Young's Double Slit Experiment

(Division of Wavefront)

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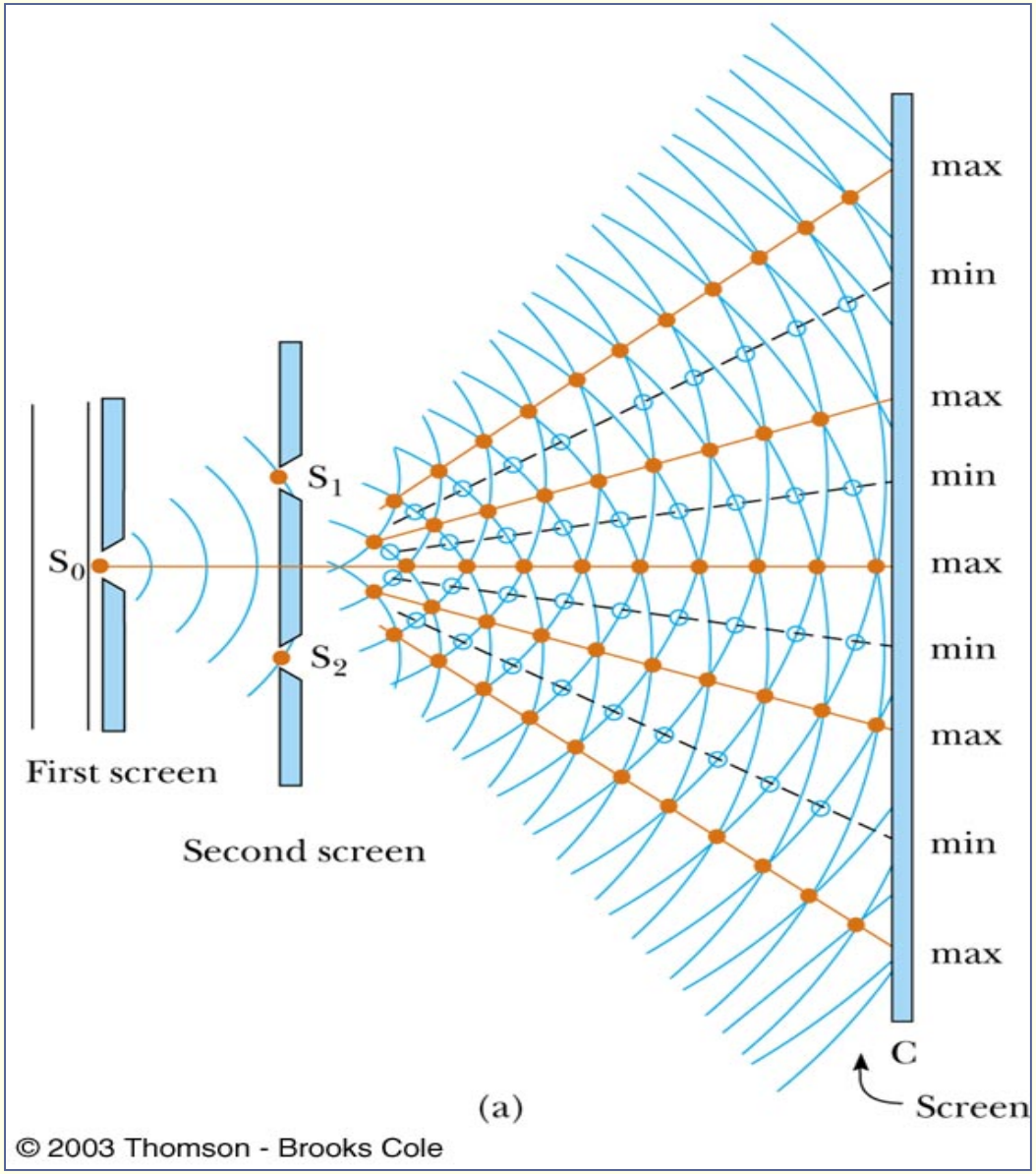
