WAVES

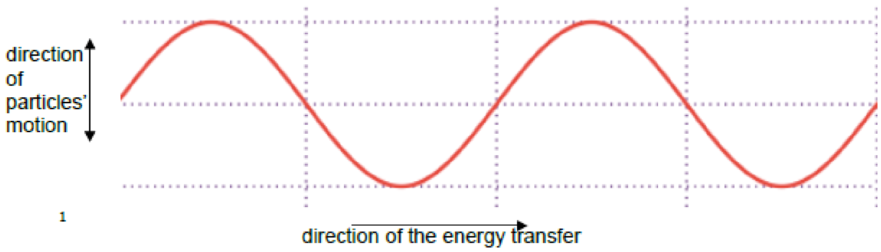
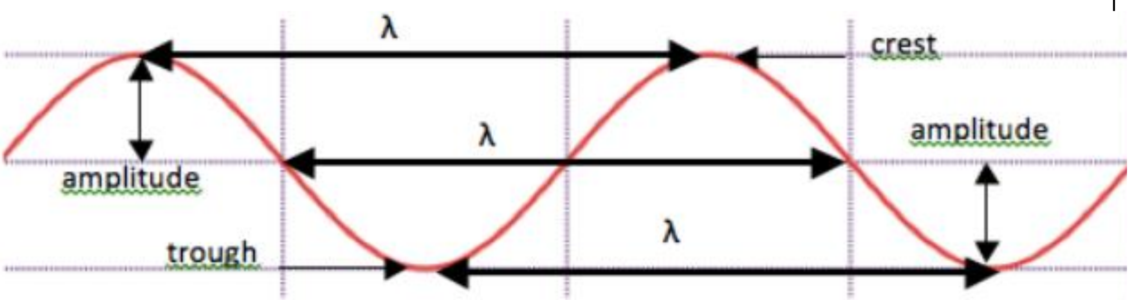
Quantities for the Waves Unit

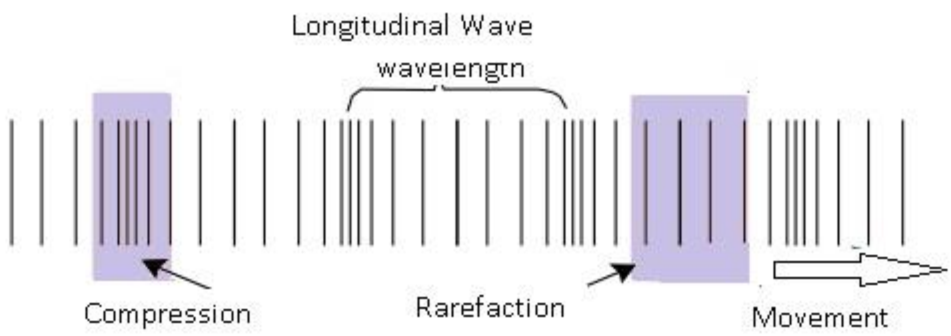
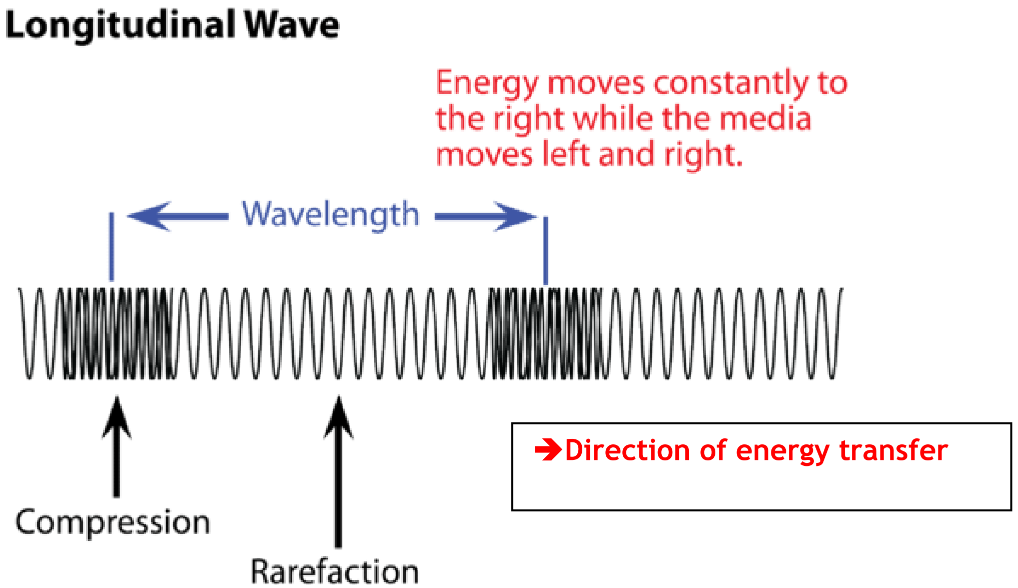
For this unit copy and complete the table.

Quantity	Symbol	Unit	Unit Symbol	Scalar / Vector
Time	t	second	s	S
Period	T	second	s	S
Frequency	f	Hertz	Hz	S
Wavelength	λ	metre	m	S
Amplitude	A	metre	m	S
Distance	d	metre	m	S
Speed	v	metres per second	ms^{-1}	S
Velocity	v	metres per second	ms^{-1}	V

THE WAVES UNIT IN NUMBERS

Quantity	Value
What is the approximate speed of sound in air?	340 ms^{-1}
What is the approximate speed of ultrasound in air?	340 ms^{-1}
Does sound travel faster or slower in solids than in air?	FASTER
How many seconds in a minute?	60 s
How many seconds in an hour?	3600 s
What is the speed of light in air?	3×10^8 ms^{-1}
What is the speed of light in glass, eg in a fibre optic cable?	3×10^8 ms^{-1}
What is the speed of microwaves in air?	3×10^8 ms^{-1}
What is the speed of a television signal in air?	3×10^8 ms^{-1}
What is the speed of a radio signals in air?	3×10^8 ms^{-1}
At what speed do X-rays travel in air?	3×10^8 ms^{-1}
At what speed does gamma radiation travel in air?	3×10^8 ms^{-1}
What is the approximate critical angle for light in glass?	3×10^8 ms^{-1}
What is the smallest angle at which total internal reflection occurs in glass?	42°

No.	CONTENT
Wave parameters and behaviours	
17.1	I can state what is transferred as waves.
17.1.1	State what is transferred when a wave travels from one place to another.
	Energy is transferred when a wave travels from one place to another.
17.1.2	State the connection between waves and energy.
	Waves transfer energy and the greater the amplitude the more energy of the wave.
17.2	I can define transverse waves.
17.2.1	Draw and label a diagram showing a transverse wave.
	
17.2.2	Mark on your diagram the wavelength, amplitude, direction of energy transfer and direction of movement of particles.
	
17.3	I can define longitudinal waves.
17.3.1	Draw and label a diagram showing a longitudinal wave.

	
17.3.2	Mark on your diagram the wavelength, rarefaction, compression, direction of energy transfer and direction of movement of particles.
	
17.3.3	What kinds of materials can sound travel through?
	Sound can travel through a solid, liquid and gas.
17.3.4	What can sound not travel through?
	Sound cannot travel through a vacuum.
17.4	I can give examples of longitudinal and transverse waves.

