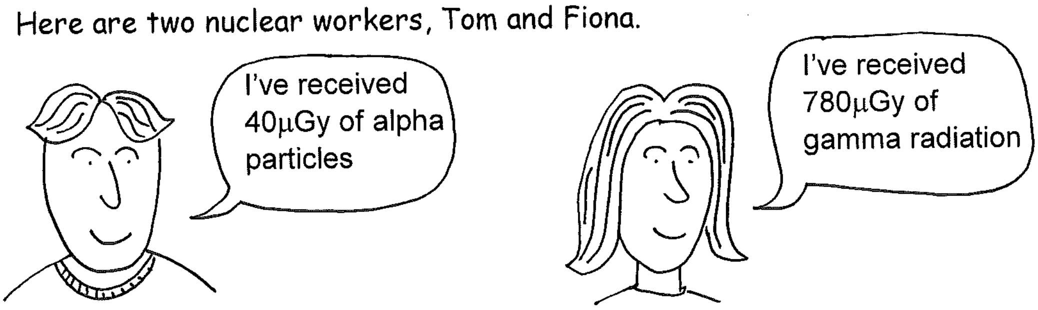
(13) Here are the weighting factors of various ionising radiations.

Type of Radiation	Weighting factor
alpha	20
beta	1
gamma	1
slow neutrons	3
fast neutrons	10
X - rays.	1

(a) A nuclear worker receives an adsorbed dose of 0.2Gy of alpha particles. What is her dose equivalent.

(b) A hospital worker receives an absorbed dose of 36mGy of slow neutrons. What is his dose equivalent.

(14) Here are two nuclear workers, Tom and Fiona.



(a) By working out the equivalent dose each receives, who should be most worried? Explain.

(15) A dental X ray produces an absorbed dose of 0.3mGy. What is the equivalent dose she receives?

(16) An industrial worker receives 200μGy from fast neutrons. What is his equivalent dose

(17) A patient receives 2mSv of radiation from a chest X - ray. What is the patients absorbed dose?

(18) A fish swallows a tiny amount of alpha radiation. If the equivalent dose received by the fish was 5μSv what is its absorbed dose?

(19) A technician in a nuclear laboratory received an absorbed dose of 47mGy of radiation. If her equivalent dose was 0.141Sv

(a) What was the weighting factor of the radiation?
(b) Use the above table to identify the type of radiation?

(20) During one day a worker receives 5mGy of fast neutrons, 2mGy of alpha particles and 12mGy of slow neutrons. What was his total equivalent dose?

(21) A nurse of mass 56kg receives 4J of alpha radiation.

(a) What was her absorbed dose?
(b) What was her equivalent dose?

(22) A nuclear worker of mass 87kg receives an equivalent dose of 16mSv from fast neutrons while in the reactor core.

(a) What was her absorbed dose?
(b) What was the total energy he received?

(23) Calculate the missing quantities in this table.

	Mass of absorber (kg)	Energy absorbed (J)	Absorbed Dose (Gy)	Type of Radiation	Weighting factor	Equivalent Dose (Sv)
(a)	2	10		Alpha		
(b)	5	50		Gamma		
(c)		25		Slow Neutron		18m
(d)	0.4			X rays		650μ
(e)	45	0.288				64m

(24) During an examination of the Fukushima power plant an inspector receives 4.4J of gamma rays and as a result her equivalent dose was 59mSv.

(a) What was his absorbed dose?
(b) What was the mass of the inspector?

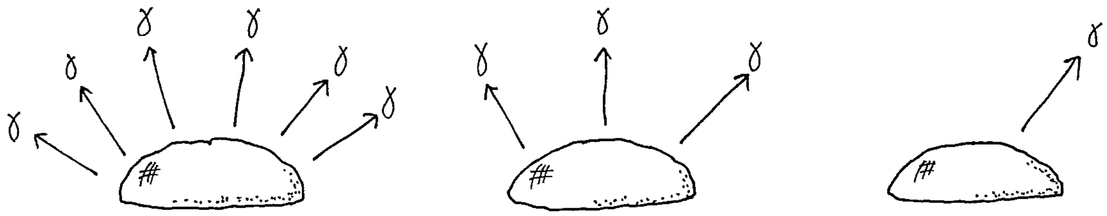
(25) A nuclear worker is told that the maximum dose he can receive is 0.2mSv. If he receives 45μSv per hour how long can he work without going over the limit?

