UNIT 2 Waves and Their Uses

Recommended Prior Knowledge
Pupils ought to have encountered unit 1 before starting this unit. In addition they will need some concept of what is meant by energy, even though it need not be de
exactly at this stage. Pupils should be able to use a protractor and to draw simple diagrams neatly. Words such as audible, pitch, vibration, reflection, medium, vacuu
echo, timbre, pre-natal, magnification, lens and spectrum are likely to be used without being separately defined by the teacher.

Context
This unit deals with waves and how they are used. It is to some extent an independent section of the syllabus with only a few other topics depending on it.
Consequently those who do not wish to follow through the units in numerical order may include this unit at almost any stage.

Outline
The unit begins by introducing the idea of wave motion in a general sense. This is an idea which though simple at one level, is in fact sometimes difficult to grasp.
When sea-waves are considered it is unlikely that much emphasis is given to their transmission of energy and this essential aspect of waves is often neglected by
pupils. The basic definitions are included and the idea that certain quantities may be represented by an equation is worth underlining for future use. Two specific cases,
sound and light, follow on from this and the fundamental properties of all waves are studied in the context of these two examples. The practical importance of the
seemingly abstract phenomenon of refraction is illustrated by the inclusion of lenses and by their use in the correction of imperfect vision. Some of the widely varying
uses of electromagnetic radiation conclude this unit.

	Learning Outcomes	Suggested Teaching Activities	Online Resources	Other resources
13(a)	Describe what is meant by wave motion as illustrated by vibrations in ropes and springs and by experiments using a ripple tank.	Energy (unit 5) transfer often involves the net movement of matter but for wave motion it does not. Stretch a long spring or rope between two pupils. One can transmit energy to the other (make the second pupil's hand move) without transferring matter. Point out the pupils' ear drums are being moved (vibrated) without the transfer of matter.	Waves: http://www.kettering.edu /~drussell/Demos/waves /wavemotion.html Ripple tanks simulation: http://www.falstad.com/ri pple/	Use ripple tanks to show water waves transferring energy. A small piece of cork vibrates as the wave passes. Compare with sound and hearing.
13(b)	State what is meant by the term wavefront.	A wave transfers energy through a medium without the medium moving as a whole.	Wavefronts: http://www.colorado.edu /physics/2000/waves_pa rticles/waves.html	The crest line or the trough line is the wavefront.
13(d)	Describe transverse and longitudinal waves in such a way as to illustrate the differences between them.	Use the long spring to show transverse waves. Get the pupils to come up with longitudinal waves. Use these terms: • crest, • trough,	Longitudinal waves: http://www.glenbrook.k1 2.il.us/gbssci/phys/mme dia/waves/lw.html Transverse waves:	Longitudinal waves include: • sound, • ultrasound, • seismic P-waves, • shock waves.

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		• compression, • rarefaction, • displacement.	http://www.bbc.co.uk/schools/gcsebitesize/physics/waves/whatarewavesrev3.shtml	
13(c)	Define the terms speed, frequency, wavelength and amplitude and do calculations using *velocity = frequency x wavelength.*	Define the terms. At this stage speed and velocity can be treated as essentially the same thing. Note that the frequency is the number of waves (**not** complete waves) passing a point in unit time. Frequency is not necessarily an integer. Deduce the formula.	Wave formula: http://www.gcse.com/waves/wave_speed.htm Wave parts: http://id.mind.net/~zona/mstm/physics/waves/partsOfAWave/waveParts.htm#wavelength	Use the formula to deduce the speed of radio waves from the published wavelength and frequency of a local station.
13(e)	Describe the use of a ripple tank to show (1) reflection at a plane surface, (2) refraction due to a change of speed at constant frequency.	Show these experimentally if not in a ripple tank then in a tray of water. Draw diagrams of waves entering a shallow (slower) region at an angle. Show where the waves would have reached if the original medium had continued and then where the waves actually are. They have skewed around as one side slows before the other.	Ripple tank reflection: http://www.crocodile-clips.com/absorb/AP4/sample/DJFPh066.html or: http://www.open.ac.uk/science/infocus/ripple.htm	Comparison: caterpillar-tracked vehicles cannot steer. By slowing down one track and speeding up the other the vehicle skews round like waves refracting. Similarly soldiers marching shoulder-to-shoulder, come to ground where they travel slower.
16(a)	Describe the production of sound by a vibrating source.	Consider: • a tuning fork, • a violin (or local stringed musical instrument), • a drum, • vibrating rulers, • cardboard strips held in the spokes of a bicycle wheel, • a loudspeaker • other examples. Pupils should feel the vibrations.	Production of sound: http://teacher.scholastic.com/lessonrepro/lessonplans/profbooks/sound.htm or: http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/waves/tfl.html Guitar strings: http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/waves/gsl.html	Place small particles on a drum or loudspeaker.