17.4.1

Copy and complete the table below and place the following waves into the correct section of the table.

e-m waves (write each member of this group out separately), sound, seismic p-waves, seismic s-waves,

Transverse Waves	Longitudinal Waves
Radio	Sound
TV	Seismic p-waves
Microwave	
Visible	
Infra Red	
UV	
Gamma	
Seismic s-waves	
X- rays	

17.4.2

Waves can be used to transmit signals. What type of waves would be used to

(a) tell competitors to start a race, **sound**

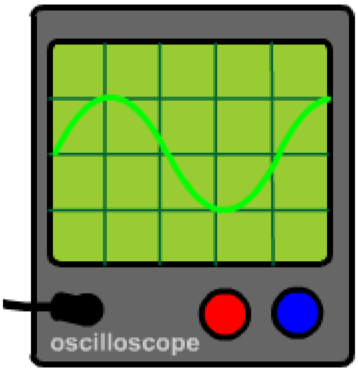
(b) broadcast TV signals, **TV(a form of Radio)**

(c) warn ships of shallow water, **Light (from a light house) or sound (from a foghorn)**

(d) warn aircraft of high towers, **light (the red lights flashing)**

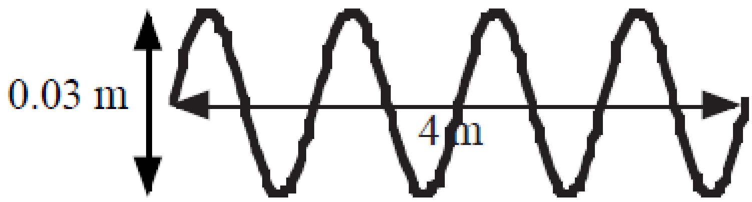
(e) pass down a fibre optic cable? **light**

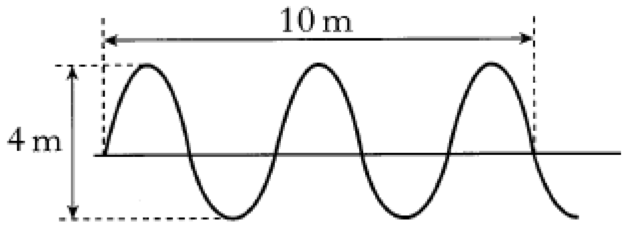
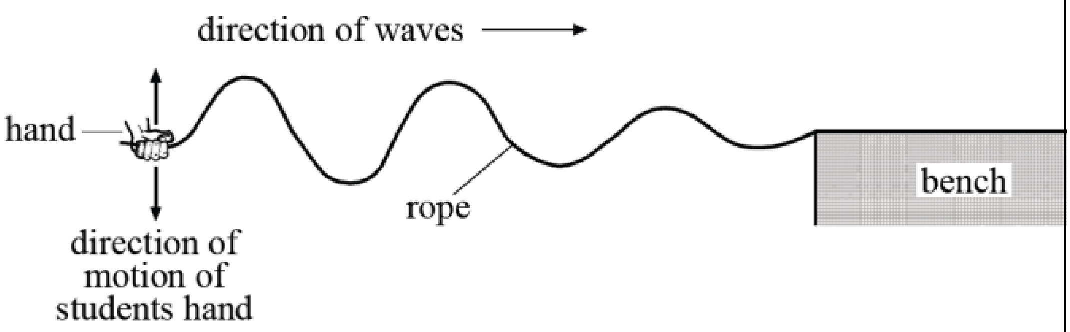
17.4.3

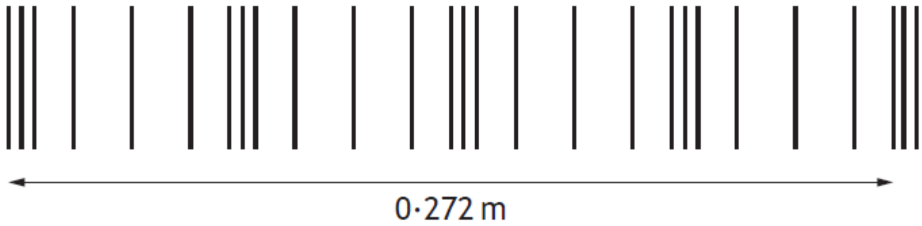


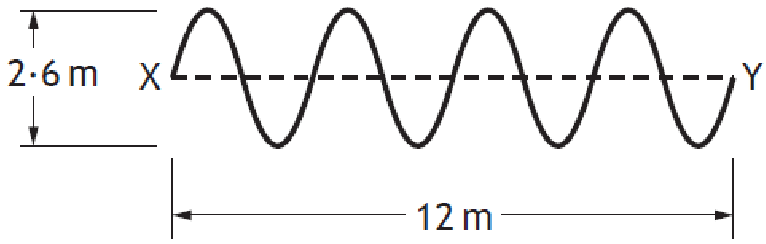
Explain how a sound wave be shown on an oscilloscope like in the diagram below although sound is a longitudinal wave.

	You can see sound waves when a microphone is connected to an oscilloscope. A microphone changes the sound waves into an electrical signal. The oscilloscope then shows what these electrical waves look like. ... High notes have a high frequency and the waves are very close together.	
17.5	I can determine the frequency, period, wavelength, amplitude and wave speed for longitudinal and transverse waves.	
17.5.1	State what is meant by the frequency of a wave.	
	The frequency of a wave is the number of waves produced or which passes a point in one second. $$f = \frac{N}{t}$$ f- frequency in Hertz N- number of wavelengths t- time in seconds	
17.5.2	State the link between period and frequency.	
	$$T = \frac{1}{f}$$ *T= period in seconds* *f=frequency in Hertz*	
17.5.3	If 20 crests pass a point in two seconds calculate the frequency of the wave.	
	N=20 t=2s f=?	$f = \frac{N}{t} = \frac{20}{2} = 10\ Hz$

17.5.4	The diagram below represents a wave 0.2 s after it has started.  Determine the a) wavelength b) amplitude c) frequency d) speed. for this wave:
	a) wavelength 4 waves = 4 m $\lambda = \frac{d}{N} = \frac{4}{4} = 1\ m$ b) amplitude peak to trough = 0.03m $a = \frac{0.03}{2}$ $a = 0.015\ m$ a) c) frequency $f = \frac{N}{t}$ $f = \frac{4}{0.2}$ $f = 20\ Hz$ b) speed. $v = f\lambda$ $v = 20 \times 2$ $v = 40\ ms^{-1}$

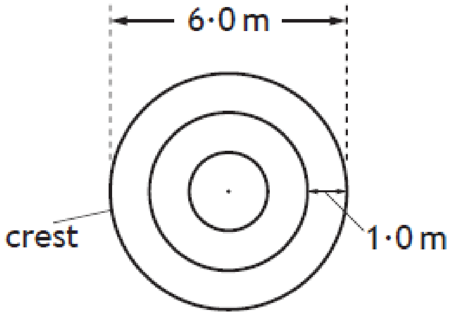
17.5.5	The following diagram gives the information about a wave.  a. Determine the amplitude of the wave. peak to trough = 4m $a = \frac{4}{2}$ $a = 2\ m$ b. Determine the wavelength of the wave. $\lambda = \frac{d}{N} = \frac{10}{2.5} = 4\ m$
17.5.6	One end of a piece of rope is clamped to the end of a bench. A student produces transverse waves in the rope by moving the free end as shown below.  The student measures the frequency and wavelength of these waves. State the relationship she would use to calculate the speed of the waves from this information. $v = f\lambda$ speed = frequency x wavelength

17.5.7 A	 Sound produced by the speaker is represented by the diagram. Determine the wavelength of the sound wave **Sound produced by the speaker is represented by the diagram. Determine the wavelength of the sound wave** **4 wavelengths = 0.272 m** $\lambda = \frac{d}{N} = \frac{0.272}{4} = 0.068\ m$
17.5.7 B	For the wave shown above, calculate the frequency of the sound wave in air
	$v = f\lambda$ $340 = f \times 0.068$ $f = \frac{340}{0.068} = 5000\ Hz$

