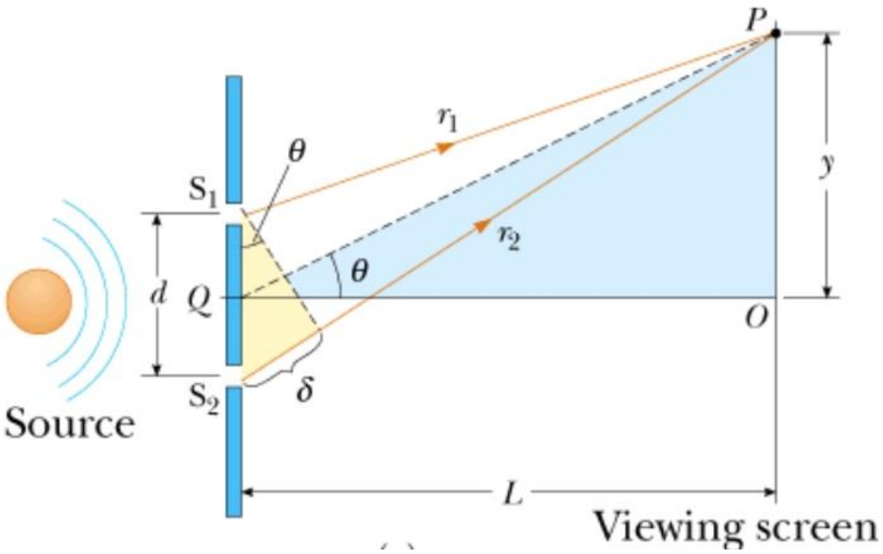
Answer on Question#38828, Physics, Optics

Discuss, with necessary theory, how is double slit interference pattern affected when a thin glass plate is introduced in the path of one of the interfering beams?

Answer.

Consider the light rays from the two coherent point sources made from *infinitesimal* slits a distance d apart. We assume that the sources are emitting monochromatic light of wavelength λ. The rays are emitted in all forward directions, but let us concentrate on only the rays that are emitted in a direction θ toward a distant screen (θ measured from the normal to the screen, diagram below) . One of these rays has further to travel to reach the screen, and the *path difference* is given by $d\sin\theta$. If this path difference is exactly one wavelength λ or an integer number of wavelengths, then the two waves arrive at the screen in phase and there is constructive interference, resulting in a bright area on the screen. If the path difference is $\frac{1}{2}\lambda$, or $\frac{3}{2}\lambda$, etc., then there is destructive interference, resulting in a dark area on the screen.



$\delta = r_2 - r_1 = d\sin\theta,$

$$\left.\begin{array}{l} Bright: \; d\sin\theta = m\lambda \\ \\ Dark: \; d\sin\theta = (m+\tfrac{1}{2})\lambda. \end{array}\right\} m=0,\pm1,\pm2..$$

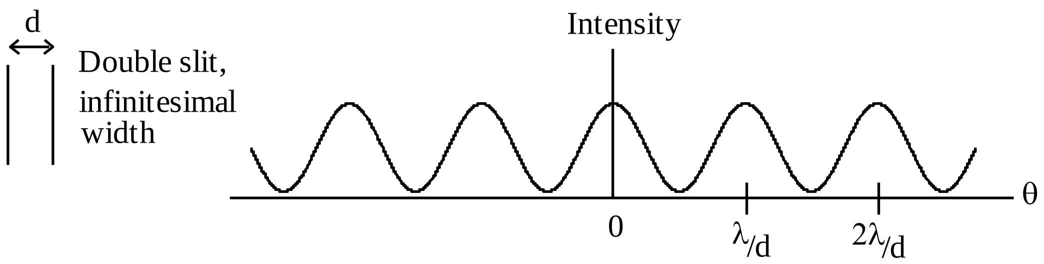
$d \gg \lambda, \qquad \sin\theta \approx \tan\theta$

$y = L\tan\theta \;\approx L\sin\theta \approx \tan\theta$

$$y_{bright} = \frac{\lambda L}{d} m$$

$$y_{dark} = \frac{\lambda L}{d}\left(m + \frac{1}{2}\right)$$

A complete analysis yields a pattern of intensity vs. angle that looks like:



When a transparent glass plate of thickness *t* and refractive index *n* is placed in one of the incoming wave path, due to the increase of the path by *(n-1)t*, the interference pattern undergoes a shift *s*.

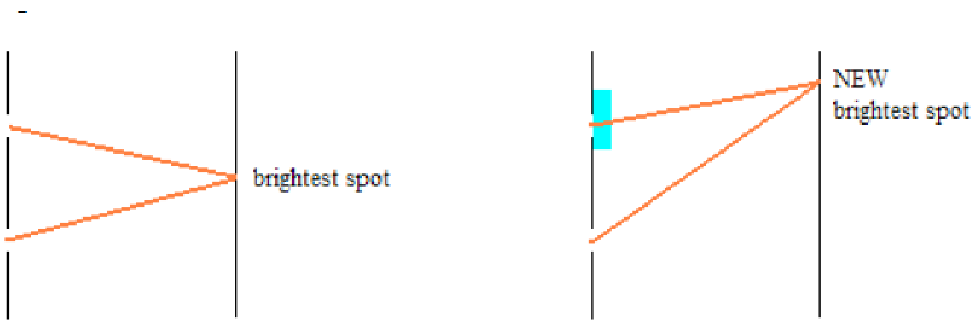


Fig. Equal effective path lengths without (left) and with (right) glass slide.

Once the glass slide is in place, the central point moves. This is due to there being more wavelengths inside the glass slide than in the air in front of the second slit.

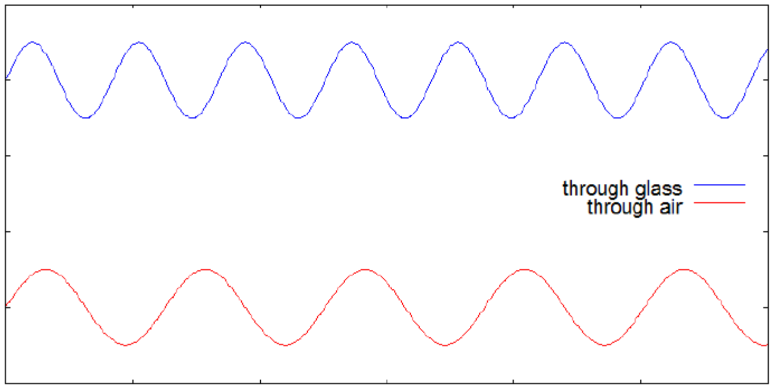


Fig. Difference in wavelengths traveling through air and glass

If the glass has a thickness t, then there are $\frac{t}{\lambda/_n}$ complete wavelengths that travel through it, while there are $\frac{t}{\lambda/_1}$ wavelengths that travel through the same thickness of air.

The number of fringes shifted is

$$m = \left|\frac{t}{\lambda/_n} - \frac{t}{\lambda}\right| = \frac{t}{\lambda}(n-1)$$

Shift of pattern $s = y_{bright} = \frac{\lambda L}{d}m = \frac{\lambda L}{d}\frac{t}{\lambda}(n-1) = \frac{L}{d}(n-1)t.$

Answer. When a transparent glass plate of thickness *t* and refractive index *n* is placed in one of the incoming wave path, due to the increase of the path by *(n-1)t*, the interference pattern undergoes a shift $s = \frac{L}{d}(n-1)t$.