Wave Optics

Ch-10

Formula Sheet

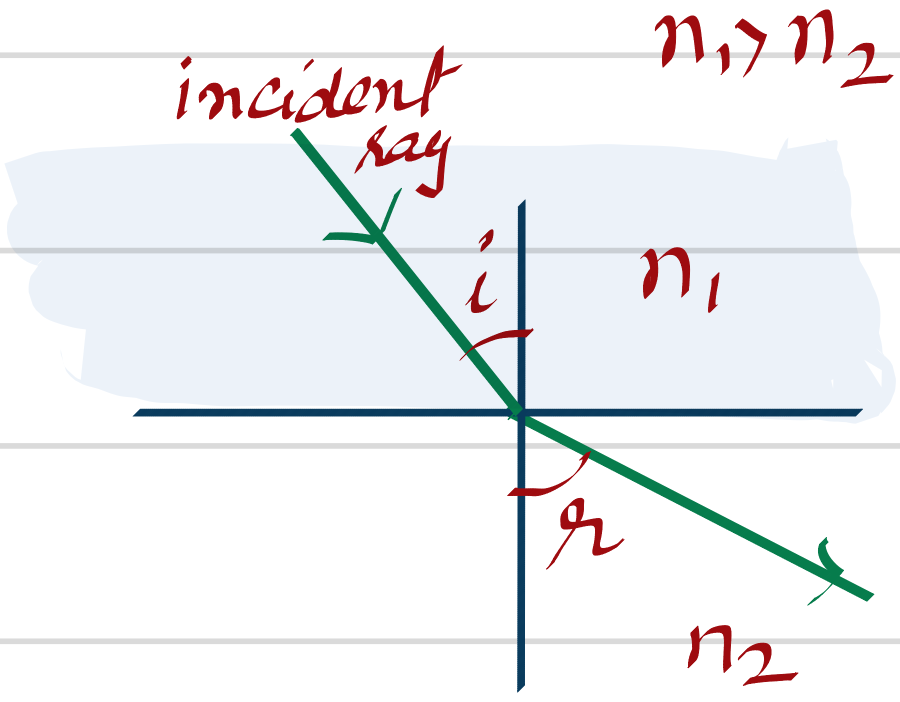
1. Laws of reflection and refraction

(i) For reflection

$$\angle i = \angle r$$

(ii) For refraction (Snell's law)

$$\frac{\sin i}{\sin r} = n_{21} = \frac{n_2}{n_1}$$



$n_{21} \rightarrow$ Refractive index of medium 2 w.r.t. medium 1

Also, when light travels air to another medium

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{c}{v} = \frac{\lambda_1}{\lambda_2}$$

