1.S: Diffraction (Summary)

Key Terms

Bragg planes	families of planes within crystals that can give rise to X-ray diffraction
destructive interference for a single slit	occurs when the width of the slit is comparable to the wavelength of light illuminating it
diffraction	bending of a wave around the edges of an opening or an obstacle
diffraction grating	large number of evenly spaced parallel slits
diffraction limit	fundamental limit to resolution due to diffraction
hologram	three-dimensional image recorded on film by lasers; the word hologram means entire picture (from the Greek word holo, as in holistic)
holography	process of producing holograms with the use of lasers
missing order	interference maximum that is not seen because it coincides with a diffraction minimum
Rayleigh criterion	two images are just-resolvable when the center of the diffraction pattern of one is directly over the first minimum of the diffraction pattern of the other
resolution	ability, or limit thereof, to distinguish small details in images
two-slit diffraction pattern	diffraction pattern of two slits of width **a** that are separated by a distance **d** is the interference pattern of two point sources separated by **d** multiplied by the diffraction pattern of a slit of width *a*
width of the central peak	angle between the minimum for $m=1$ and $m=-1$
X-ray diffraction	technique that provides the detailed information about crystallographic structure of natural and manufactured materials

Key Equations

Destructive interference for a single slit	$a\sin\theta = m\lambda$ for $m=\pm1,\pm2,\pm3,\ldots$
Half phase angle	$\beta = \frac{\phi}{2} = \frac{\pi a \sin\theta}{\lambda}$
Field amplitude in the diffraction pattern	$E = N\Delta E_0 \frac{\sin\beta}{\beta}$
Intensity in the diffraction pattern	$I = I_0 (\frac{\sin\beta}{\beta})^2$
Rayleigh criterion for circular apertures	$\theta = 1.22\frac{\lambda}{D}$
Bragg equation	$m\lambda = 2d\sin\theta, m=1,2,3\ldots$

Summary

4.1: Single-Slit Diffraction

- Diffraction can send a wave around the edges of an opening or other obstacle.

- A single slit produces an interference pattern characterized by a broad central maximum with narrower and dimmer maxima to the sides.

4.2: Intensity in Single-Slit Diffraction

- The intensity pattern for diffraction due to a single slit can be calculated using phasors as

$$I = I_0 \left(\frac{\sin\beta}{\beta}\right)^2,$$

where $\beta = \frac{\phi}{2} = \frac{\pi a \sin\theta}{\lambda}$, a is the slit width, λ is the wavelength, and θ is the angle from the central peak.

4.3: Double-Slit Diffraction

- With real slits with finite widths, the effects of interference and diffraction operate simultaneously to form a complicated intensity pattern.
- Relative intensities of interference fringes within a diffraction pattern can be determined.
- Missing orders occur when an interference maximum and a diffraction minimum are located together.

4.4: Diffraction Gratings

- A diffraction grating consists of a large number of evenly spaced parallel slits that produce an interference pattern similar to but sharper than that of a double slit.
- Constructive interference occurs when $d \sin\theta = m\lambda$ for $m = 0, \pm1, \pm2, \ldots$, where d is the distance between the slits, θθ is the angle relative to the incident direction, and m is the order of the interference.

4.5: Circular Apertures and Resolution

- Diffraction limits resolution.
- The Rayleigh criterion states that two images are just resolvable when the center of the diffraction pattern of one is directly over the first minimum of the diffraction pattern of the other.

4.6: X-Ray Diffraction

- X-rays are relatively short-wavelength EM radiation and can exhibit wave characteristics such as interference when interacting with correspondingly small objects.

4.7: Holography

- Holography is a technique based on wave interference to record and form three-dimensional images.
- Lasers offer a practical way to produce sharp holographic images because of their monochromatic and coherent light for pronounced interference patterns.