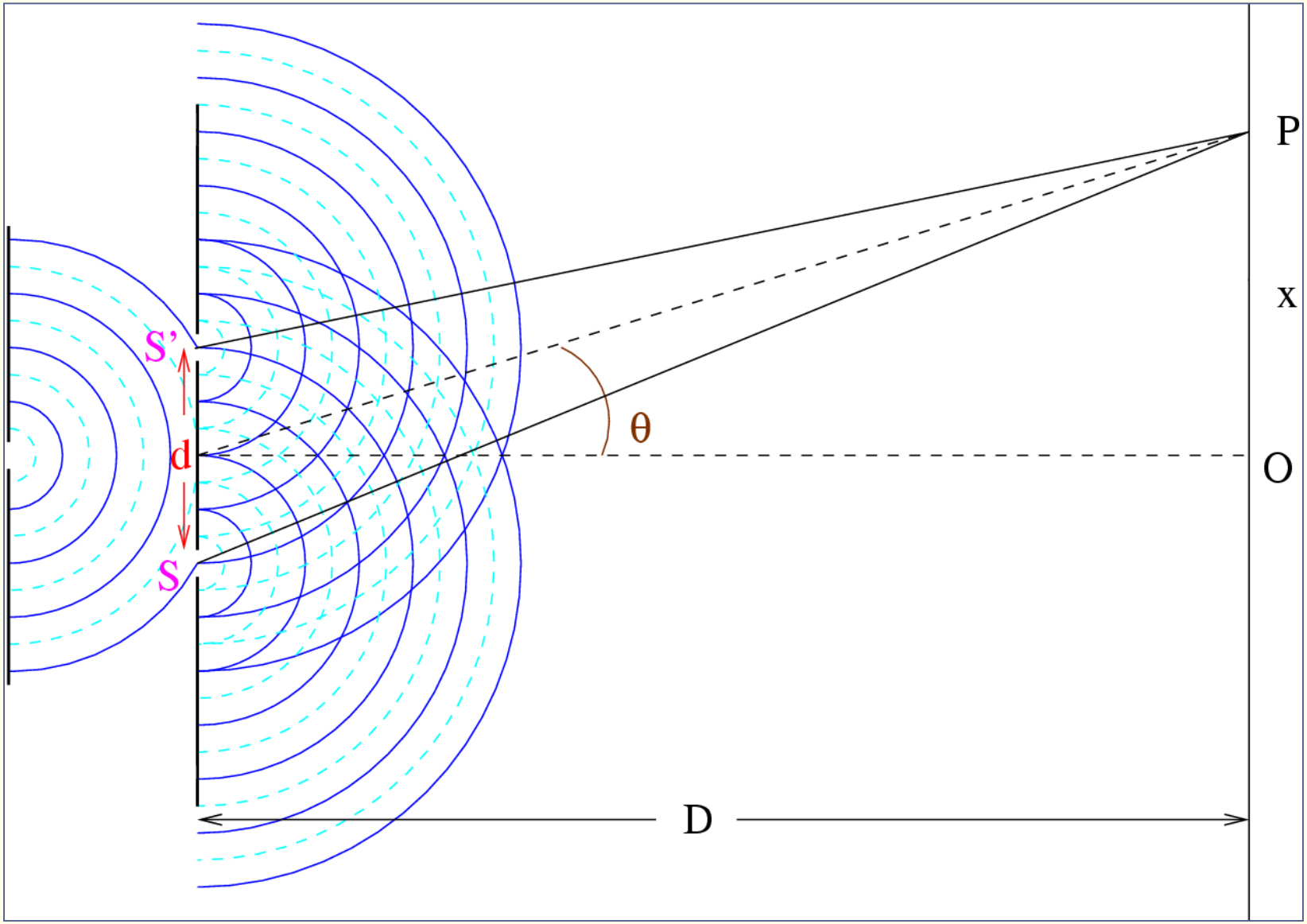
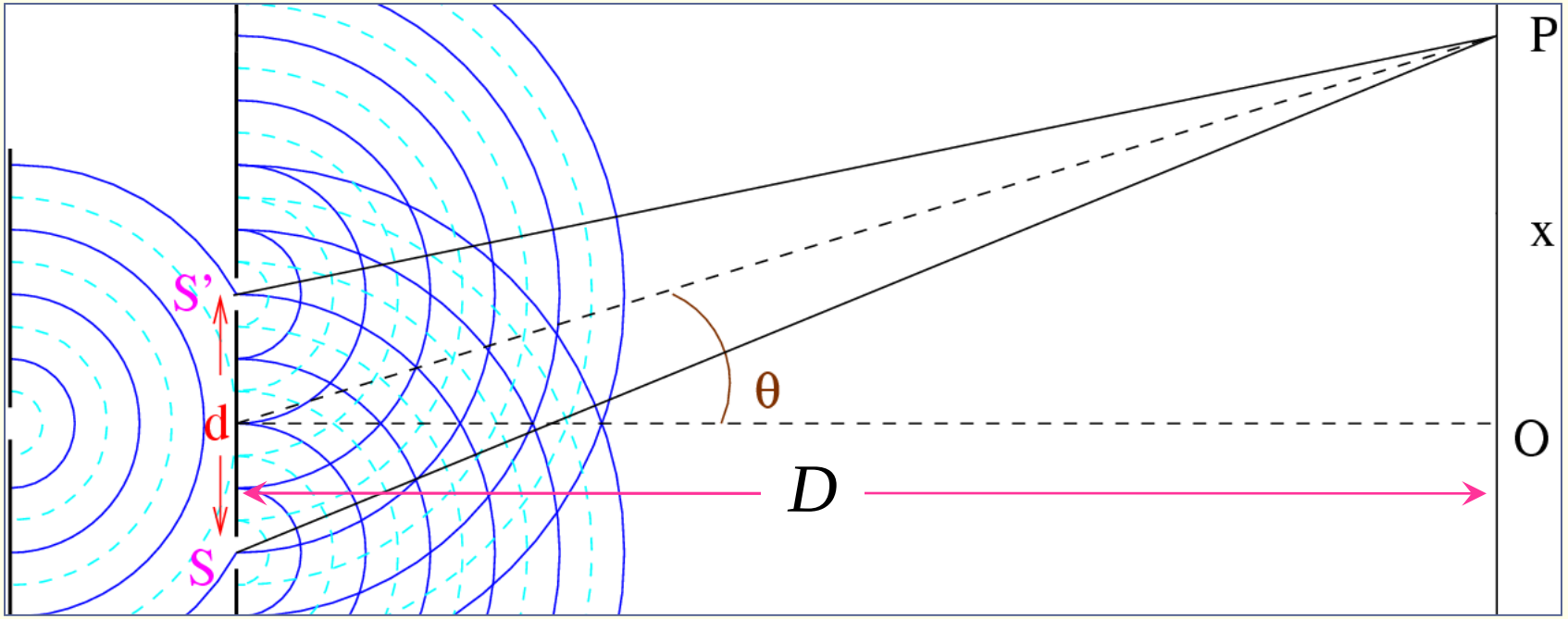