$\lambda \rightarrow$ wavelength

2. Principle of Superposition of waves

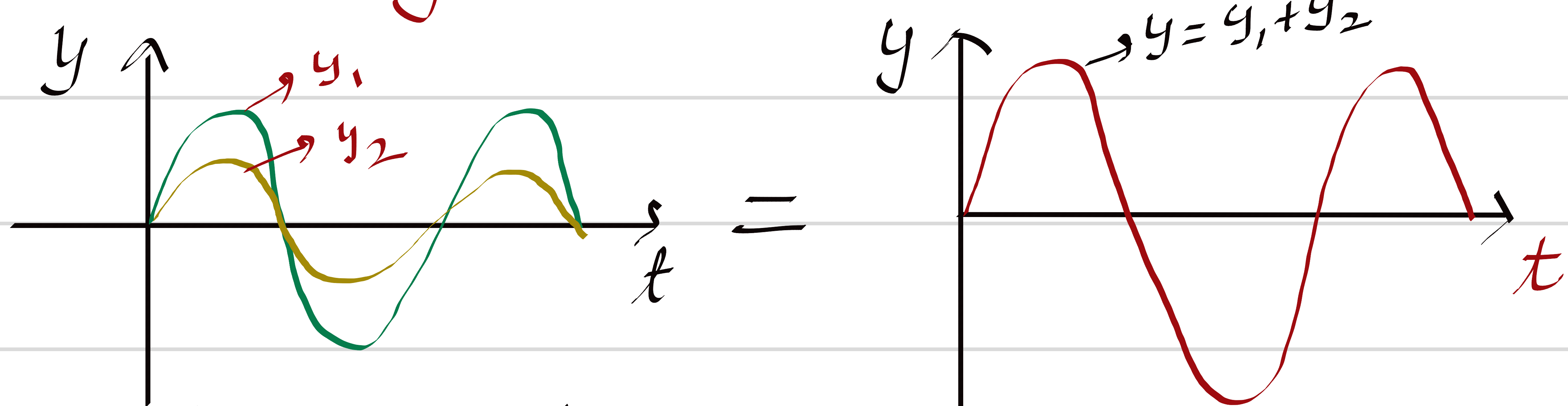
$$y = y_1 + y_2 + \ldots$$

[Algebraic sum]

$y \rightarrow$ displacement of resultant wave

$y_1, y_2, y_3 \ldots$ are individual displacements of superposing waves at any instant of time.

e.g.



Amplitude of Resultant wave

$$R^2 = a_1^2 + a_2^2 + 2a_1a_2\cos\phi$$

a_1 and a_2 are amplitudes of individual waves.

Intensity of Resultant wave (I)

Intensity $\propto$ (amplitude)^2

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$$ [$I \propto a^2$]

$\phi \rightarrow$ phase difference

3. Relation b/w path difference (Δx) and phase difference ($\Delta\phi$)

$$\phi = \frac{2\pi}{\lambda} \times \Delta x$$

$$\Delta x = \frac{\lambda}{2\pi} \times \phi$$

4. Constructive interference [$I_{maximum}$]

(i) Phase difference $\Delta\phi = 2\pi n$ [$n = 0, 1, 2, 3 \ldots$]

(ii) Path difference $\Delta x = n\lambda$

5. Destructive interference [$I_{minimum}$]

(i) Phase difference $\Delta\phi = (2n+1)\pi$ [$n = 0, 1, 2, 3 \ldots$]

(ii) Path difference $\Delta x = (2n+1)\frac{\lambda}{2}$

6. Interference of two waves of intensities I_1 and I_2

$$\frac{I_{max}}{I_{min}} = \frac{(a_1 + a_2)^2}{(a_1 - a_2)^2} = \frac{(\sqrt{I_1} + \sqrt{I_2})^2}{(\sqrt{I_1} - \sqrt{I_2})^2}$$

$I_{max} \rightarrow$ for constructive interference

$I_{min} \rightarrow$ for destructive interference

7. Resultant intensity at any point.

Intensity chages between 0 and 4 times the intensity.

