

## Unit 4

### Waves & Our Universe

An understanding of the principles in this unit and in the general requirements is expected in familiar and unfamiliar situations. In examination questions where the context is beyond the content of the specification it will be fully described.

#### Circular motion

Unit	Topic	Content
4.1	Angular speed, period & frequency	Relationship between angular speed, period, frequency. $\omega = \frac{\Delta\theta}{\Delta t}$ , $v = \omega r$ , $T = \frac{2\pi}{\omega}$ , $f = \frac{\omega}{2\pi}$ The definition of the radian.
4.2	Acceleration and resultant force.	For a body moving at a constant speed in a circular path, acceleration $a = \frac{v^2}{r}$ Resultant force, $F$ , towards the centre of the circle is given by $F = \frac{mv^2}{r}$ Idea of apparent weightlessness when objects are in free fall.

#### Simple harmonic motion

Unit	Topic	Content
4.3	Simple harmonic motion.	Variation of displacement, velocity and acceleration with time, treated graphically. An understanding that s.h.m. results when acceleration is proportional to displacement and in the opposite direction.
4.4		Frequency and period for simple harmonic motion. The equation $a = -(2\pi f)^2 x$ and $T = \frac{1}{f}$
4.5	Undamped simple harmonic oscillations	$x = x_0 \cos 2\pi ft$ Angles expressed in both degrees and radians. Maximum speed $v_{\max} = 2\pi f x_0$ Velocity as gradient of displacement-time graph. Acceleration as gradient of velocity-time graph.
4.6	Mechanical oscillators.	Experimental study of a simple pendulum. Period of simple pendulum: $T = 2\pi \sqrt{\frac{l}{g}}$ for small amplitude Experimental study of mass-spring system.
4.7	Free and forced vibrations	Mechanical resonance. An experimental and qualitative knowledge of mechanical resonance. Damping.

## Waves

Unit	Topic	Content
4.8	Mechanical waves	Mechanical waves on water, along springs and in air (sound). The emphasis should be on the generation of waves and the transmission of energy in the medium.
4.9	Electromagnetic waves	It is expected that electromagnetic wave phenomena will be demonstrated using visible light and microwaves. The electromagnetic spectrum. An outline of the whole spectrum: the order of magnitude of the wavelengths of the main regions should be known.
4.10	Progressive waves: longitudinal and transverse waves	Amplitude, speed, wavelength, frequency and phase interpreted graphically. Plane polarisation. Plane polarisation as a property of transverse waves demonstrated using light and microwaves. Wave equation: $c = f\lambda$
4.11	Conservation of energy for waves in free space from a point source.	Inverse square law. Energy flux or intensity measured in $\text{W m}^{-2}$ . Intensity $I = \frac{P}{4\pi r^2}$

## Superposition of waves

Unit	Topic	Content
4.12	The principle of superposition	Waves combined using a graphical treatment
4.13	Wavefronts	By definition, all points on a wavefront are in phase. Meaning of <i>phase difference</i> and <i>path difference</i> . $\Delta(\text{phase}) = \frac{2\pi\Delta(\text{path})}{\lambda}$
4.14	Stationary waves and resonance	Demonstration using waves on strings and microwaves. Half-wavelength separation of nodes or antinodes should be known but need <i>not</i> be derived.
4.15	Diffraction at a slit	Demonstrated using water waves, microwaves and light. Appreciation of dependence of the width of central maximum on relative sizes of slit and wavelength.
4.16	Two slit interference patterns.	Coherence. Interpretation of the observed patterns using the principle of superposition, illustrated by the overlapping of two sets of circular waves on water. Measurements of wavelength with both visible light and microwaves. Knowledge of experimental details and typical dimensions is expected. $\lambda = \frac{xS}{D}$ for light; the limitations should be understood but the proof is <i>not</i> required.

## Quantum phenomena

Unit	Topic	Content
4.17	The photon model of electromagnetic radiation.	The Planck constant. $E = hf$ <i>Measurement of the Planck constant using photocell.</i> The photoelectric effect. Work function and the photoelectric equation. Simple demonstration (eg discharge of negatively charged zinc plate). The concept of stopping potential and its measurement. Maximum energy of photoelectrons $W = hf - \phi$
4.18.	Energy levels	The electronvolt. Possible energy states of an atom as fixed and discrete. $hf = E_1 - E_2$ The emission and absorption line spectrum of atomic hydrogen related to electron energy levels.
4.19	Wave properties of free electrons.	Electron diffraction. Wave-particle duality. The de Broglie wavelength. $\lambda = \frac{h}{p}$ Stationary waves in the hydrogen atom. Wave properties of electrons in atoms.

## The expanding Universe

Unit	Topic	Content
4.20	Optical line spectra.	Demonstration of spectra using a diffraction grating. Star spectra emission and absorption lines and their relation to chemical composition.
4.21	Electromagnetic Doppler effect	Doppler shift of spectral lines. $\frac{\Delta f}{f} = \frac{\Delta \lambda}{\lambda} = \frac{v}{c}$ , where $v$ is the speed of a star or galaxy towards or away from the Earth. The light year. Expansion of the Universe. Hubble's law. The Big Bang. The red shift of galaxies $v = Hd$ , with $H$ in $s^{-1}$ . The age of the Universe: uncertainty in $d$ and $H$ .
4.22	Open and closed Universes	The average mass-energy density of the Universe: indefinite expansion or final contraction.