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16(c)	State the approximate range of audible frequencies.	Use a loudspeaker and a signal generator to test the frequency range of the pupils' hearing.	Sound and the ear: http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/waves/edl.html	The actual frequency range varies from person to person but a standard range of 20 → 20 000 Hz is usually taken for a person of normal hearing.
16(g)	Explain how the loudness and pitch of sound waves relate to amplitude and frequency.	Use a microphone and C.R.O. to show how the trace varies with frequency and with amplitude. Relate these observations to pitch and loudness.	Loudness: http://gcsephysics.com/pwav9.htm	
16(b)	Describe the longitudinal nature of sound waves and describe compression and rarefaction.	Use the vibrations of a loudspeaker to explain that the vibration direction is parallel to that of the sound wave. Compare this with a long spring or trolleys joined by springs.	Sound waves: http://www.glenbrook.k12.il.us/gbssci/phys/Class/sound/u11l1a.html	
16(d)	Explain why a medium is required in order to transmit sound waves and describe an experiment to demonstrate this.	Show the bell-jar experiment if at all possible; the clanger can be seen striking the bell but little or no sound is heard.	Bell jar experiment: http://www.gcse.com/waves/sound2.htm	Consider: the Sun can be seen but not heard, astronauts communicate in space using radio (or by touching helmets).
13(f)	Describe simple experiments to show the reflection and refraction of sound waves.	Demonstrate an echo from the front of a large building or cliff (~100 m away if possible). This can be extended to measure the speed of sound – use two blocks of wood to make a short, distinct clap or a loud whistle or a high-pitched feedback sound from a megaphone. Measure the distance with rulers, rope or a pedometer. Clapping in time with the echo from a closer wall (30m) allows the time taken for the sound to travel to the wall and back to be measured more accurately.	Speed of sound: http://www.sv.vt.edu/classes/ESM4714/Student_Proj/class95/physics/speed.html Reflection in sound: http://www.physics.lsa.umich.edu/demolab/demo.asp?id=871 Refraction in sound: http://tonydude.net/physics201/p201chapter3.html	Refraction in sound can be demonstrated/described using a beach-ball filled with CO_2. This can act as a sound lens (later in this unit) and be used to focus sound (lenses work by refraction). If filled with He, it would be a diverging lens.

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16(h)	Describe how the reflection of sound may produce an echo.	Refer to methods involving firing guns or simply observing someone claps the two pieces of wood together from a few kilometres away (these rely on the speed of light being very much larger indeed than that of sound).		
16(e)	Describe a direct method for the determination of the speed of sound in air and make the necessary calculation.	Sound travels much faster in solids and liquids. When a hammer strikes a long length of metal railings, two sounds are heard: one through the railings; one through the air.	Speed of sound in materials: http://www.glenbrook.k12.il.us/gbssci/phys/Class/sound/u11l2c.html	
16(f)	State the order of magnitude of the speeds of sound in air, liquids and solids.	Quote speed of sound values for air, liquids and gases.		
16(i)	Describe the factors which influence the quality (timbre) of sound waves and how these factors may be demonstrated using a CRO.	Emphasise that the same note played on different instruments differ only in the shape of the trace on a C.R.O. not in their periodic times. Show this using musical instruments, a microphone and a C.R.O. Show that the amplitude does not affect the shape of the trace.	Timbre: http://www.open2.net/soundoflife/prog_pages/soundslife/viewer/object/5716.html	
16(j) **16(k)**	Define ultra sound. Describe the uses of ultra sound in cleaning, quality control and pre-natal scanning.	Define ultra sound and give a variety of uses: • cleaning sensitive artefacts, • quality control, pre-natal scanning, • distance measurers (dataloggers in universities/schools).	Uses of ultrasound: http://www.google.co.uk/search?q=Uses+of+ultrasound&btnG=Search&hl=en or: http://www.bbc.co.uk/schools/gcsebitesize/physics/waves/soundultrasoundandseismicwavesrev4.shtml	Bats use ultra sound to form a picture of their surroundings. Dogs can hear ultra sound (dog whistles).
14(a)	Define the terms used in reflection including normal, angle of incidence and angle of reflection.	These topics are best covered experimentally; pupils may use mirrors and ray-boxes, torches or (optical) pins.		