$I = 0$ for min^m intensity

$I = 4I_0$ for max^m intensity

ie. $$I = 4I_0 \cos^2\frac{\phi}{2}$$

8. Young's double slit experiment (YDSE)

(i) For constructive interference

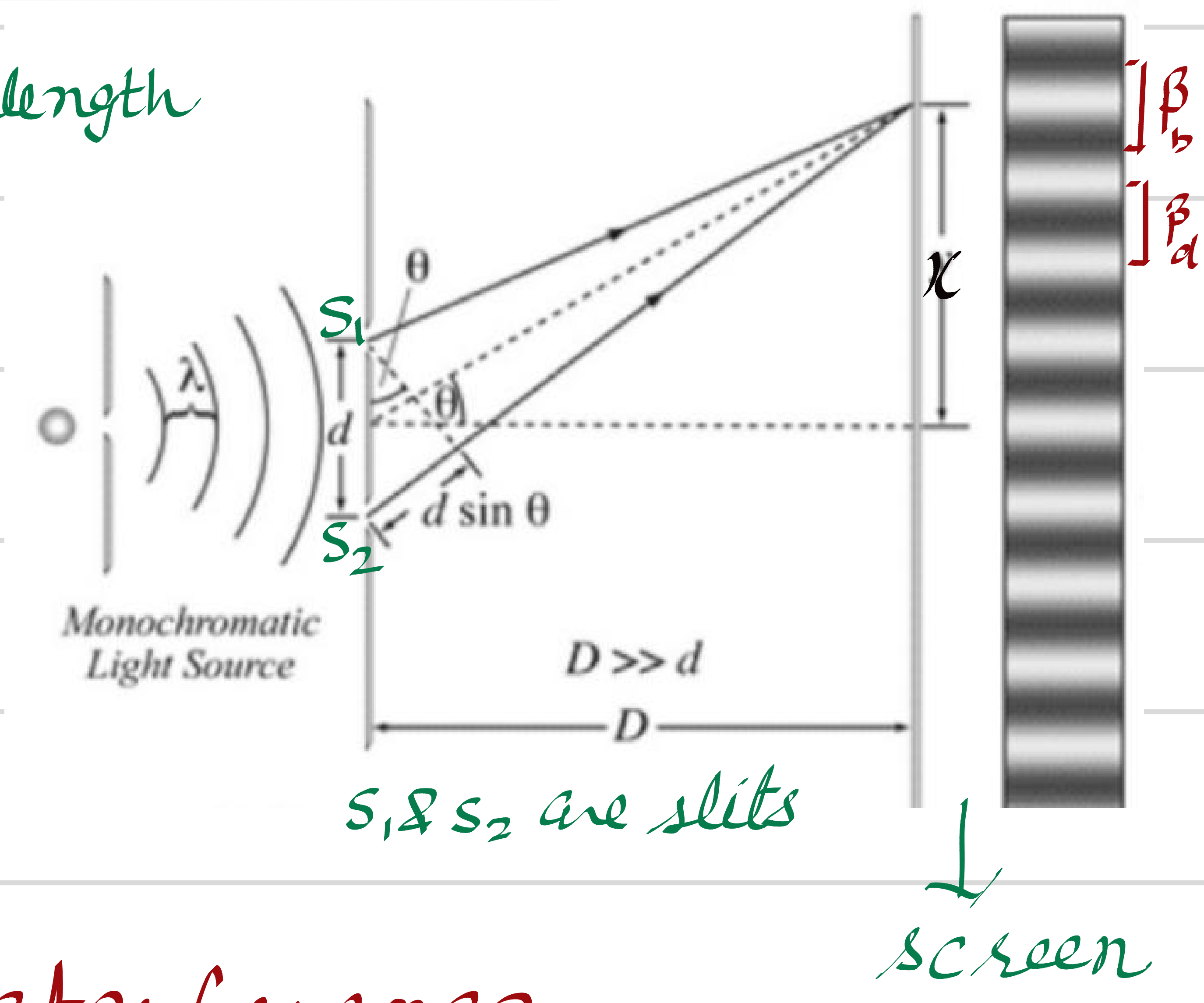
$$\frac{xd}{D} = n\lambda \qquad n = 0, 1, 2, 3 \cdot \cdot \cdot \cdot$$

D → distance b/w slits and screen

$$x = x_n = \frac{nD\lambda}{d}$$

λ → wavelength

distance b/w S_1 & S_2 ← d



Fringe Width (β)