Young's double slit





Path difference: $SP - S'P$

$$= \sqrt{D^2 + \left(x + d/2\right)^2} - \sqrt{D^2 + \left(x - d/2\right)^2}$$

$$D >> x, d$$

Path difference calculation

$$= D\left[1+\frac{\left(x+d/2\right)^2}{D^2}\right]^{1/2} - D\left[1+\frac{\left(x-d/2\right)^2}{D^2}\right]^{1/2}$$

For $1 >> x$

$$\left(1+x\right)^n \approx 1+nx$$

$$= \frac{\left(x+d/2\right)^2 - \left(x-d/2\right)^2}{2D}$$

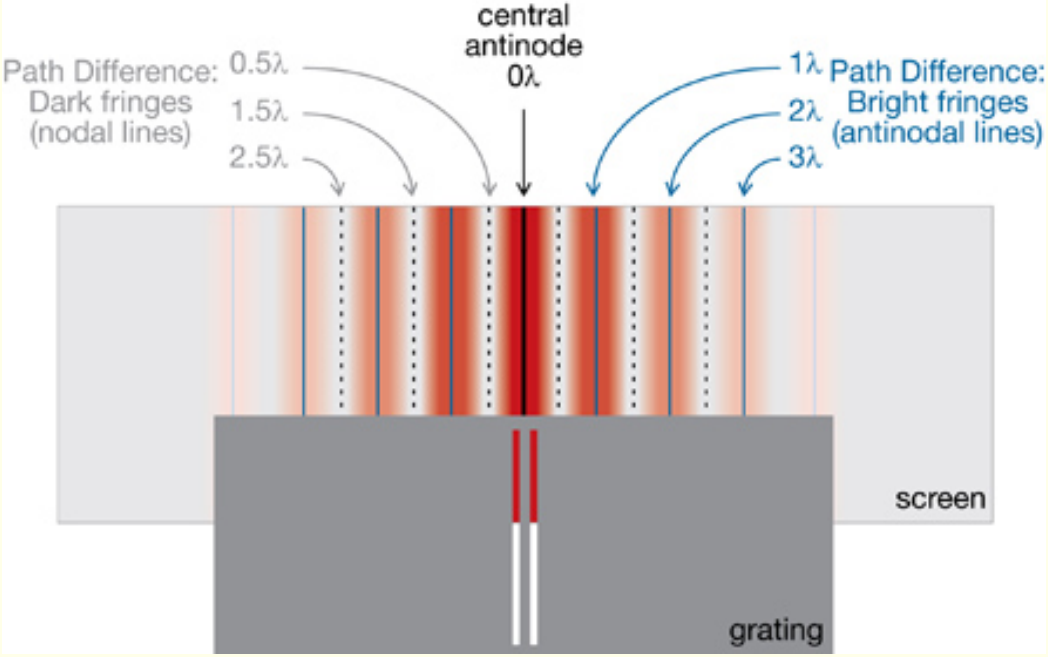
$$= \left[\left(2x\right)d\right]/2D = xd/D$$

