Waves

Fairlight Tuition

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Waves 1 [Concepts A]

1. **Wave definition:** The transmission of energy through a propagating medium.

2. **Transverse wave:** Medium oscillates perpendicular to the direction of energy propagation, forming peaks and troughs (e.g. electromagnetic radiation, surface water waves, seismic S-waves).

3. **Longitudinal wave:** Medium oscillates parallel to the direction of energy propagation, forming compressions and rarefactions (e.g. sound waves, compression waves on a spring, seismic P-waves).

4. **Amplitude** (A [or x_o]) metres [m] + direction
   [maximum magnitude of displacement of medium oscillation from the equilibrium position]

5. **Wavelength** (λ) metres [m]
   [minimum distance between two successive points in a wave that are in phase]

6. **Frequency** (f) hertz [Hz]
   [number of complete oscillations per second]

7. **Period** (T) seconds [s]
   [number of seconds per complete oscillation]

Waves 2 [Concepts B]

1. **Wave Equation:** $c = f\lambda$

2. **Frequency-Period relationship:** $f = \frac{1}{T}$

3. **Polarisation:** Confining the displacement vector of a transverse wave to a single plane of oscillation. Longitudinal waves cannot be polarised as their displacement vectors are parallel, not perpendicular, to the direction of energy propagation.

4. **Refraction:** The change in direction of a wavefront when changing speed at an interface (unless incident along normal).

5. **Diffraction:** The spreading out of a wavefront (and hence of the wave energy) when incident upon an edge (or aperture).

6. **Coherence:** Waves with the same frequency and a constant phase relationship.

7. **Lasers:** Light is: coherent; polarised; monochromatic (single frequency); collimated (parallel beams).

Waves 3 [Refraction]

1. **Frequency** remains constant during refraction $\therefore c \propto \lambda$

2. **Snell's Equation:** $${}_1n_2 = \frac{n_2}{n_1} = \frac{\sin\theta_1}{\sin\theta_2} = \frac{c_1}{c_2} = \frac{\lambda_1}{\lambda_2}$$ [where $n_1 = \frac{c}{c_1}$]

3. **Total Internal Reflection:** Angle of incidence is larger than the critical angle. Only possible when $n_1 > n_2$ (i.e. ${}_1n_2 < 1$).

4. **Critical Angle:** $$\frac{n_2}{n_1} = \sin\theta_c$$ [as $\sin\theta_2 = \sin 90 = 1$]

5. **Optical Fibre Cladding:** Protects surface of core from damage; prevents signal crossover.; increases chance of TIR at core-cladding boundary (✷ n_{core} must be ≫ $n_{cladding}$ ✷)

6. **Modal Dispersion:** Pulse broadening due to light rays entering the optical fibre at different angles and hence taking different paths (hence also 'multipath dispersion'). Reduced by using very narrow core (monomode, rather than multimode fibres), which also increases probability of TIR and rate (and quality) of data transfer. [Or use more repeaters.]

7. **Material Dispersion:** Pulse broadening due to refractive index of fibre varying with light frequency, and hence different frequencies travelling at different speeds. Reduced by using monochromatic light. [Or use more repeaters.]

Waves 4 [Interference]

1. **Principle of Superposition:** The net displacement of a complex wave is the vector sum of the displacements of its component simple waves.

2. **Interference:** Coherent progressive waves move across each other and superpose, creating an *interference pattern*.

3. **Constructive interference:** Waves meet in phase (path difference is an even number of half wavelengths); the vector sum of displacements is therefore a maximum.

4. **Destructive interference:** Waves meet in anti-phase (path difference is an odd number of half wavelengths); the vector sum of displacements is therefore a minimum.

5. **Stationary wave conditions:** Component waves must: have a constantly varying phase difference; be same wave-type and frequency; superpose; have same speed but opposite directions (often following reflection); have (ideally) similar amplitudes.

6. **The distance** between adjacent nodes [minima] (or anti-nodes [maxima]) is $\lambda/2$. [✷ Watch out for reflections/wedges etc. ✷]

7. **Progressive/Stationary Comparison:** frequency same along whole wave/frequency zero at nodes; amplitude same along whole wave/amplitude varies along wave (nodes and anti-nodes); transient interference/permanent interference; net energy transfer/no net energy transfer.

Waves 5 [Slits and Gratings]

1. **Single slit:** $sin\theta = \frac{m\lambda}{a}$

   [θ = angle from central axis to mth minimum. Central maximum ≈ double width of subsidiary maxima]

2. **Double slit:** $w = \frac{\lambda D}{s}$

3. **Coherency:** Two separate light sources would not form a clear interference pattern as they emit light in *incoherent bursts*. Coherency for double slit patterns is therefore created by first diffracting light from a *single* source through a single slit equidistant from the double slits (creating a constant phase relationship for the light reaching them). The double slits must be *narrow* enough to cause significant diffraction and *close* enough to cause superposition.

4. **White light** produces a white central maximum. Initial subsidiary maxima form spectra with blue interior edges and red exterior edges.

5. **Diffraction grating:** $sin\theta = \frac{n\lambda}{d}$

   [θ = angle from central axis to nth maximum]

6. **Diffraction gratings produce** maxima that are brighter and sharper than two slit systems as more light is transmitted and constructive interference is 'reinforced' by multiple slits.

7. **Diffraction gratings are** used in spectrometers (such as those analysing line emission or line absorption spectra from stars to discover composition).