$$\beta_{bright} = \frac{D\lambda}{d}$$

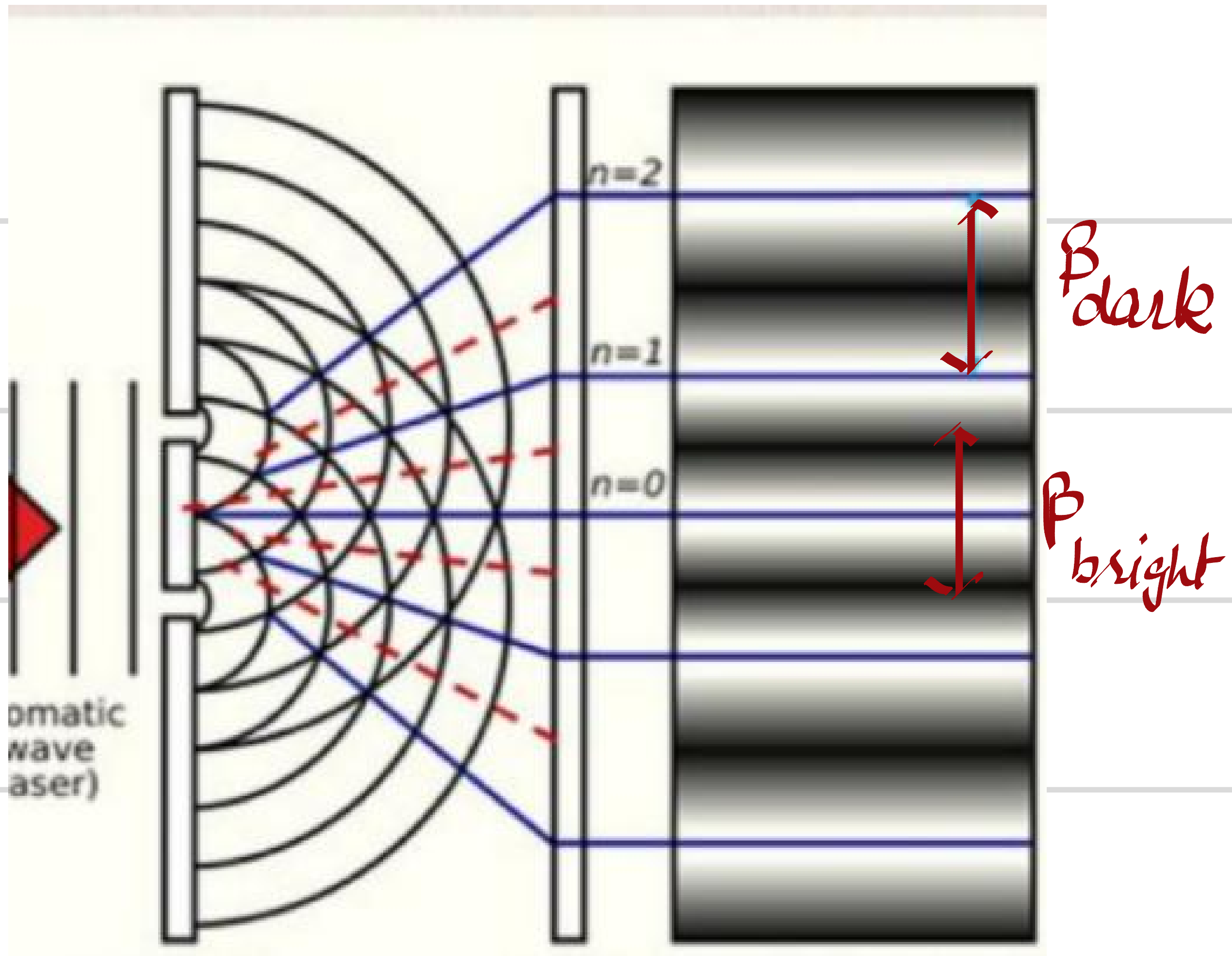
(ii) For destructive interference

$$\frac{xd}{D} = (2n+1)\frac{\lambda}{2}$$

$$x = x_n = (2n+1)\frac{D\lambda}{d} \qquad n = 0, \pm 1, \pm 2, \text{---}$$

Fringe Width (β)

$$\beta_{dark} = \frac{D\lambda}{d}$$



* For YDSE

$$\beta_{bright} = \beta_{dark}$$

9. Young's single slit experiment (YSSE)

(i) Width of central maximum

$$\beta_c = 2\beta = 2\frac{D\lambda}{a}$$ [Linear width]