Path difference: $SP - S'P = \dfrac{xd}{D}$

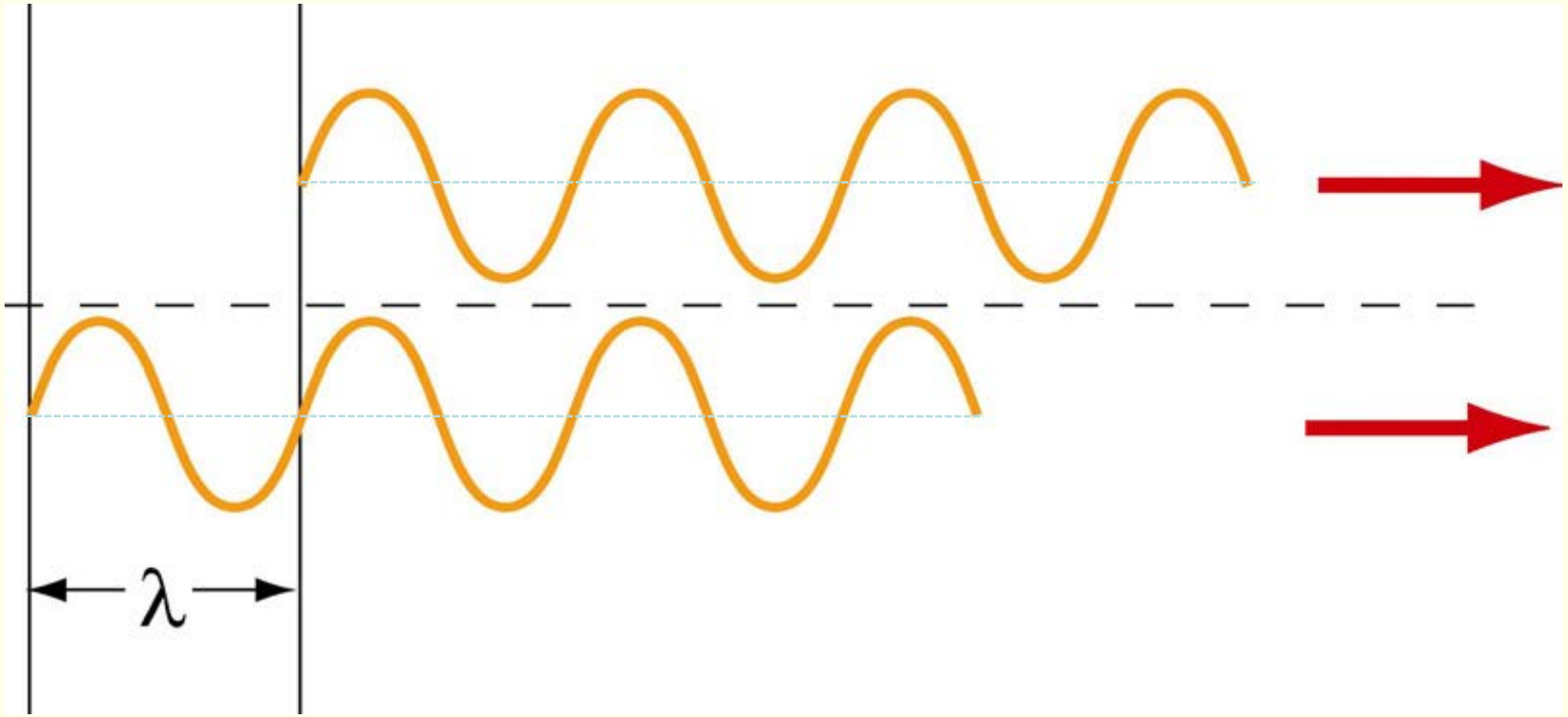
For a bright fringe, $SP - S'P = m\lambda$