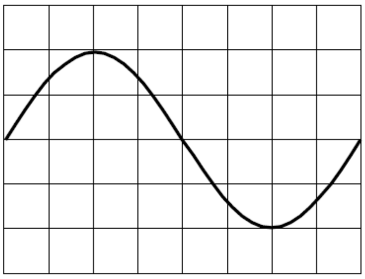
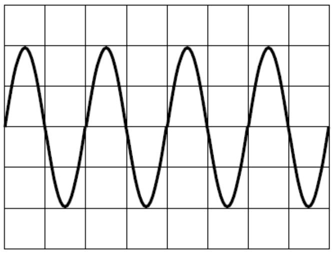
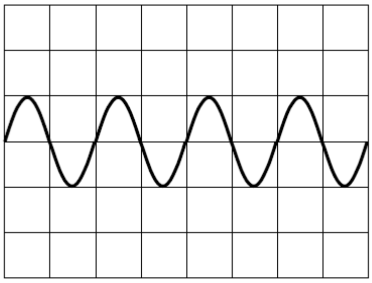
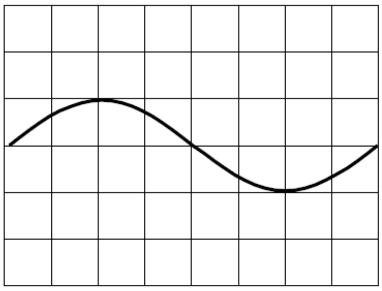
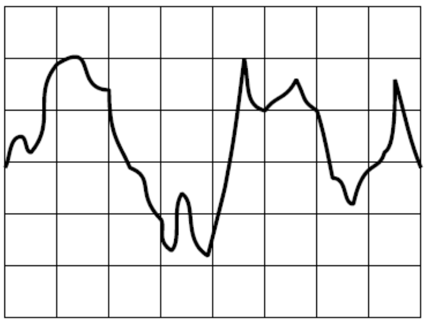
17.5.8	The diagram represents a wave travelling from X to Y.  The wave travels from X to Y in a time of 0·5 s. Determine the amplitude, wavelength, frequency and speed of this wave. **a)** Wavelength $\lambda = \frac{distance}{number\ of\ waves}$ $\lambda = \frac{12}{4}$ $\lambda = 3.0\ m$ b) Amplitude $a = \frac{2.6}{2}$ $a = 1.3\ m$ c) Frequency $f = \frac{N}{t}$ $f = \frac{4}{0.5}$ $f = 8.0\ Hz$ d) speed. $v = f\lambda$ $v = 8 \times 3$ $v = 24\ ms^{-1}$ OR $v = \frac{d}{t}$ $v = \frac{12}{0.5} = 24\ ms^{-1}$
	CHECK YOUR JOTTER

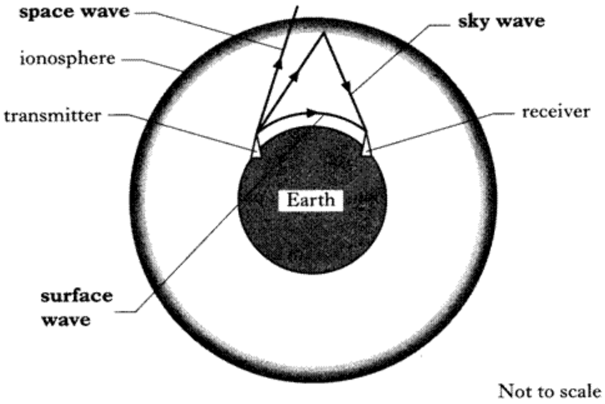
17.6	I can make use of the relationships between wave speed, frequency, wavelength, distance, number of waves and time ***(v = f λ) (d = vt)(f=1/T) (f=N/t) (λ=d/N.).***
17.6.1	State the link between frequency, Number of waves and time for that number of waves. $$f = \frac{N}{t}$$
17.6.2	A water wave travels 200m in 15s, calculate the speed of the wave. $$v = \frac{d}{t}$$ $$v = \frac{200}{15} = 13\ ms^{-1}$$
17.6.3	Calculate the time taken for the water wave given in 17.6.2 to travel a distance of 10 **km**? $$v = \frac{d}{t}$$ $$13 = \frac{10\ 000}{t}$$ $$t = \frac{10\ 000}{13} = 670\ s$$
17.6.4	State the formula linking speed, wavelength, and frequency, state the letter for each term and the unit each is measured in. $v = f\lambda$ **Speed = frequency x wavelength** **Speed measured in metres per second** **Frequency measured in Hertz** **Wavelength measured in metres**
17.6.5	If the speed of sound is 340 ms^{-1}, what is the wavelength of a sound wave with a frequency of 2.0 kHz? $$v = f\lambda$$ $$340 = 2000 \times \lambda$$ $$\lambda = 0.17\ m$$

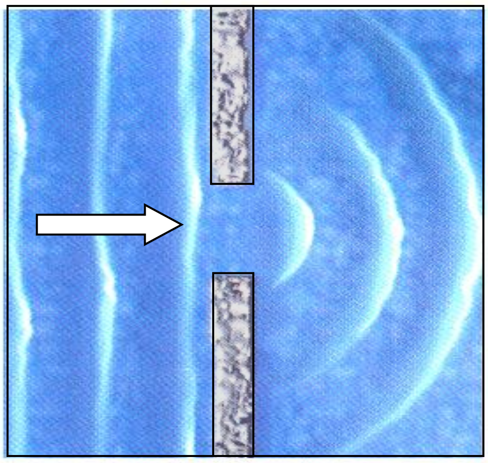
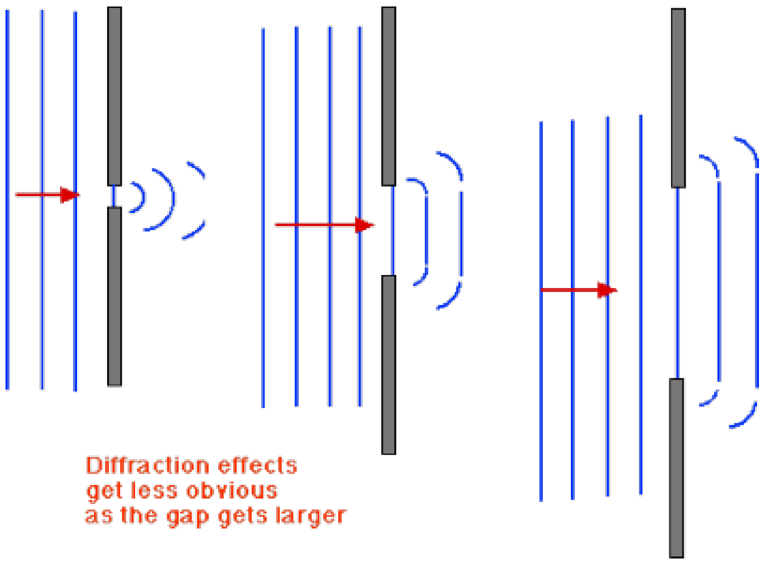
17.6.6	Twenty water waves pass a point in 30 seconds. Each wave has a wavelength of 1.2 m (A) Calculate the frequency of the waves. $f = \frac{N}{t}$ $f = \frac{20}{30}$ $f = 0.67\ Hz$ (B) Calculate the speed of the waves. $v = f\lambda$ $v = 0.67 \times 1.2$ $v = 0.8\ ms^{-1}$
17.6.7	A sound wave has a frequency of 2.0 kHz, calculate the period of this wave. $T = \frac{1}{f}$ $T = \frac{1}{2000} = 0.0005\ s\ or\ 0.5\ ms$
17.6.8	A radio wave has a frequency of 97.7 MHz, state the number of waves generated per second. **This is asking for the frequency so the answer is 97.7 million waves per second.**
17.6.9	State the time it would take one of the radio waves of frequency 97.7 MHz to pass a point. **This question is asking for the period, so** $T = \frac{1}{f}$ $T = \frac{1}{97.7 \times 10^6} = 1 \times 10^{-8} s$