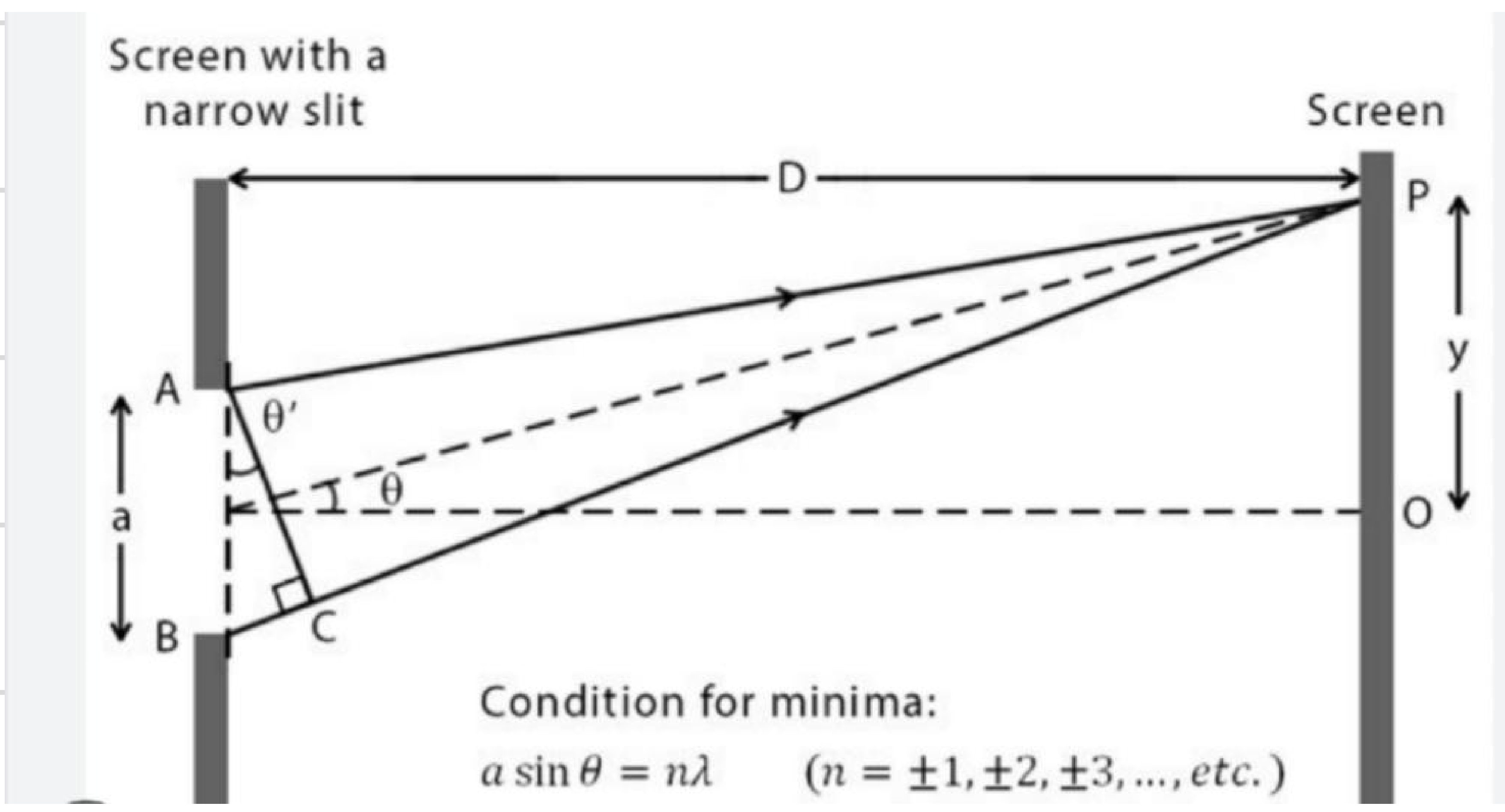
$$2\theta = \frac{\lambda}{a}$$ [Angular width]

(ii) Angular position of nth minimum [dark fringe]