m: any integer

For a dark fringe, $SP - S'P = (2m+1)\lambda/2$



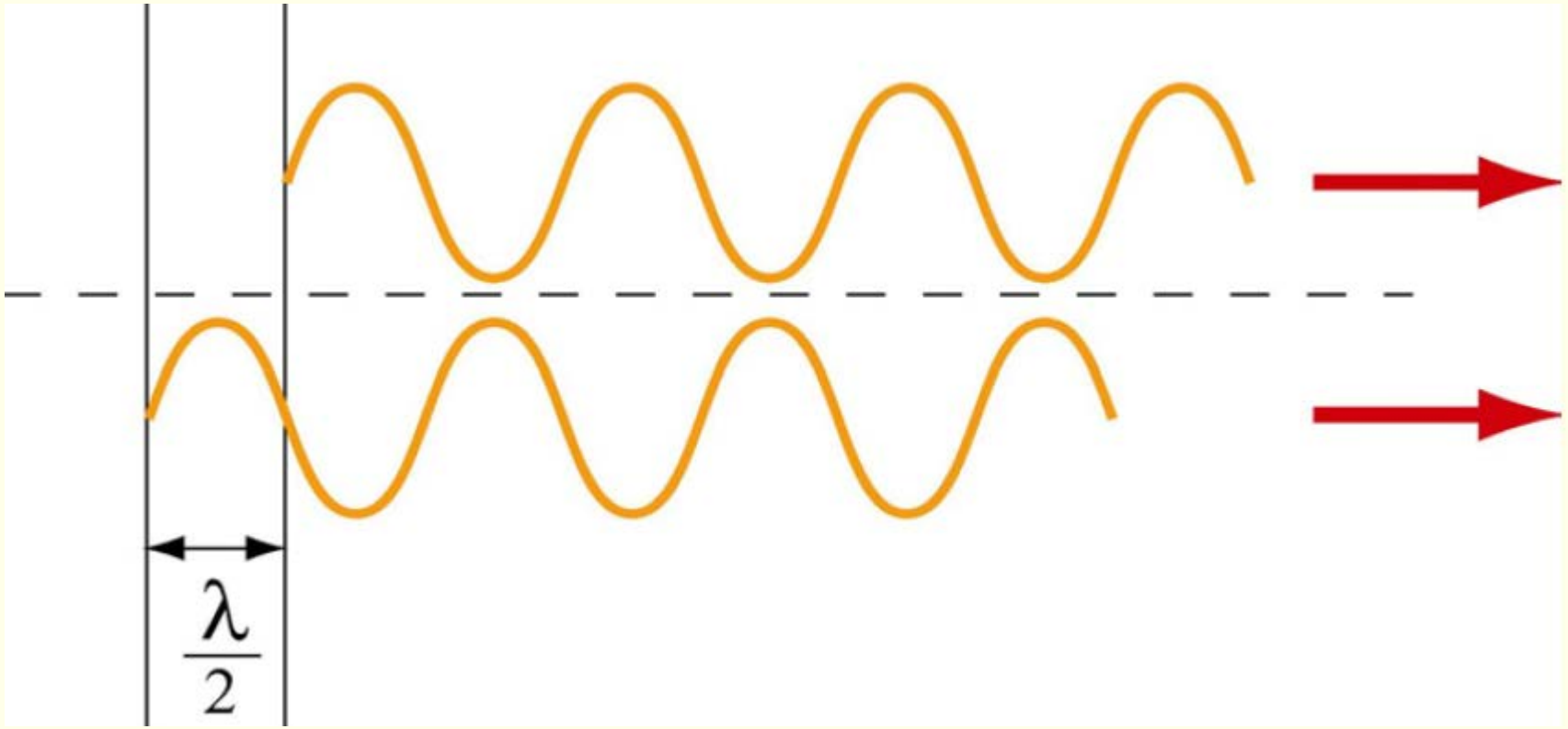
Constructive Interference



Path difference $= m\lambda \quad (m = 1, 2, 3, 4, ...)$

Phase difference $= m\lambda \times \dfrac{2\pi}{\lambda}$

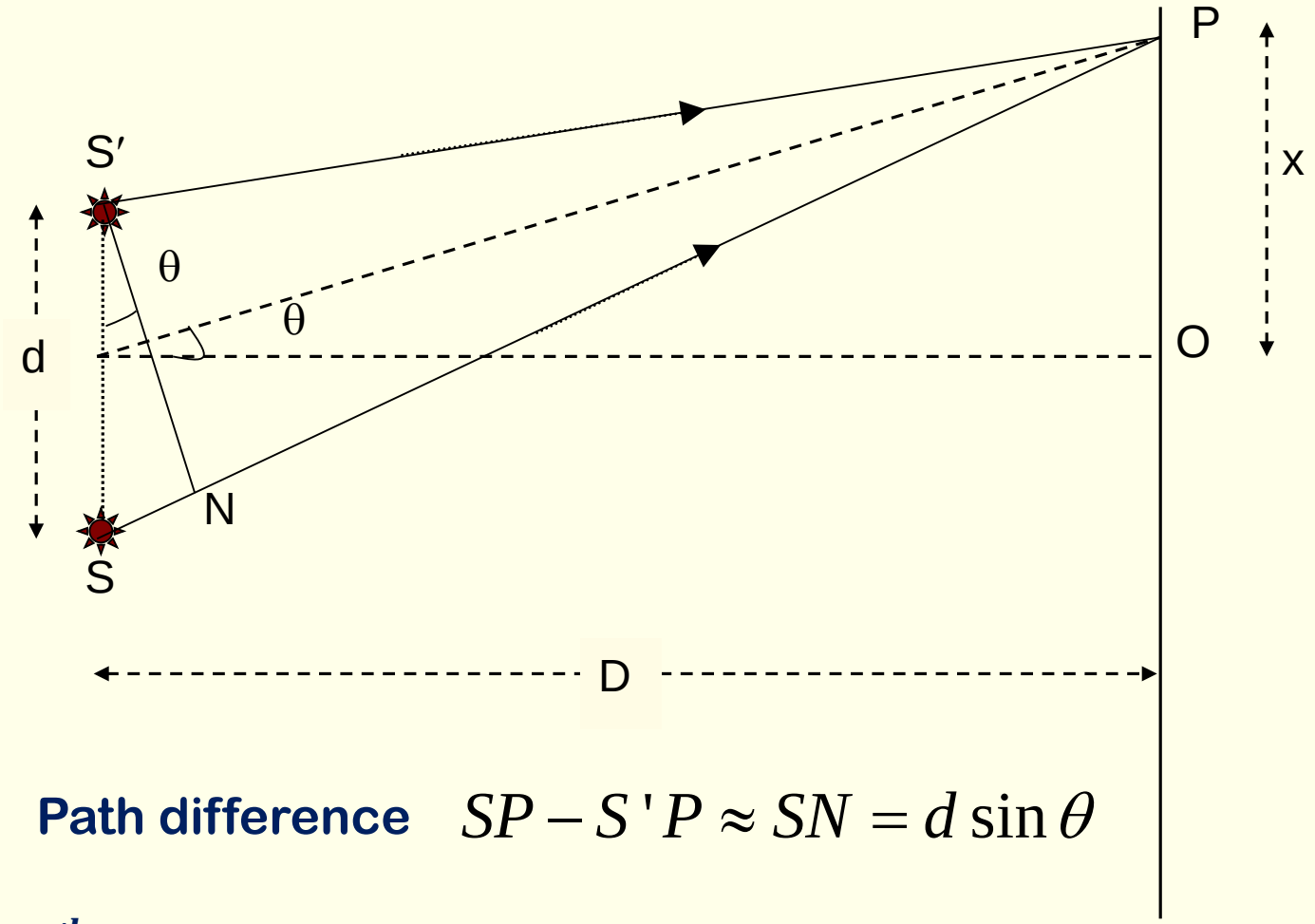
Destructive interference



Path difference $= (2m+1)\dfrac{\lambda}{2} \quad (m = 0,1,2,3,4,....)$