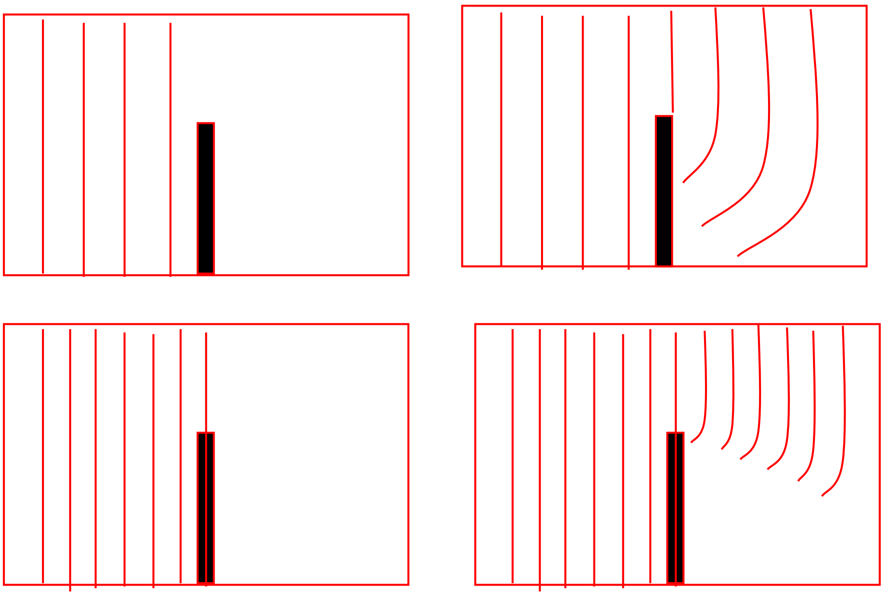
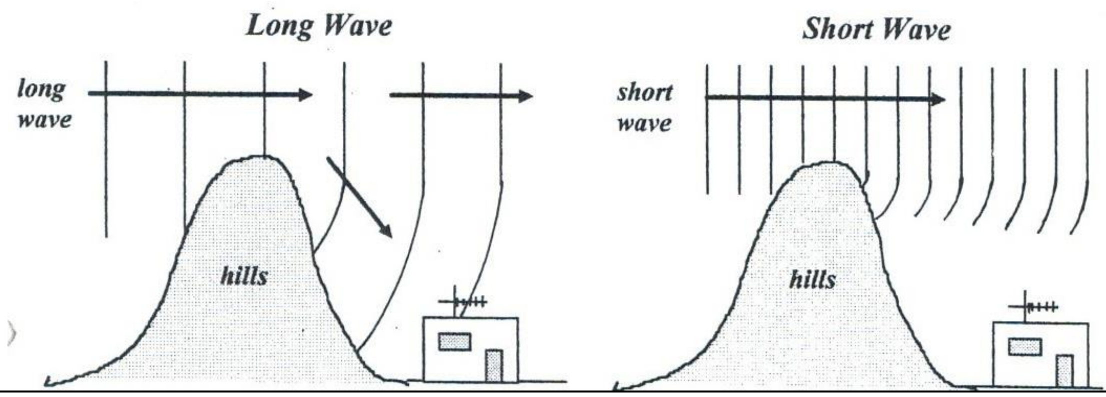
17.6.10	The diagram represents the position of the crests of waves 3 seconds after a stone is thrown into a pool of still water.  Calculate the speed and the frequency of the waves. **The temptation is to think the ways has travelled 6.0m in 3s but it started in the middle so it has only moved outwards by 3.0 m. If in doubt work it out by v=fλ** $v = \frac{d}{t}$ $v = \frac{3}{3} = 1\ ms^{-1}$ $f = \frac{N}{t}$ $f = \frac{3}{3}$ $f = 1.0\ Hz$ $v = f\lambda$ $v = 1.0 \times 1.0$ $v = 1.0\ ms^{-1}$
17.6.11	The period of vibration of a guitar string is 8 ms. Calculate the frequency of the sound produced by the guitar string. $T = \frac{1}{f}$ $8 \times 10^{-3} = \frac{1}{f}$ $\underline{f = 125\ Hz}$

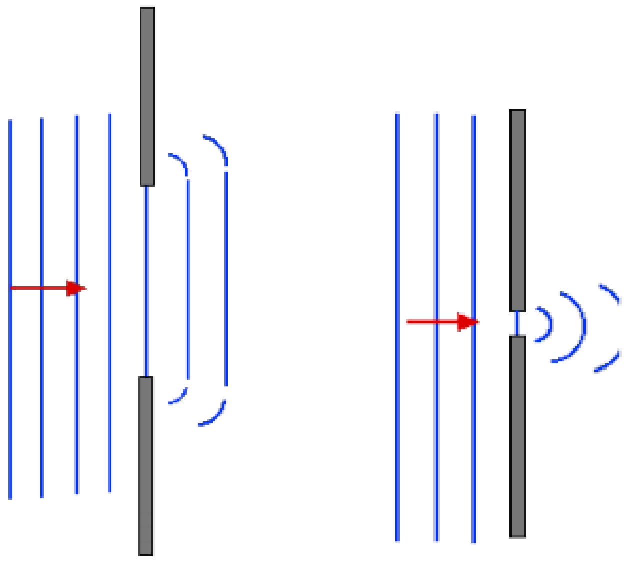
17.6.12	(A) It takes 2.5**μs** for light to travel 500m down a fibre optic. Determine the speed of the light in the fibre? $$v = \frac{d}{t}$$ $$v = \frac{500}{2.5 \times 10^{-6}}$$ $$v = 2.0 \times 10^{8}\ ms^{-1}$$ (B) Calculate the time taken for light to travel along 500km of this fibre? $$v = \frac{d}{t}$$ $$v = \frac{500}{2.5 \times 10^{-6}}$$ $$2.0 \times 10^{8} = \frac{500 \times 10^{3}}{t}$$ $$t = 2.5 \times 10^{-3}\ s$$

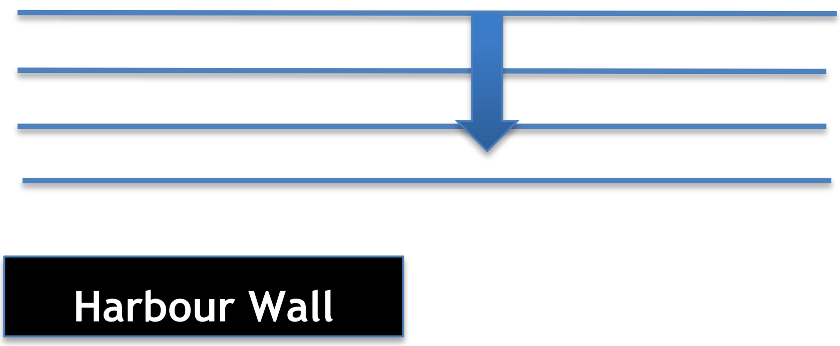
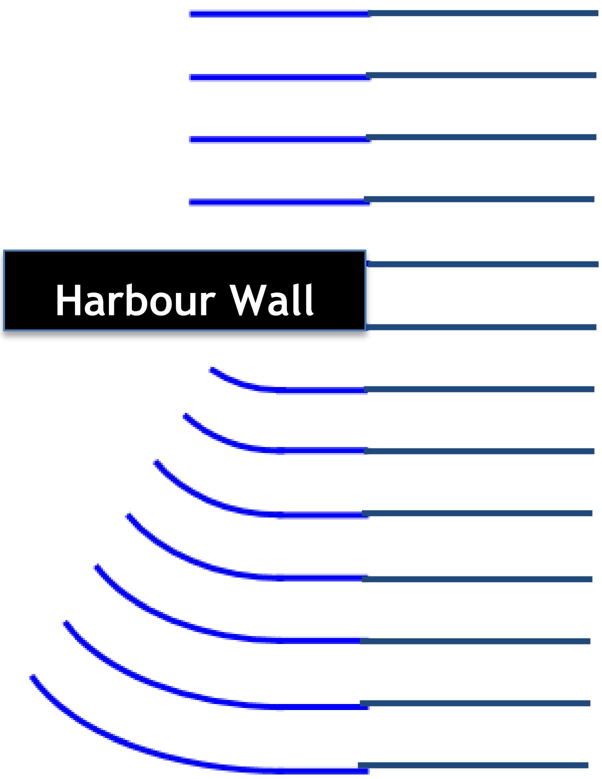
17.6.13	An oscilloscope can be used to display the signal in a telephone line. Draw diagrams showing what the pattern would be like for: (a) a loud, low pitched sound, (b) a loud, high pitched sound, (c) a quiet, high pitched sound, (d) a quiet, low pitched sound, (e) speech. (a) a loud, low pitched sound,  (b) a loud, high pitched sound,  (c) a quiet, high pitched sound,  (d) a quiet, low pitched sound,  (e) speech. 
17.7	I can describe diffraction and associated practical limitations.