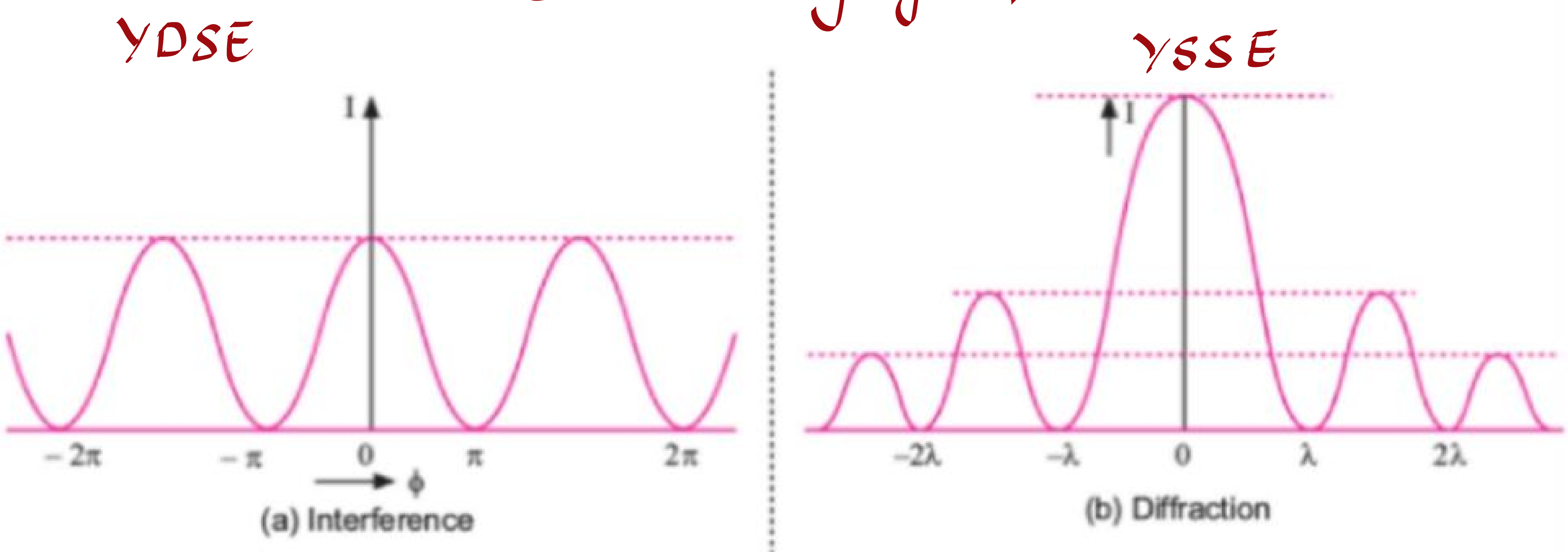
$$\theta_n = \frac{n\lambda}{d}$$ $n = \pm1, \pm2, \pm3 ---$

(iii) Angular position of nth maximum [bright fringe]

$$\theta_n = (2n+1)\frac{\lambda}{2a}$$ $n = \pm1, \pm2, \pm3 ----$



Intensity graph



Intensity Patterns

Differences between interference and diffraction

Interference	Diffraction
(i) It is due to the superposition of two waves coming from two coherent sources.	(i) It is due to the superposition of secondary wavelets originating from different parts of the same wavefront.
(ii) The width of the interference bands is equal.	(ii) The width of the diffraction bands is not the same.
(iii) The intensity of all maxima (fringes) is same.	(iii) The intensity of central maximum is maximum and goes on decreasing rapidly with increase in order of maxima.

Very important relation for conceptual Ques.

(I)
$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$$

(II) For fringe width (β)
$$\frac{\beta_1}{\beta_2} = \frac{n_2}{n_1} = \frac{\lambda_1}{\lambda_2} = \frac{I_1}{I_2} = \frac{a_1^2}{a_2^2}$$

I is intensity and 'a' is amplitude of light wave

n → Refractive index of the medium

v → speed of light in any medium

λ → Wavelength of light wave