Phase difference $= (2m+1)\dfrac{\lambda}{2} \times \dfrac{2\pi}{\lambda}$

Transverse section –Straight fringes



Path difference $SP - S'P \approx SN = d \sin\theta$

For m^{th} bright fringe the path difference $\Rightarrow$ $d \sin\theta_m = m\lambda$

Path difference

$$SP - S'P \approx SN \approx d \sin\theta_m = m\lambda$$

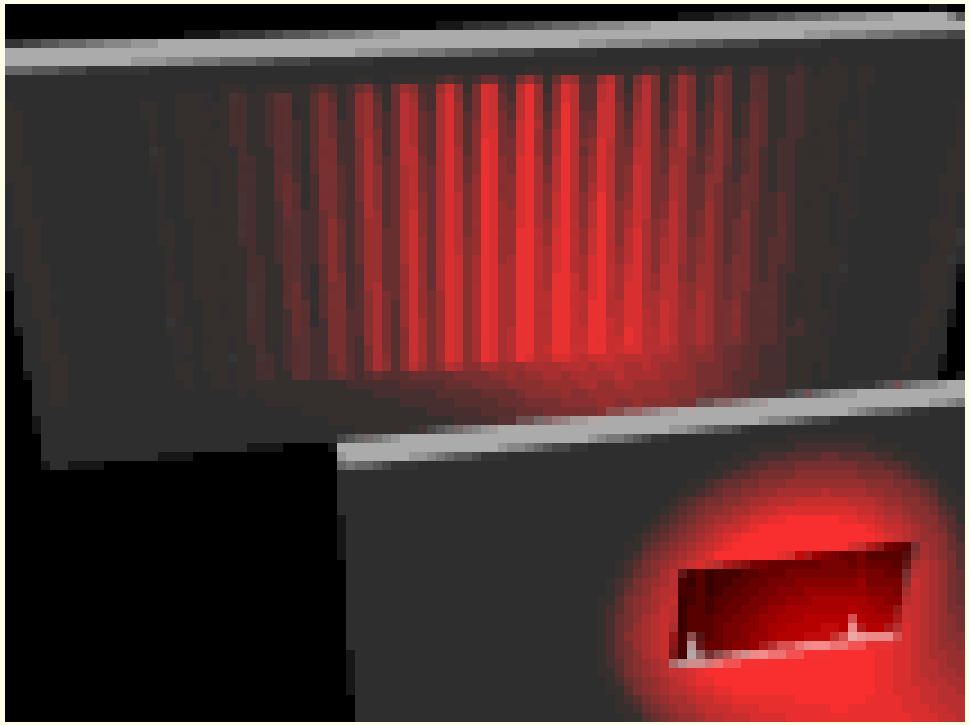
The distance of m^{th} bright fringe from central maxima