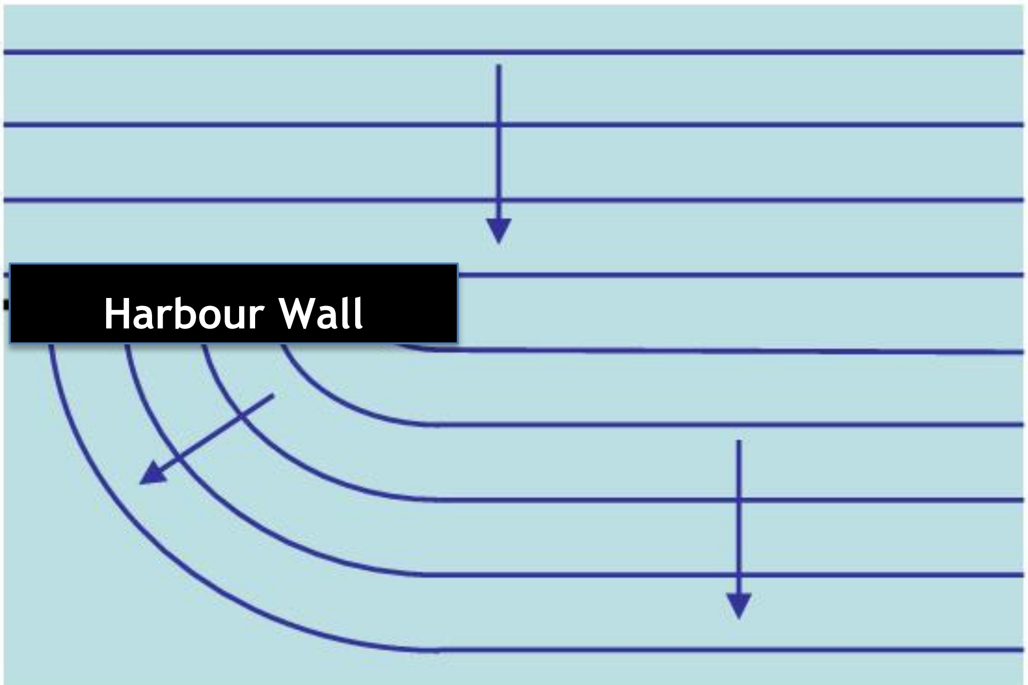
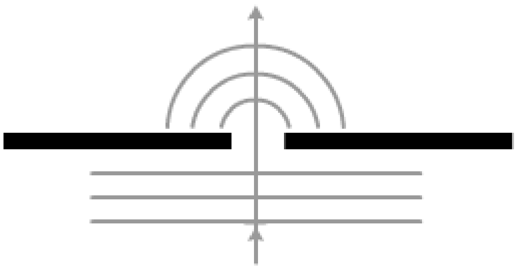
17.7.1	Explain what is meant by the term diffraction. *You may use diagrams to help you.* ***Diffraction is the bending of waves round barriers and obstacles.***
17.7.2	 This diagram shows three types of signal in which radio waves can be sent between a transmitter and receiver. State the signal with the longest wavelength. *You musy justify your answer*.
	Surface waves have the longest wavelength as these are the waves that have diffracted most. The sky waves have reflected and the space waves have gone out to space through the ionosphere.
17.8	I can make comparisons of long wave and short-wave diffraction.
17.8.1	State which waves have the longer wavelength - those used for radio or TV. **Radio waves have a longer wavelength than TV waves.**
17.8.2	Explain in terms of diffraction, why radio reception in an area can be good, but TV reception poor. **Radio waves have a longer wavelength than those used for TV. Long waves diffract more, and so the radio waves can bend round behind obstacles like hills, while the short waves used for TV cannot.**
17.9	I know when diffraction of waves occurs.
17.9.1	State examples when diffraction occurs. • **Bending of water waves in the sea around barriers such as harbour walls,** • **Bending of sound waves round buildings** • **Bending of light in a diffraction grating** • **rainbow pattern seen when looking at a CD or DVD** • **small particles can cause a bright ring to be visible around a bright light source like the sun or the moon.** • **The speckle pattern when laser light falls on an optically rough surface. When deli meat appears to be iridescent, that is diffraction off the meat fibres**

17.9.2	When waves diffract through a gaps state what happens to the a) wave speed No change b) frequency No change c) wavelength No change
17.10	I can compare how long waves and short waves diffract.
17.10.1	The diagram below shows water waves passing through a gap in a harbour wall. The arrow shows the direction the wave is travelling.  Water waves with a shorter wavelength are now passed through the same gap. What difference, if any, will this have after they have passed through? A ship breaks into the harbour wall and breaks a piece off making the gap larger. What difference, if any, will this have after waves pass through the harbour? 

17.10.2	Copy and complete the diagram to show the difference between long waves and short waves as they diffract around a barrier.  

17.10.3	When waves pass through a gap, the width of the gap changes the way the waves emerge from the gap. Draw a diagram (a) to show how waves diffract when the gap is greater than one wavelength. (b) to show how waves diffract when the gap is less than one wavelength. 
17.11	I can draw diagrams using wavefronts to show diffraction when waves pass through a gap or around an object.

17.11.1	The diagram shows wavefronts arriving at a harbour wall. Copy and complete the diagram to show the wavefronts passing the harbour wall.   NB The waves should be continuous!

17.11.2	Repeat the question above showing the same habour wall when waves of a longer wavelength arrive at it. 
17.11.3	Waves exit a gap as shown in the diagram below. For the waves to exit as semi-circular waves what can you state about the width of the gap compared to the wavelength of the waves.  **The gap must be one wavelength or less.**

Electromagnetic Spectrum

18.1	I can state the relative frequency and wavelength bands of the electromagnetic spectrum.
18.1.1	List the members of the electromagnetic spectrum in order of increasing wavelength.

	GAMMA RAYS **X-RAYS** **ULTRAVIOLET(UV)** **VISIBLE** **INFRA RED (I.R)** **MICROWAVES** **RADIO & TV**
18.1.2	As the wavelength of the radiation increases, state what happens to its frequency. **As the wavelength increases the frequency decreases as frequency multiplied by wavelength will equal 300 000 000 ($v=f\lambda$)**
18.1.3	State a member of the electromagnetic spectrum has a shorter wavelength than visible light and a lower frequency than X-rays. **UV has a lower wavelength than visible and lower frequency than X-rays**
18.1.4	Radio waves have a wide range of frequencies. The table gives information about different wavebands. <table><tr><th>Waveband</th><th>Frequency Range</th><th>Example</th></tr><tr><td>Low frequency, (LF)</td><td>30 kHz- 300 kHz</td><td>Radio 4</td></tr><tr><td>Medium frequency, (MF)</td><td>300 kHz - 3 MHz</td><td>Radio Scotland</td></tr><tr><td>High frequency, (HF)</td><td>3 MHz- 30 MHz</td><td>Amateur Radio</td></tr><tr><td>Very High frequency, (VHF)</td><td>30 MHz - 300 MHz</td><td>Radio 1 FM</td></tr><tr><td>Ultra High frequency, (UHF)</td><td>300 MHz - 3 GHz</td><td>BBC1 and ITV</td></tr><tr><td>Very High frequency, (SHF)</td><td>3 GHz - 30 GHz</td><td>Satellite TV</td></tr></table> Coastguards use signals of frequency 500 kHz. State the waveband these signals belong to. **These signals are Medium Frequency (MF)**
18.1.5	A student makes the following statements about different types of electromagnetic waves. I Light waves are transverse waves. ✓correct ALL EM waves are transverse II Radio waves travel at 340 m s^{-1} through air. ✗ Radio waves are EM waves so travel at 3×10^8 ms^{-1} III Ultraviolet waves have a longer wavelength than infrared waves. ✗ UV waves have a higher frequency but shorter wavelength than IR. Copy each statement and mark a tick or a cross to indicate if each of the student's statements are correct.