(26) A pilot receives an equivalent dose of 6μSv per hour. Calculate his total equivalent dose on a 7 hour flight?

(27) Apart from absorbed dose and type of radiation what other factor affects the biological harm radiation can do?

3. Half Life

The following pictures of a radioactive source were taken over 3hours.



What do you notice happens to the activity as time passes? Yes that's right it decreases. This is because as time passes more and more of the radioactive unstable atoms become stable so there are less and less radioactive atoms left until eventually all the unstable atoms have become stable and the activity falls to zero.

Now it is impossible to know when one unstable atom is going to decay, but we can predict the activity of the source at any time using a term called the half life. The half life of a source is the time it takes the activity of the source to fall to half its previous value. Or the time taken for half the unstable atoms to decay and become stable.

Each radioactive source will have its own half life.
Some half lives are in the order of a millionth of a second, others have have half lives of millions of years

Activity 38	Half Life

Activity 39	Half life - Radiation Squad

Tutorial 11	Attempt Q 1 - 18

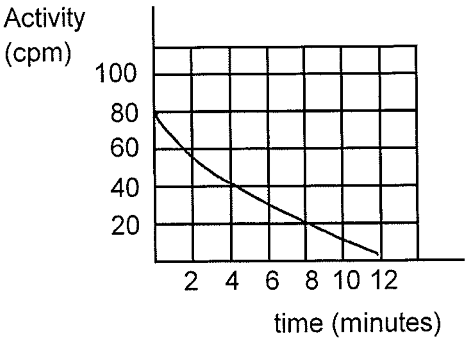
Activity 40	Half life - Correcting for background radiation

Tutorial 11	Attempt Q 19 - 21

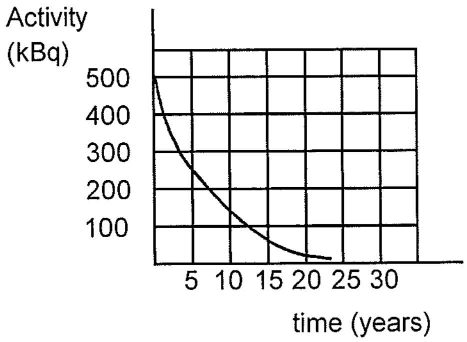
Tutorial 11 — Half Life

(1) Look at these two graphs showing the decay of radioactive sources.

(a)



(b)



(a) Estimate the half life of each source.

(2) It takes 45 days for a sources activity to half. What term describes this time?

(3) A radioactive source has an activity of 400Bq and a half life of 2minutes. What is its activity after 6minutes?

(4) The activity of a source is 720kBq. If its half life is a week, what is its activity after 4 weeks?

(5) A radioactive paint has a half life of 1 hour. The initial activity of the paint when made is 320Bq. What is the activity after 3 hours?

(6) The activity of a source on 1st Jan 2010 was 1152MBq. If its half life is 20 years what is the activity on the 1st Jan 2090?

(7) A doctor receives a radioactive tracer at 9am. Its activity is 432kBq. If its half life is 3 hrs, what is its activity at 6pm?

(8) The half life of a certain radioactive rock is 12hrs. What is the activity after 2 days given the initial activity was 160MBq?

(9) At 10pm, at the end of a shift, the activity of a nuclear reactor cooling rod was 14kBq. If the half life was 4 hrs. What was its activity at 10am the previous morning? (hint - count backwards).

(10) The half life of a source is 5 minutes. What is the initial activity of a source whose activity falls to 20kBq in 15 minutes.

(11) A radioactive source has a half life of 8minutes. What fraction of the activity is left after

(a) 8mins (b) 16mins (c) 32mins ?

(12) A radioactive source has a half life of 20seconds. For how long has it being decaying if the fraction of its activity is

(a) 1/2 (b) 1/4 (c) 1/64

(13) A sample of Uranium has an activity of 600MBq. After 14 days its activity has dropped to 150MBq. What is the half life of the source?