$$x_m \approx D \sin\theta_m = D\frac{m\lambda}{d}$$

Fringe separation/ Fringe width $\Delta x = x_m - x_{m-1}$

$$\Delta x = \frac{D\lambda}{d}$$

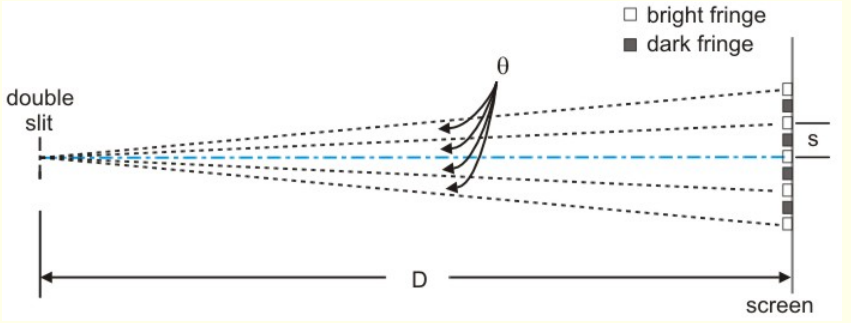
Interference Animation



If the separation between the slits decreases, then

1. **Angular spacing of the fringes increases**

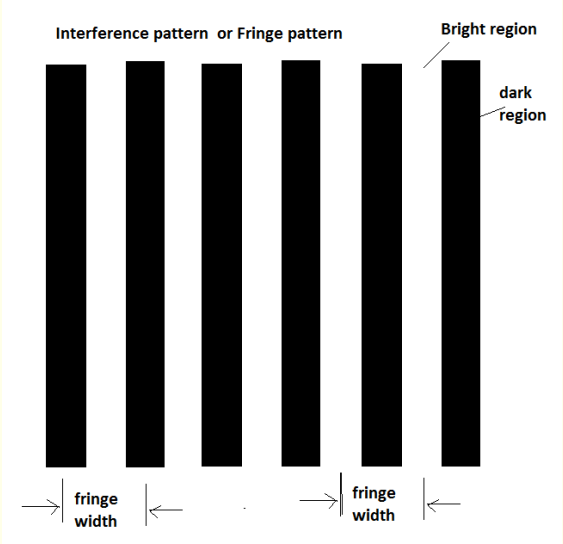
2. **Fringe width increases**



The angular spacing of the fringes, θ, is given by:

$$\theta \approx \frac{\lambda}{d}$$ (where d is the separation between slits)

$$\Delta x = \frac{D\lambda}{d}$$ (Fringe width)



Total irradiance ⇒ $I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\delta$

For two beams of equal irradiance (I_0)

$$I = 2I_0(1+\cos\delta) = 4I_0\cos^2\frac{\delta}{2}$$

$$\left(\delta = \textit{phase difference}\right)$$

Path difference $= d\sin\theta$ ⇒ $\delta = d\sin\theta \times \frac{2\pi}{\lambda}$

Phase difference

$\sin\theta = \frac{x}{D}$ ⇒ $I = 4I_0\cos^2\frac{\pi x d}{\lambda D}$

Visibility of the fringes (V)

$$V \equiv \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}}$$

Maximum and adjacent minimum of the fringe system

Photograph of real fringe pattern for Young's double slit