18.1.6	Calculate the wavelength of a 88 MHz radio wave. $v = f\lambda$ $3 \times 10^8 = 88 \times 10^6 \times \lambda$ $\lambda = 3 \cdot 4\ m$
18.1.7	A radio station has a wavelength of 252m determine the frequency of this wave. $v = f\lambda$ $3 \times 10^8 == f \times 252$ $f = \frac{3 \times 10^8}{252} = 1.2 \times 10^6\ Hz\ or\ 1.2MHz$
18.1.8	Calculate the time taken for a radio wave to travel 1.0 km $v = \frac{d}{t}$ $3 \times 10^8 = \frac{1000}{t}$ $t = \frac{1000}{3 \times 10^8}$ $t = 3.33 \times 10^{-6}\ s\ or\ 3.3\ \mu s$
18.1.9	Calculate the distance a TV signal travels in 1.25 seconds? (for comparison, the distance between the earth and the moon is 3.84 x 10^8m) $v = \frac{d}{t}$ $3 \times 10^8 = \frac{d}{1.25}$ $d = 3 \times 10^8 \times 1.25$ $d = 3.8 \times 10^8\ m$

18.1.10 OEQ

Using your knowledge of Physics explain why certain radio bands are used for particular things.

Different radio bands have different wavelengths, and so have different properties. Very long waves can diffract round the curve of the earth, and so can be used for long distance communication. However, because their frequency is so low, only a limited amount of information can be carried. Also very large aerials are needed. Short waves are reflected by the ionosphere, and so can also be used for long distance communication. They can carry a reasonable amount of information, and aerials are fairly small, but the ionosphere is an unreliable reflector, and reception varies with the time of day. Microwaves have very short wavelengths, and can pass through the ionosphere, and so are used for satellite communications, as well as short range transmissions for mobile phones.

18.2 I can make reference to typical sources, detectors and applications, of the electromagnetic spectrum.

18.2.1

Draw a table listing a detector for each member of the electromagnetic spectrum. For each type of wave in the e-m spectrum give an example of the following

(a) typical source producing this type of waves

(b) detector

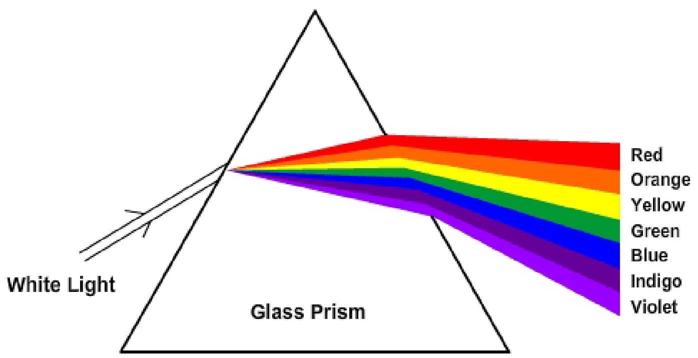
(c) A practical use for the radiation

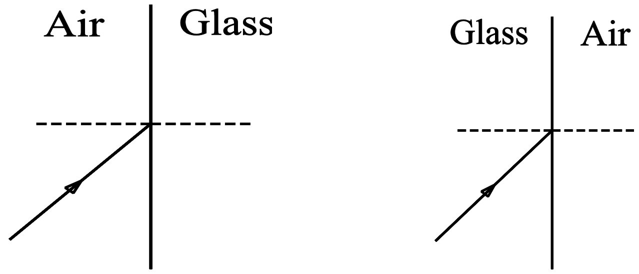
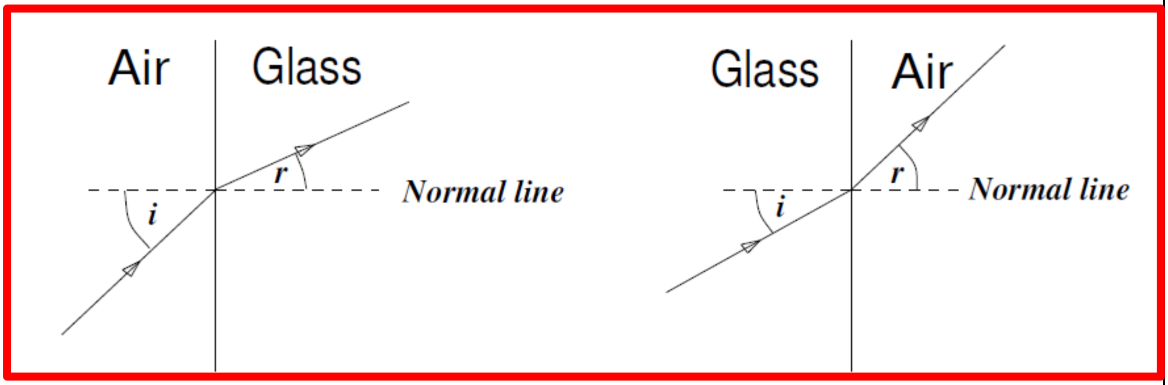
Type of EM Waves	Use	Detector	Danger	Protector	Source
Radio & TV	communication (under the sea, in space, radio and TV)Watching TV programmes, films, listening to the news,	Aerial	Large doses of radio waves are believed to cause cancer, leukaemia and other disorders.	metal	transmitter, outer space
Microwaves	cooking through microwave ovens, communications	Aerial	cataracts	metal screen	magnetron, transmitters, outer space
Infra Red	Turning on TVs through remote controls, security systems.	Photodiode, thermocouple, thermistor	Some people claim that the very low frequency field from overhead power cables near their homes has affected their health, although this has not been reliably proven.	aluminium foil, thermal insulators	warm objects, sun
Visible	humans viewing the world, photography,	Photodiode / photographic film	cataracts	polarising glasses, filter glasses	Stars and the sun
Ultra violet	detecting forged bank notes, causing white shirts to look cleaner?	Photodiode / photographic film / fluorescent materials	skin cancer, Arc eye is caused by UV radiation. This damages the outmost protective layer of cells in the cornea.	glass / sunscreen cream	Fluorescent tubes, very hot objects, sun
X-Ray	detecting broken bones, checking suitcases at the airport,	Photodiode / photographic film	cancer premature ageing	lead	X-ray machines, stars
Gamma Rays	medical tracers to detect cancer, killing bacteria, sterilizing instruments, detecting broken pipes underground	Photodiode / photographic film / Geiger Muller Tube	cause damage to DNA, cancer	several cm of lead or several m of concrete	Radioactive nuclei, outer space (stars)

"cataracts" in your eyes, is a clouding of the lens preventing you from seeing clearly (if at all!)

