UNIT 5: Waves

Recommended Prior Knowledge Students should be able to describe basic wave behaviour, gained through study of optics. They should be aware of the basic ideas of reflection and refraction of light.

Context Waves and wave theory are an important aspect of any physics course since wave phenomena are present throughout our everyday lives. The course provides an understanding for those students who will not be studying physics beyond AS level and a basis for further study in the A2 course, including wave-particle duality.

Outline The quantities by which a wave is specified are considered. Different types of wave are studied. Emphasis is placed on the phenomena of superposition, interference and diffraction.

Learning Outcomes		Suggested Teaching Activities	Resources
	Candidates should be able to		
			Reference should be made to the list of textbooks printed in the Syllabus document. Note that some of these texts are more suitable as reference texts for the teacher whilst others are more suitable as student texts. Some Internet sites are shown within certain topics. The list of sites is by no means comprehensive but provides examples of what is available. Material may provide a link with O-level and IGCSE studies, thus providing background experience, as well as reinforcing AS studies. All examples of examination questions are taken from Physics 8702 and 9702 papers.
15(a) 15(e)	describe what is meant by wave motion as illustrated by vibration in ropes, springs and ripple tanks. show an understanding that energy is transferred due to a progressive wave.	Discussion: wave as a means of energy transfer by vibrations no mass motion of the medium (if there is one)	rope, slinky spring, ripple tank http://www.explorescience.com

15(b) 15(c) 15(d)	show an understanding and use the terms displacement, amplitude, phase difference, wavefront, period, frequency, wavelength and speed. deduce, from the definitions of speed, frequency and wavelength, the equation $v = f\lambda$. recall and use the equation $v = f\lambda$.	Discussion: meaning/ definitions of (i) frequency f and period T (ii) displacement x and amplitude A (iii) wavefront and wavelength λ (iv) speed (v) phase difference/angle between two points on a wave and between two continuous waves *x/t* and *x/distance* graphs as worked examples Derivation of $v = f\lambda$ Worked examples	sine wave generator, loudspeaker, leads microphone, c.r.o. ripple tank Examples sheet including Specimen Paper 1, question 27 May/June 2002, Paper 1, question 26 Examples sheet including Specimen Paper 2, question 6(b) May/June 2001, Paper 1, question 27
15(f)	recall and use the relationship, *intensity* $\propto$ *(amplitude)*^{2}.	Revision: a wave as a means of energy transfer Discussion: what is intensity define as power incident per unit area – units W m^{-2} *intensity* $\propto$ *(amplitude)*^{2}. Worked example: For point source and no power dissipation, *intensity* $\propto 1 / x^2$	See also Oct/Nov 2001, Paper 1, question 27 May/June 2001, Paper 2, question 6(b) May/June 2002, Paper 1, question 27
15(g)	compare transverse and longitudinal waves.	Transverse waves: defined in terms of direction of vibration and of energy transfer Examples	slinky spring, rope, ripple tank

		Longitudinal waves: defined in terms of direction of vibration and of energy transfer Examples	slinky, sine wave generator, large-cone loudspeaker, leads, dry sand See also Specimen Paper 1, question 26 Specimen Paper 2, question 6(a) May/June 2001, Paper 2, question 6(a)
15(h)	analyse and interpret graphical representations of transverse and longitudinal waves.	Transverse: plotting displacement (y-axis) and distance or time (x-axis) Longitudinal: mapping undisturbed and disturbed layers of air – compressions and rarefactions. Displacement along direction of travel plotted on y-axis. Could also be excess pressure (y-axis) against distance or time (x-axis). Similarity of transverse & longitudinal graphs Worked examples	sine wave generator, loudspeaker, microphone, leads, c.r.o. http://library.thinkquest.org/11924/index.html Examples sheet including Oct/Nov 2001, Paper 1, question 28 May/June 2001, Paper 2, question 6(b)
15(i)	show an understanding that polarisation is a phenomenon associated with transverse waves.	Discussion: oscillations in one direction only in plane normal to direction of energy transfer Polarisation only associated with transverse waves Polarisation by reflection	Polaroid sunglasses, sheets of Polaroid
15(j)	determine the frequency of sound using a calibrated c.r.o.	Expt: determine of frequency of a sound wave extend to include period	sine wave generator, loudspeaker, microphone, leads, c.r.o.

