

Refraction, diffraction and interference

6

Interference

Interference:

The process of two coherent waves creating a resultant wave either through cancellation or reinforcement.

The process of interference can occur with sound, visible light and other electromagnetic waves.

Coherent:

Sources of waves are coherent if they emit waves of the same frequency with constant phase difference.

Path difference:

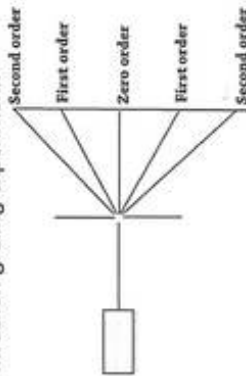
The difference in the distances between two coherent wave sources to an interference fringe.

- Lasers are often used in interference experiments as they produce monochromatic light.
- Lasers can operate at high power and can cause damage to the retina and blindness if looked at directly, as well as potentially causing skin burns.
- Care and safety protocols must be followed when working with lasers.

Diffraction

Diffraction: The process of waves spreading when passing through a gap or a barrier. A **diffraction grating** is a screen with many thin slits.

Diffraction grating experiment:



Grating equation:

$$d \sin \theta = n\lambda$$

d = grating spacing

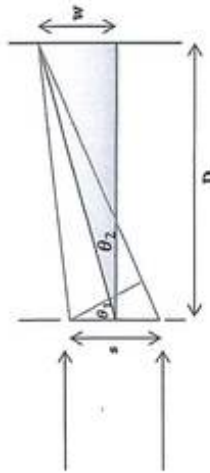
θ = angle between central beam and n th beam

λ = wavelength of light used

Exam Tip!

You will be expected to know how to derive this equation.

Young's double-slit experiment



Fringe spacing:

$$w = \frac{\lambda D}{s}$$

w = fringe spacing
 D = distance between slits
 λ = wavelength of light
 s = distance between slits

The interference pattern created by white light is similar to that of monochromatic light.

White light interference will still produce a fringe pattern, however. Since white light is made up of a spectrum of different wavelengths, each fringe will be a spectrum of fringes varying in colour. Shorter wavelengths (blue) will be on the inner edge of each fringe, while longer wavelengths (red) will be on the outer edge.

Applications of diffraction gratings

Diffraction gratings are used to split white light into its visible colour spectrum:

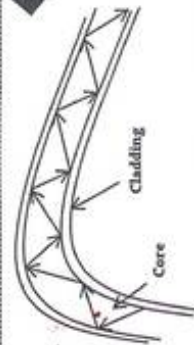
- The tracks on a CD are used as the diffraction grating.

Diffraction gratings are used in the field of spectroscopy:

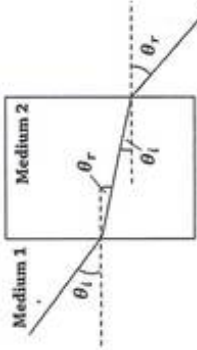
- The spectra of different elements can be observed using a diffraction grating to split spectral lines.



Optical fibre



Refraction at a plane surface



Exam Tip!

Note that you will be expected to recall that the refractive index of air is approximately 1.

Refractive index of a substance:

$$n = \frac{c}{c_s}$$

c = speed of light in vacuum
 c_s = speed of light in substance

Snell's law:

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

n_1 = refractive index of medium 1

n_2 = refractive index of medium 2

θ_1 = angle of incidence

θ_2 = angle of refraction

Total internal reflection:

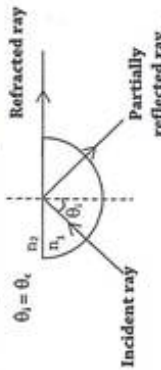
Total internal reflection refers to the situation when the incident light ray enters at angle of incidence greater than the critical angle, and the light ray doesn't refract out of the boundary but reflects back upon itself into the material.

Critical Angle:

$$\sin \theta_c = \frac{n_2}{n_1}$$

Conditions for total internal reflection:

- The incident substance has a **greater refractive index** than the second, i.e. $n_1 > n_2$.
- The angle of incidence is **greater** than the critical angle of the substance, i.e. $\theta_i > \theta_c$.



Optical fibres

- Optical fibres use repeated total internal reflection to transmit light down their length.
- Optical fibres are used in medicine to image internal organs of the human body.
- The core of the optical fibre is coated in a cladding made of a material with a lower refractive index to ensure total internal reflection down the length of the core and to ensure that no light is transmitted between optical fibres.
- Modal dispersion:** pulse dispersion that occurs as a result of the light ray undergoing total internal reflection travelling a longer distance than the light travelling along the axis
- Material dispersion:** pulse dispersion that occurs from using white light - light made up of different colours that will result in each travelling at a different speed down the length
- Pulse broadening:** As dispersion occurs, pulses of light passing through the optical fibre spread out. This can result in different pulses joining together and distorting the signal.
- Absorption:** Impurities in the optical fibre can result in light getting absorbed. This results in the strength of the signal decreasing.