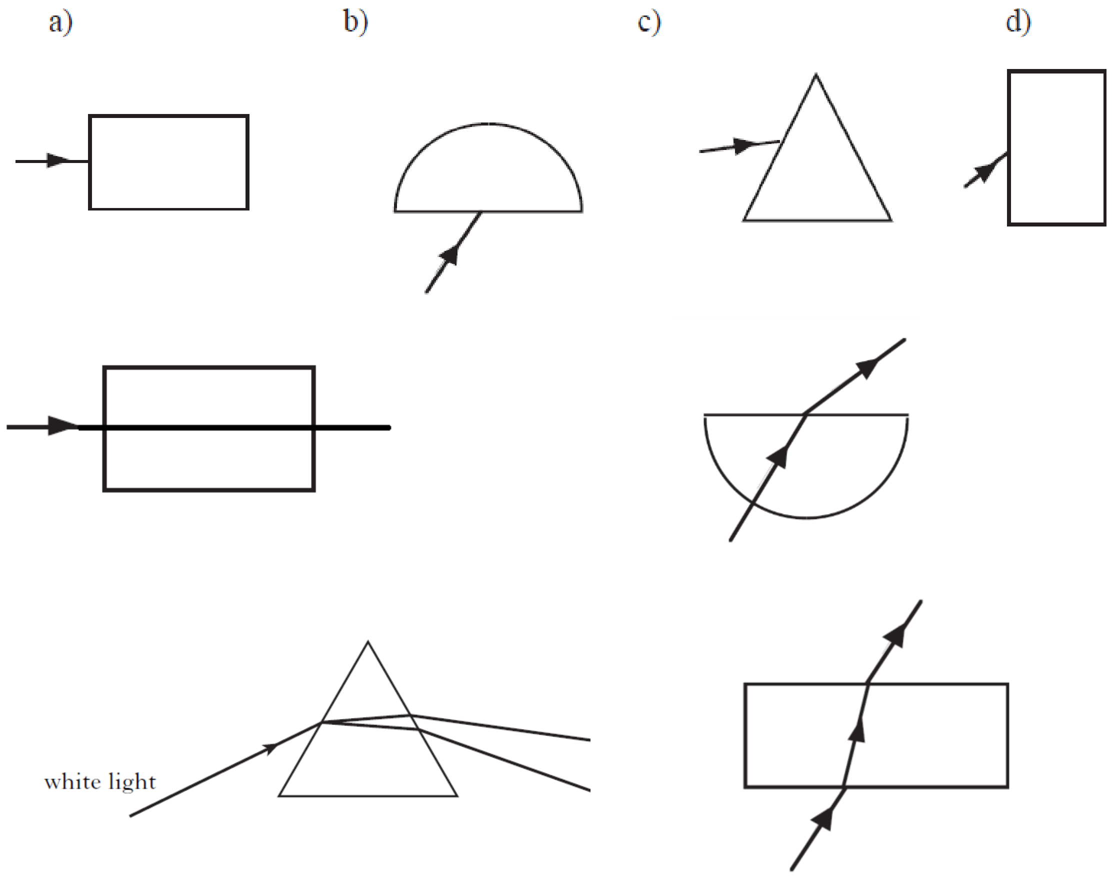
http://www.darvill.clara.net/emag/

18.3	I can state whether radiations in the electromagnetic spectrum are transverse or longitudinal waves.
18.3.1	Copy the sentence below inserting the correct type of wave. Radiations in the electromagnetic spectrum are transverse ~~longitudinal~~ waves.
18.4	I can state what all radiations in the electromagnetic spectrum have in common.
18.4.1	List the electromagnetic waves in the electromagnetic spectrum in order of increasing frequency. **RADIO & TV** **MICROWAVES** **INFRA RED (I.R)** **VISIBLE** **ULTRAVIOLET(UV)** **X-RAYS** **GAMMA RAYS**
18.4.2	Write out a mnemonic to remember the order of the waves in the electromagnetic spectrum Randy — RADIO & TV Monkeys — MICROWAVES Invade — INFRA RED (I.R) Venezuela — VISIBLE Using — ULTRAVIOLET(UV) Xylophone — X-RAYS Gunships — GAMMA RAYS
18.4.3	State what all waves in the electromagnetic spectrum have in common. • **All travel at 3×10^8 ms^{-1} in air** • **All carry energy** • **All are transverse waves** • **All have no mass** • **All are electrical fields vectors and magnetic field vectors vibrating at 90 degrees to each other**
18.4.4	State the speed of light in air. **3×10^8 ms^{-1}**
18.4.5	State how the speed of light in air compares to the speed of light in glass. **The speed of light in air is greater than the speed of light in glass 3×10^8 ms^{-1} compared to 2×10^8 ms^{-1}**

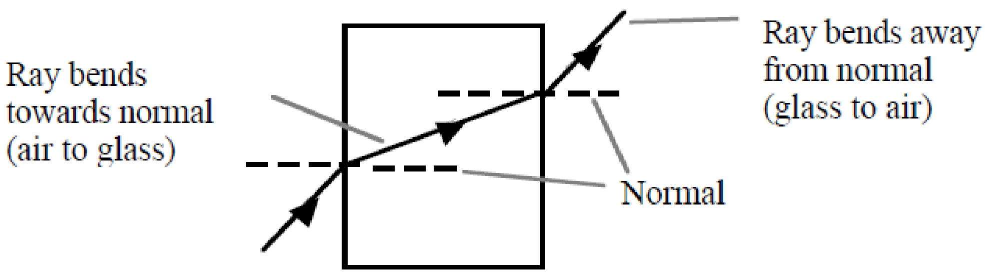
18.4.6	List these colours in terms of increasing wavelength:- *Red, orange, yellow, green, blue, violet.*
18.4.7	Write out a mnemonic to remember the colours of the visible spectrum in order of decreasing wavelength. *Richard Of York Gained Battles In Vain* *ROY Green BIV*
18.4.8	State how white light can be split up into different colours (it's spectrum)? Using a prism
18.4.9	Draw a diagram of showing the above. 
Refraction	
19.1	I know when refraction occurs.
19.1.1	State what causes the refraction of light. **Refraction occurs when waves pass between materials (medium) of different density.** **When waves move into a material of higher density the** • **Speed decreases** • **Wavelength decreases** **Frequency stays the same.**
19.1.2	State a cause of refraction in water waves at the beach. **Refraction occurs at the beach when waves move from deep to shallow water. The greater the steepness of the beach the more refraction.**
19.2	I can give a description of refraction.

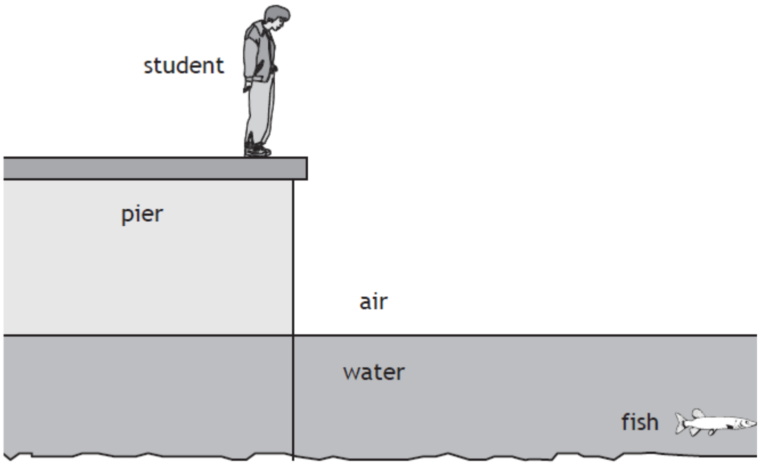
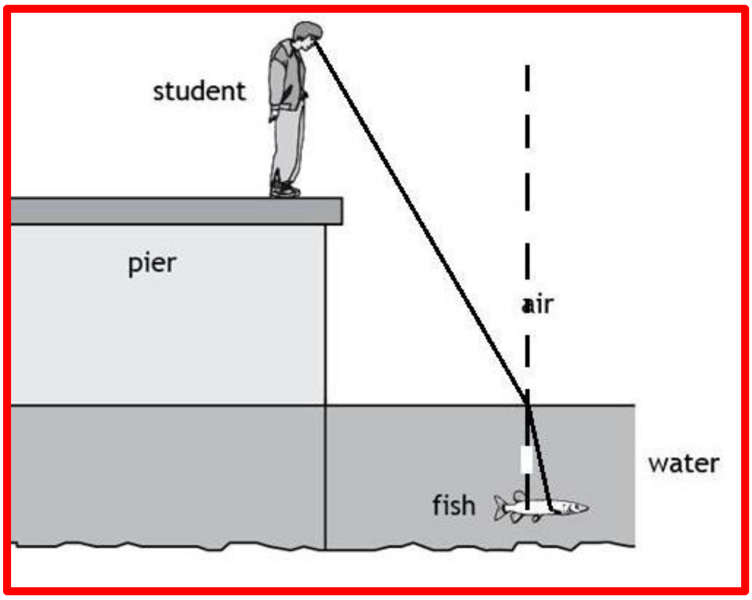
19.2.1	State what is meant by the term refraction. **Refraction is the change in speed and wavelength as a wave passes between materials of different optical densities/depths/materials. This often results in a change of direction.**
19.2.2	Copy and complete these diagrams showing how light passes from air to glass, and glass to air.  
19.2.3	On each of your completed diagrams above mark the following (a) the angle of incidence, (b) the angle of refraction, (c) the normal line. **See above**