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14(b)	Describe an experiment to illustrate the law of reflection.	The law may be modelled in 3D using rods or rulers to represent the rays and the normal and the desk top to act as a mirror.	Law of reflection: http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/optics/lr.html	
14(d)	State that for reflection, the angle of incidence is equal to the angle of reflection and use this in constructions, measurements and calculations.	Observe that there are many rays for which the angle of reflection equals the angle of incidence but the correct one lies in the same plane as the normal and the incident ray. Emphasise that all angles are measured between the ray and the normal.	Diffuse and regular reflection: http://www.glenbrook.k12.il.us/gbssci/phys/Class/refln/u13l1d.html	
14(c)	Describe an experiment to find the position and characteristics of an optical image formed by a plane mirror.	Emphasise that an image is the location from which the light **seems** to come. It has not actually travelled behind the mirror. An eye or a photographic plate placed at the image position would not detect anything. For a mirror hanging on a wall, the image may well be in the next room or building and someone there would not be able to see the person standing in front of the mirror.	Plane mirror images: http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/optics/ifpm.html	Consider more complicated examples such as two mirrors at right-angles or a kaleidoscope.
14(e)	Define the terms used in refraction including angle of incidence, angle of refraction and refractive index.	Show some simple examples of refraction: the bent stick, apparent reduction in depth, heat haze, pass a ray of light into a tank containing two liquids of different densities – a **very** small amount of paint in the liquids will scatter light so that the path of the ray may be seen.		Refer back to the skewing round of caterpillar tracked vehicles when the tracks are driven at different speeds.
14(f)	Describe experiments to show refraction of light through glass blocks.	Carry out experiments with a glass block and a ray-box, torch or a slit in a blind/curtain or (optical) pins.	Refraction: http://www.glenbrook.k12.il.us/gbssci/phys/Class/refrn/u14l1d.html	Emphasise that as the light leaves the second face of a rectangular block, it reverses the procedure which occurred at the first and emerges parallel to the incident ray.
14(g)	Do calculations using the equation $\sin i/\sin r$ = constant.	Measure i and r. Plot i → r. Calculate sin(i) and sin(r). Plot sin(i) → sin(r). Measure the gradient. Calculate sin(i)/sin(r). State that using the gradient gives more emphasis to those points nearest to the average behaviour. Averaging the values of sin(i)/sin(r) does not.	Reflection and refraction: http://www.phy.ntnu.edu.tw/java/light/flashLight.html	

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14(i)	Describe experiments to show total internal reflection.	Explain that when a ray emerges from glass into air, the emergent angle is larger than the angle at which it strikes the surface. In due course, it emerges at 90° to the lower face. If the angle at which it strikes the surface increases, then the emergent angle exceeds 90° and it passes back into the glass. This is reflection not refraction. Refraction out of the glass is now impossible.	Total internal reflection: http://www.phy.ntnu.edu.tw/java/light/flashLight.html	Pass a ray into the curved face of a semi-circular glass block, into the side face of a glass block or a tank of water. Move the ray. There comes a point at which no light at all emerges through the surface.
14(h)	Define the terms critical angle and total internal reflection.	Emphasise the fact that **two** conditions must be met before T.I.R. can occur: • The light must pass from the slow to the fast medium. • The angle at the surface must exceed the critical angle.	Fish-eye view: http://www.phy.ntnu.edu.tw/java/fishEye/fishEye.html Retroreflectors: http://users.ipfw.edu/masters/Graphics/AM/Refraction.html#TIR	
14(j)	Describe the use of optical fibres in telecommunications and state the advantages of their use.	Optical fibres rely on T.I.R. Digital pulses (light/no light) transmit the information. Advantages include: more information can be sent per second (many phone calls on one line), less prone to interference, less easy to tap into, fewer repeaters. Optical fibres need to be sheathed to prevent light passing from one fibre into the next.	Optical fibres: http://www.bbc.co.uk/schools/gcsebitesize/physics/waves/reflectionrefractionanddiffractionrev5.shtml	There are transoceanic optical fibre cables and it is possible to have an optical link straight into a personal computer or telephone.
14(k)	Describe the action of thin lenses (both converging and diverging) on a beam of light.	Pass a ray of light from a ray-box or torch into a lens (ideally curved in only one dimension) and observe the path of rays at different distances from the centre. This is difficult to do with optical pins.	Converging lenses: http://www.glenbrook.k12.il.us/gbssci/phys/Class/refrn/u14l5da.html	
14(l)	Define the term focal length.	Pass a beam of parallel rays into a lens and observe the convergence. Define focal length.		
14(m)	Draw ray diagrams to illustrate the formation of real and virtual images of an object by a lens.	Emphasise three types of ray: (1) Incident, paraxial rays refract through the focal point. (2) Incident rays striking the optical centre emerge undeviated. (3) Incident rays which pass through or seem to have passed through the focal point emerge paraxially.	Image formation: http://www.glenbrook.k12.il.us/gbssci/phys/Class/refrn/u14l5da.html	(1) These three special rays are not the only ones to originate from the object point, but all the others also meet at or seem to have come from the same

