10. Young's Double Slit Experiment

(a) Condition for Interference Pattern

The light waves from the two slits must be **coherent**, meaning they have a constant phase relationship.

(b) Conditions for Interference

For a path difference $\Delta r = d\sin\theta$:

- **Constructive (Maxima):** $d\sin\theta = m\lambda, \quad m = 0, \pm 1, \pm 2, ...$
- **Destructive (Minima):** $d\sin\theta = (m + \frac{1}{2})\lambda, \quad m = 0, \pm 1, \pm 2, ...$

(c) Distance Between Adjacent Fringes

Using the small-angle approximation $\sin\theta \approx y/\ell$, the position of the m-th bright fringe is $y_m = \frac{m\lambda\ell}{d}$. The distance between adjacent fringes is:

$$\Delta y = y_{m+1} - y_m = \frac{\lambda\ell}{d}$$

(d) Intensity of the Maxima

The intensity I is proportional to the square of the electric field amplitude. The superposition of two waves with amplitude E_0 and phase difference δ gives a resultant amplitude $A = 2E_0\cos(\delta/2)$. If I_0 is the intensity from one slit ($I_0 \propto E_0^2$), the intensity distribution is:

$$I(\theta) = 4I_0\cos^2(\delta/2) = 4I_0\cos^2\left(\frac{\pi d\sin\theta}{\lambda}\right)$$

At the maxima, $d\sin\theta = m\lambda$, so the argument of the cosine is $m\pi$, and $\cos^2(m\pi) = 1$. Thus, the intensity of the maxima is $I_{maxima} = 4I_0$.