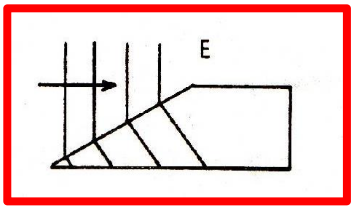
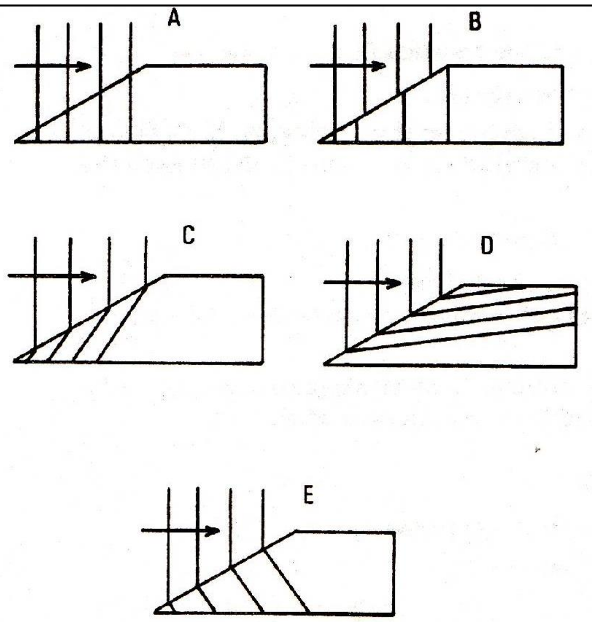
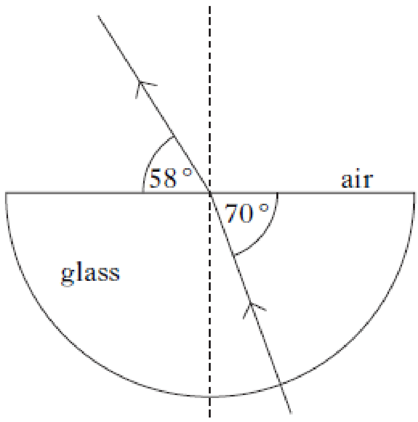
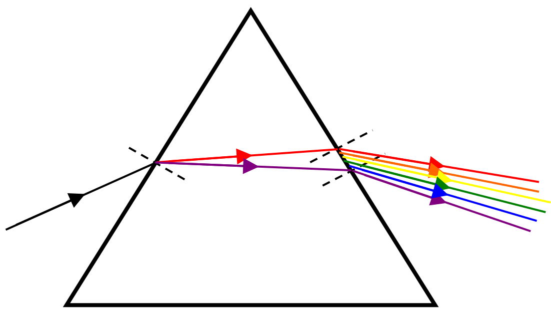
19.2.4 Copy and complete the diagrams below to show the path of the rays.

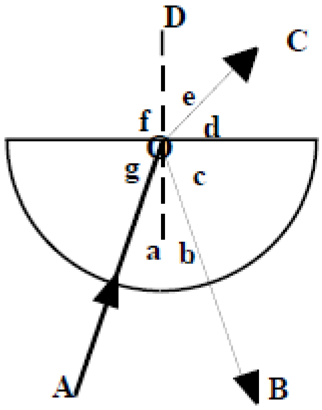


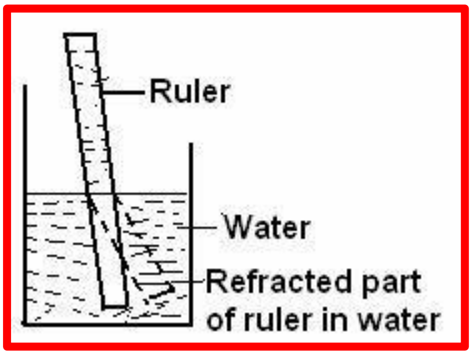
If the light entering the prism is monochromatic there would be a single ray through the prism, either of which would do.



19.2.5	A student looking from a pier into some calm water sees a fish. Copy and complete the diagram to show the path of a ray of light from the fish to the student. (diagrams available on the website and from your teacher) You should include the normal in your diagram  (1) mark for ray changing direction at water/air boundary (1) mark for angle in water less than angle in air. Angle of incidence in water should be less than the angle of refraction in air. (1) mark for correct normal (must be placed at the point where a ray meets the water/air boundary) 

19.2.6	Copy out the correct diagram which represents the refraction of light waves after meeting a glass block as shown?  
19.2.7	Copy the diagram below and state  a) the angle of incidence The angle of incidence = 90-58 =32 ° b) the angle of refraction. The angle of refraction = 90-70 =20°
19.2.8	Draw a diagram of white light passing through a prism. Mark on the colours exiting the prism in the correct order. (Rough angles are important)
	 starting at the top the colours are Red, Orange, Yellow, Green, Blue, indigo, violet.
19.3	I can describe the qualitative (info) relationship between the frequency and the energy associated with a form of radiation.

19.3.1	State the relationship between the frequency and the energy of waves. **The greater the frequency of the wave the more energy it has.** $E = hf$.
19.3.2	For electromagnetic waves, E=hf or Energy = Planck's Constant x frequency. a) Find out the value of Planck's constant, and **h=Planck's constant = 6.63×10^{-34} Js** b) Calculate the energy associated with a wave of frequency 6×10^{14} Hz $E = hf$ $E = 6.63 \times 10^{-34} \times 6 \times 10^{14}$ $E = 4.0 \times 10^{-19} J$
19.3.3	State whether radio waves or infrared radiation have greater energies associated with them. *You must justify your answer*. **Infra-red has the higher frequency and so the greatest energy.**
19.4	I can identify the normal, angle of incidence and angle of refraction in ray diagrams showing refraction.
19.4.1	Identify the following from the diagram shown below. i) the incident ray **A** ii) the reflected ray **B** iii) the refracted ray **C** iv) the normal **D** v) the angle of incidence **a** vi) the angle of refraction **e** vii) the angle of reflection. **b** 
19.4.2	Explain why a ruler, placed in a beaker of water, appears to change as it enters the water. **When we look at a ruler it looks "bent". Light from the top of the water travels straight to the eye. Light from the part that is underwater is refracted when it goes from the water to air it changes the direction.**

19.4.3	Draw a diagram to show this, by trying it for yourself  https://www.kenyaplex.com/questions/38826-illustrate-using-diagrams-reflection-and-refraction-of-light.aspx