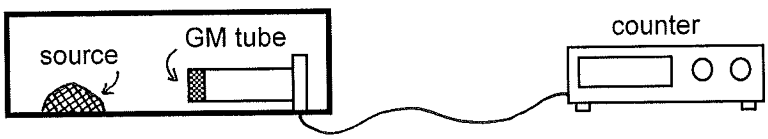
(14) The activity of a source is 1800MBq. If after 24years its activity has dropped to 112.5MBq calculate the half life of the source.

(15) Calculate the half life of a source given that it takes 45mins for its activity to drop from 2400 counts per minute to 75 counts per minute.

(16) A beta source drops from 1.2MBq to 150kBq in a time of 120 years. Calculate the half life of the source. (hint get kBq and MBq into Bq).

(17) A nuclear inspector records a radioactive source producing 48000 beta particles in 2 minutes. He returns 36weeks later and counts 3000 counts in 1 minute. Calculate the half life of the source. (Hint - activity)

(18) A student sets up the following apparatus to measure the half life of Carbon 11. The experiment takes place inside a lead lined container so background radiation can be assume to be zero.



The following results were obtained

Time (minutes)	0	10	20	30	40	50	60	70
Activity (cpm)	800	550	410	310	230	170	120	80

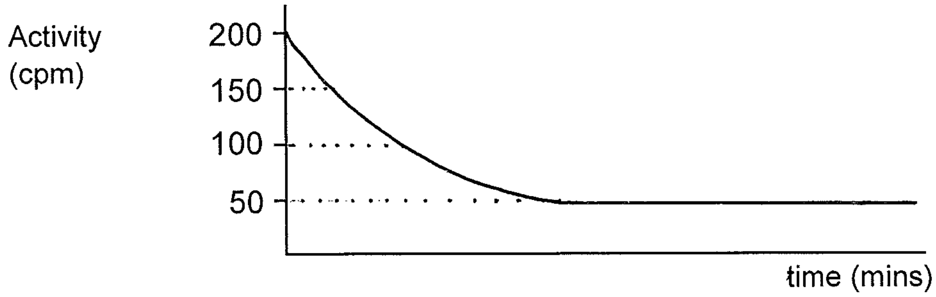
(a) Use the figures to estimate the half life of carbon 11.

(b) Plot a graph to find a more accurate answer.

---

(19) During an experiment Eddie measured the activity of a rock to be 68cpm. 12 days later the activity was 13.75cpm. The rock was removed and the background count rate was measured at 6cpm. By correcting for background radiation work out the half life of the source.

(20) This graph show the **uncorrected** activity of a source.



(a) What is the background count rate?

(b) Sketch the original graph and indicate with a dotted line its shape if the readings had been corrected for background radiation.

(21) On a day when the background count rate was 30cpm a technician measured the activity from a source.

Time (hrs)	0	1	2	3	4	5	6	7
Activity (cpm)	230	190	160	130	110	95	80	70

(a) Write down the corrected count rate after each hour.

(b) Without drawing a graph state the half life of the source.

4. Nuclear Fission and Fusion

At the end of the 2nd World war the Japanese were refusing to surrender and the US army was looking at a long bloody war to finally defeat them. However the US government had a brand new device which they hoped would make the Japanese surrender quickly.
On a still morning on Aug 5th 1945 a US military aircraft known as the Enola Gay took off from the island of Tinian in the South Pacific. 6hrs later it was over the Japanese city of Hiroshima. The bomb doors were opened and a bomb, called Little Boy, by the scientists who worked on it, was dropped onto the unsuspecting Japanese city. The explosion confirmed the awesome power of Einstein's equation $E=mc^2$ In the bomb, a mass of uranium the size of a sugar cube was turned into energy. When this tiny mass was converted to energy there was enough to destroy a whole city.

The method by which the mass was turned to energy was called **Nuclear Fission**. Happily humanity seems to have come to its senses and no nuclear bombs have been used in anger since 1945. However the Fission process has become extremely important in creating the electricity we need to power our technological civilisation.

Activity 41	Nuclear Fission

Tutorial 12	Attempt Q 1- 3

Activity 42	Electricity Generation

Now, as we have seen Nuclear Fission has one big disadvantage as a way of creating electricity. So Scientists have been looking to the Sun for help in creating a new nuclear reaction called Fusion.

Activity 43	Nuclear Fusion

Tutorial 12	Attempt Q 4 - 5

Activity 44	The Future of Nuclear Power.