Coherence: Two or more EM waves are in step with one another.

Superposition: Two or more EM waves occupy the same medium. [First studied with waves on water by Leonardo da Vinci.] If $y_i(x,t)$ are the individual wave functions, the resulting wave is just the sum: $y(x,t) = \Sigma_i y_i(x,t)$.

Interference: The result of superposition. If two waves are right in step, this is called **constructive interference**, whereas if they are out of step by half a wavelength, this is called **destructive interference.**

Diffraction: The filling-in of waves behind obstacles, especially noticable when the wavelength is about the size of the obstacle. Diffraction often leads to interference, as in the famous case of **the double slit**.

THE DOUBLE SLIT: The path difference of $d \sin\theta$ leads to constructive interference if it is an integer multiple of a wavelength, and to destructive interference if it is an odd-integer multiple of a half-wavelength. Since we view the interference pattern on a screen a distance $L >>> \lambda$ or d from the slits, the $\tan\theta$ or $\sin\theta$ can be replaced by θ in radians.

Bright lines are centered at $y_b \approx m\lambda L/d$, while dark bands are centered at $y_d \approx (m + 1/2)\lambda L/d$, with m an integer.

A simple argument shows that the intensity of the double slit diffraction pattern varies as

$$I(y) = 4I_0 \cos^2\left[\frac{\pi dy}{\lambda L}\right].$$

DIFFRACTION GRATING:

$$d \sin\theta = m\lambda, \text{ with } \frac{\lambda}{\Delta\lambda} = mN.$$

The approximation that $\sin\theta \approx \tan\theta \approx \theta$ is almost always invalid for gratings, because of their large dispersion.

X-RAY DIFFRACTION:

$$2d \sin\theta = m\lambda$$

Beginning in a medium with n_1, reflecting from surface with $n_2 > n_1$, there is a 180° phase change in the wave.

Beginning in a medium with n_1, reflecting from surface with $n_2 < n_1$, there is NO phase change in the wave.

Thin Film: Suppose the film has thickness t and assume perpendicular incidence. Consider whether there is a phase change for light reflected from the front of the film. Then consider whether there is a phase change for light reflected from the back of the film. Then consider that the path difference between the two reflected waves is $2t$, and that the wavelength in the film is λ/n if the film has index of refraction n. Taking all this into account you can decide whether the wave reflected from the front of the film is in phase or out of phase with the wave reflected from the back of the film, for a given t and n. There is NO "formula."

Interferometers were the key to discovering and observing gravitational radiation!

Huygens' Principle is the key to understanding diffraction.

Single Slit:

$$a \sin\theta = m\lambda, \text{ destructive, } m \neq 0.$$

Intensity:

$$I(\phi) = I_0 \Big[\frac{\sin(\phi/2)}{\phi/2}\Big]^2.$$

Rayleigh Criterion for Diffraction Limit:

$$\theta_{\min} = 1.22\frac{\lambda}{D}.$$

DIFFRACTION OF WAVES