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				image point. (2) It is usual to use the top point of an object as the object point but every other point on the object also produces an image.
14(n)	Define the term linear magnification and draw scale diagrams to determine the focal length needed for particular values of magnification (converging lens only).	Scale diagrams will only be accurate if drawn carefully. Start with the object and the lens and find the image or start with the object and the image and find the focal points.		
14(o)	Describe the use of a single lens as a magnifying glass and in a camera, projector and photographic enlarger and draw ray diagrams to show how each forms an image.	Pupils can be given incomplete or unlabelled diagrams and instructed to complete them. Pupils should know the position of the object relative to the principal focus in the different devices.	Magnifying glass: http://www.physics.pomona.edu/sixideas/labs/LRM/LR07.pdf Camera: http://science.howstuffworks.com/camera1.htm Enlarger: http://en.wikipedia.org/wiki/Enlarger	It is helpful if pupils have seen these devices operating or partially dismantled. Make a large model of the camera /enlarger using a cardboard box and an appropriate lens.
14(p)	Draw ray diagrams to show the formation of images in the normal eye, a short-sighted eye and a long-sighted eye.	A model eye can be made from a fish bowl or a round-bottomed flask with a lens held to the outside with a ring of modelling clay. Fill the bowl or flask with water and a very small amount of paint to scatter the light. Pass light into the model eye.	The eye: http://www.glenbrook.k12.il.us/gbssci/phys/Class/refrn/u14l6a.html	
14(q)	Describe the correction of short-sight and long-sight.	Explain the causes of both short- and long-sightedness and describe the way in which lenses are used to solve the problems.	Short sight: http://www.glenbrook.k12.il.us/gbssci/phys/Class/refrn/u14l6e.html	

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			Long sight: http://www.glenbrook.k12.il.us/gbssci/phys/Class/refrn/u14l6d.html	
15(a)	Describe the dispersion of light as illustrated by the action on light of a glass prism.	Best shown in practice using a glass/water prism and a ray-box, torch or slit in a blind/curtain. Light is split up according to its wavelength.	Prisms: http://webphysics.ph.msstate.edu/javamirror/ipmj/java/dispprizm/index.html	
15(b)	State the colours of the spectrum and explain how the colours are related to frequency/wavelength.	This leads to the traditional seven colours of the spectrum/rainbow. The higher the frequency, the greater the extent of the refraction. "Violet refracts violently" or "blue bends best". Use an infra-red detector (e.g. a thermometer with bulb blackened) to detect radiation beyond the red end of the visible spectrum and show that some sections of the spectrum cannot be detected by the human eye.	Rainbows: http://www.phy.ntnu.edu.tw/java/Rainbow/rainbow.html or: http://eo.ucar.edu/rainbows/	
15(c)	State that all electromagnetic waves travel with the same high speed in air and state the magnitude of that speed.	List properties shared by all electromagnetic radiations, include: • speed in air, • transverse nature, • travel in vacuum.		Some pupils will point out that light cannot be a wave as it does not require a medium. One might point out that magnetic and electric fields do pass through a vacuum and that light is an oscillation of such fields.
15(d)	Describe the main components of the electromagnetic spectrum.	Emphasise that the boundaries between regions are arbitrary and conventional – a snake or an insect have different end wavelengths for their visible regions.	The electromagnetic spectrum: http://www.phy.ntnu.edu.tw/java/emWave/emWave.html	
15(e)	Discuss the role of the following components in the stated applications: (1) radiowaves: radio and	Emphasise that electromagnetic wave properties change gradually as the frequency changes. Avoid referring to "The seven types of electromagnetic radiation".	Applications of I.R: http://www.ebs-thermography.com/gallery/index_e.html	

	Learning Outcomes	Suggested Teaching Activities	Online Resources	Other resources
	television communications, (2) microwaves: satellite television and telephone, (3) infra-red: household electrical appliances, television controllers and intruder alarms, (4) light: optical fibres in medical uses and telephone, (5) ultra-violet: sunbeds, fluorescent tubes and sterilisation, (6) X-rays: hospital use and engineering applications, (7) gamma rays: their use in medical treatment.	This topic provides ideal material for pupil projects. The pupils can research these areas themselves and then talk to the rest of the class about what they have found. There is a huge amount of information published on the internet and the difficulty is likely to be keeping it accurate and relevant.	The electromagnetic spectrum: http://imagine.gsfc.nasa.gov/docs/science/know_l1/emspectrum.html or: http://www.electro-optical.com/bb_rad/emspect.htm	