9.3 - Interference

Nature of science:

Curiosity: Observed patterns of iridescence in animals, such as the shimmer of peacock feathers, led scientists to develop the theory of thin film interference. (1.5)

Serendipity: The first laboratory production of thin films was accidental. (1.5)

Understandings:

- Young's double-slit experiment
- Modulation of two-slit interference pattern by one-slit diffraction effect
- Multiple slit and diffraction grating interference patterns
- Thin film interference

Applications and skills:

- Qualitatively describing two-slit interference patterns, including modulation by one-slit diffraction effect
- Investigating Young's double-slit experimentally
- Sketching and interpreting intensity graphs of double-slit interference patterns
- Solving problems involving the diffraction grating equation
- Describing conditions necessary for constructive and destructive interference from thin films, including phase change at interface and effect of refractive index
- Solving problems involving interference from thin films

Theory of knowledge:

- Most two-slit interference descriptions can be made without reference to the one-slit modulation effect. To what level can scientists ignore parts of a model for simplicity and clarity?

Utilization:

- Compact discs are a commercial example of the use of diffraction gratings
- Thin films are used to produce anti-reflection coatings

Aims:

- **Aim 4:** two scientific concepts (diffraction and interference) come together in this sub-topic, allowing students to analyse and synthesize a wider range of scientific information
- **Aim 6:** experiments could include (but are not limited to): observing the use of diffraction gratings in spectroscopes; analysis of thin soap films; sound wave and microwave interference pattern analysis
- **Aim 9:** the ray approach to the description of thin film interference is only an approximation. Students should recognize the limitations of such a visualization

Guidance:

- Students should be introduced to interference patterns from a variety of coherent sources such as (but not limited to) electromagnetic waves, sound and simulated demonstrations
- Diffraction grating patterns are restricted to those formed at normal incidence
- The treatment of thin film interference is confined to parallel-sided films at normal incidence
- The constructive interference and destructive interference formulae listed below and in the data booklet apply to specific cases of phase changes at interfaces and are not generally true

Data booklet reference:

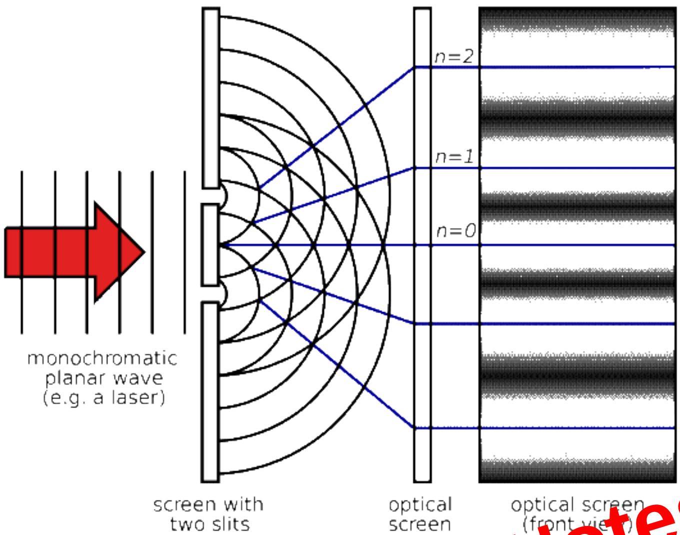
- $n\lambda = d \sin\theta$
- Constructive interference: $2dn = \left(m + \frac{1}{2}\right)\lambda$
- Destructive interference: $2dn = m\lambda$

Young's Double Slit Experiment

Interference takes place when identical waves are emitted from two sources and observe at the same point in space.

In Thomas Young's 1801 experiment, light from a candle was incident on a single slit. It diffracted and the turned into plane wavefronts by passing through a lens.

In the modern version, the light is laser light and it is incident on two slits. Light diffracts at each slit and spreads out. The diffracted light is seen at the screen and the lights interfere with each other. The result is a pattern of bright and dark bands.



Coherent light means light where the phase difference between any two points on the same cross section of the beam is constant.

Monochromatic light means light of the same wavelength.

Resolution Questions

1. Work out angle θ_A from $\frac{1.22\lambda}{b}$ (in radians)
2. Work out how far the two objects must be by using $\theta_A = \frac{s}{d}$ (work out s)
3. The questions may ask you how it is affected in a different medium

Diffraction Grating Solution

Two pattern characteristics of intensity patterns for multi-slit interference:

1. The more slits, the higher the intensity of the primary maxima.
2. The more slits, the narrower the primary maxima.

A **diffraction grating** can be thought of as a collection of narrow slits. A diffraction grating has the ability to resolve, or to see distinct two lines in a spectrum that correspond to wavelengths λ_1 and λ_2 that are very close to each other. The resolution for a grating will be will be proportional to the number of lines.

The resolvance of a diffraction grating is:

$$R = \frac{\lambda_{avg}}{\Delta\lambda}$$

where

λ_{avg} is the average of λ_1 and λ_2

$\Delta\lambda$ is their difference

The higher the resolving power, the smaller the differences in wavelength that can be resolved.

It can be said that $R = mN$, where m is the order at which the lines are observed and N is the total number of slits on the diffraction grating. So we have:

$$\frac{\lambda_{avg}}{\Delta\lambda} = mN$$

which gives the smallest difference in wavelengths that can be resolved.