15(l)	state that all electromagnetic waves travel with the same speed in free space and recall the orders of magnitude of the wavelengths of the principal radiations from radio waves to γ-rays.	Discussion: speed of sound in gases and solids speed of e.m. waves in free space The e.m. spectrum – principal radiations - wavelengths Worked examples – calculation of corresponding frequencies	http://www.colorado.edu/physics/2000/index.pl http://observe.ivy.nasa.gov/nasa/education/reference/emspec/emspectrum.html Handout of spectrum See also Specimen Paper 1, question 28 May/June 2001, Paper 1, question 26 Oct/Nov 2001, Paper 1, question 26 May/June 2002, Paper 1, question 25
16(a)	explain and use the principle of superposition in simple examples.	Discussion: what happens when two waves meet Development: principle of superposition	Slinky spring
16(b)	show an understanding of experiments which demonstrate stationary waves using microwaves, stretched strings and air columns.	Demonstration of stationary waves Waves of same frequency travelling in opposite directions – conditions for stationary wave to be established Nodes and antinodes observed	Slinky spring Frequency generator, oscillator, thread, weights, pulley Resonance tube, tuning forks 3 cm microwave equipment to demonstrate stationary waves
16(c)	explain the formation of a stationary wave using a graphical method, and identify nodes and antinodes.	Discussion: graphical construction for formation of stationary wave phase change on reflection nodes and antinodes Phase of particles in internodal loops Amplitude of particles in internodal loops	See also Oct/Nov 2001, Paper 1, question 31 May/June 2002, Paper 1, question 29
15(k)	determine the wavelength of sound using stationary waves.	Expt: determination of wavelength of stationary sound wave Extension to determination of speed of sound if frequency is known Worked examples on stationary waves	either: resonance tube, tuning forks, metre rule or: large plane reflector, loudspeaker, leads, sine wave generator, microphone, c.r.o. metre rule Examples sheet including May/June 2001, Paper 1, question 29

16(e) 16(d)	show an understanding of experiments which demonstrate diffraction including the diffraction of water waves in a ripple tank with both a wide gap and a narrow gap. explain the meaning of the term diffraction.	Demonstration: diffraction of waves Discussion: meaning of diffraction 'degree' of diffraction dependent on ratio of wavelength and slit width	Ripple tank, wide and narrow slits Laser, single slit (of adjustable width) screen Examples sheet including Specimen Paper 1, question 29 May/June 2001, Paper 1, question 28 May/June 2002, Paper 2, question 7(a)
16(f) 16(g)	show an understanding of the terms interference and coherence. show an understanding of experiments which demonstrate two-source interference using water, light and microwaves.	Demonstration: interference of two waves	Rotating tuning fork two loudspeakers, sine wave generator, leads http://vsg.tripod.com/interfer.html See also Oct/Nov 2001, Paper 1, question 30 May/June 2002, Paper 1, question 28
16(h)	show an understanding of the conditions required if two-source interference fringes are to be observed.	Discussion: meaning of interference interference with light? meaning of coherence	monochromatic source and single slit or laser double slit (adjustable if available), screen See also May/Jun 2001, Paper 2, question 6(c) and (d)
16(i)	recall and solve problems using the equation $\lambda = ax / D$ for double slit interference using light.	Demonstration: two-source interference with light – effect of changing a, x, D, λ and *intensity* on fringe appearance Derivation of expression λ ax / D not essential Discussion: form of equation $\lambda = ax / D$ conditions for it to apply Expt: measurement of wavelength of light	http://theory.uwinnipeg.ca/physics/light/node9.html http://surendranath.tripod.com/DblSlt/DblSltApp.html monochromatic source and single slit or laser double slit (adjustable if available), screen, metre rule, mm scale

		Worked examples	Examples sheet including Specimen Paper 1, question 30 Specimen Paper 2, question 6(c) May/June 2001, Paper 1, question 30 Oct/Nov 2001, Paper 2, question 6 May/June 2002, Paper 1, question 28
16(j)	recall and solve problems using the formula $d \sin\theta = n\lambda$ and describe the use of a diffraction grating to determine the wavelength of light. (The structure and use of the spectrometer is not included.)	Discussion: the diffraction grating Demonstration: use of grating the grating formula - $d\sin\theta = n\lambda$ normal incidence orders of diffracted light Expt: measurement of wavelength of light Worked examples	Diffraction gratings of various grating elements either monochromatic light source and collimator or laser, diffraction grating, screen either monochromatic light source and collimator or laser, diffraction grating, screen, metre rule Examples sheet including Specimen Paper 1, question 31 Specimen Paper 2, question 9 Oct/Nov 2001, Paper 1, question 29 May/June 2002, Paper 2, question 7(b) and 7(c)