Lectures: Physics 3306

Provides an introduction to a wide variety of topics in classical (pre-quantum) physics as a bridge to prepare students for subsequent upper-level courses in physics. The topics covered include thermodynamics, fluid mechanics, mechanical waves, optics, radiation, electromagnetic phenomena, atoms, and laboratory techniques. Prerequisites: C- or better in PHYS 1106; and in PHYS 1304 or PHYS 1308.

Saptaparna Bhattacharya

April 27th, 2026

Based on Simon Dalley's lectures taught in Spring 2025

Labs

Lectures

Schedule

No class

Month	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
January	19	20	21 ✅	22	23 ✅	24	25
	26 ❄️🌨️❄❄❄	27	28 ❄️🌨️❄❄❄	29	30 ✅	31	1
February	2 ✅	3	4 ✅	5	6 ✅	7	8
	9 ✅	10	11 HWB due ✅	12	13 ✅	14	15
	16 ✅	17	18 ✅	19	20 HWC due ✅	21	22
	23 Hegi Center ✅	24	25 HWD due ✅	26	27 ✅	28	1
March	2 ✅	3	4 HWE due	5	6 ✅	7	8
	9 ✅	10	11	12	13 Midterm	14	15
	16	17	18	19	20	21	22
	23 ✅	24	25	26	27 ✅	28	29
April	30 Lecture 11 ✅	31	1 HWF due	2	3	4	5

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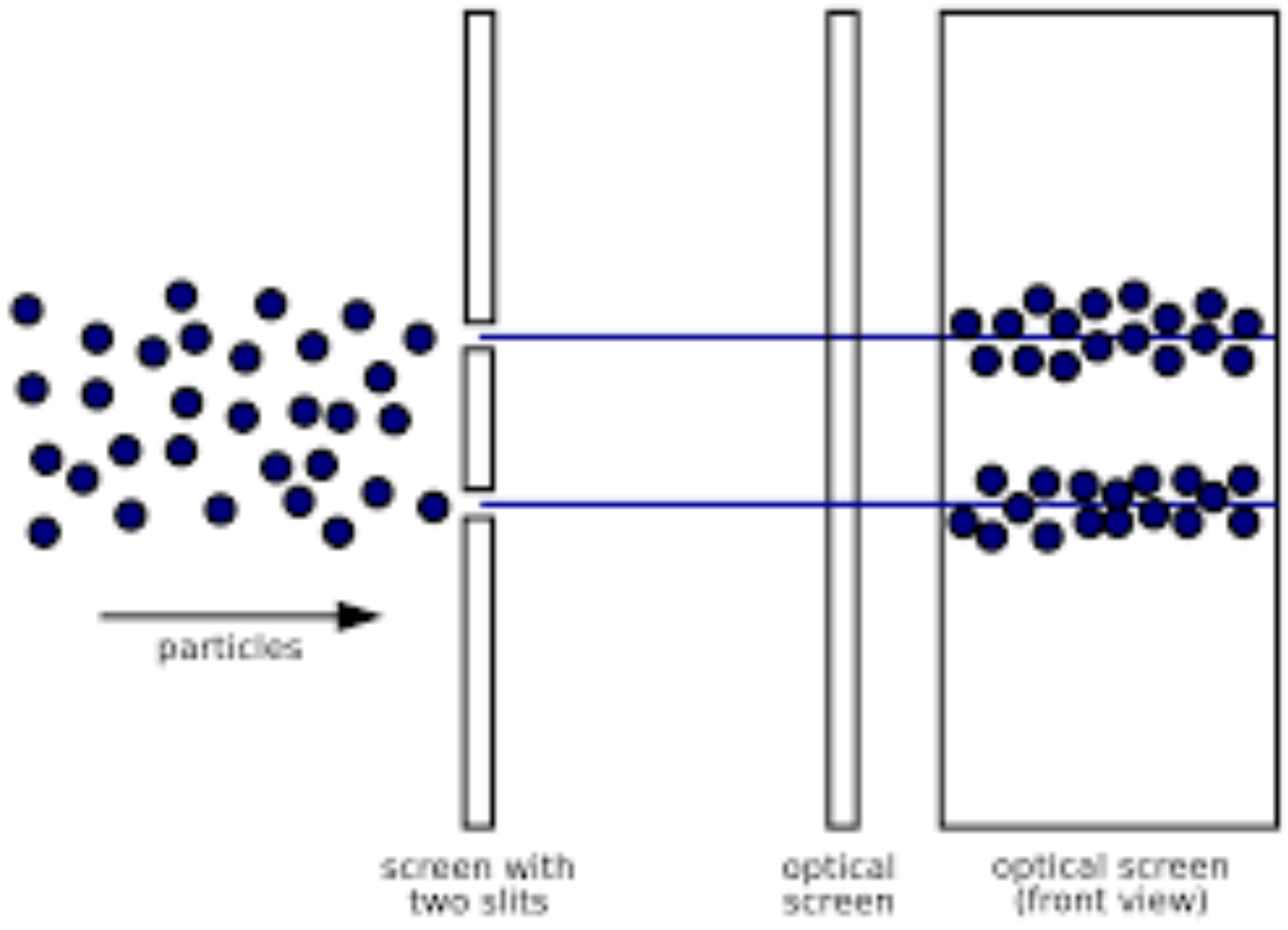
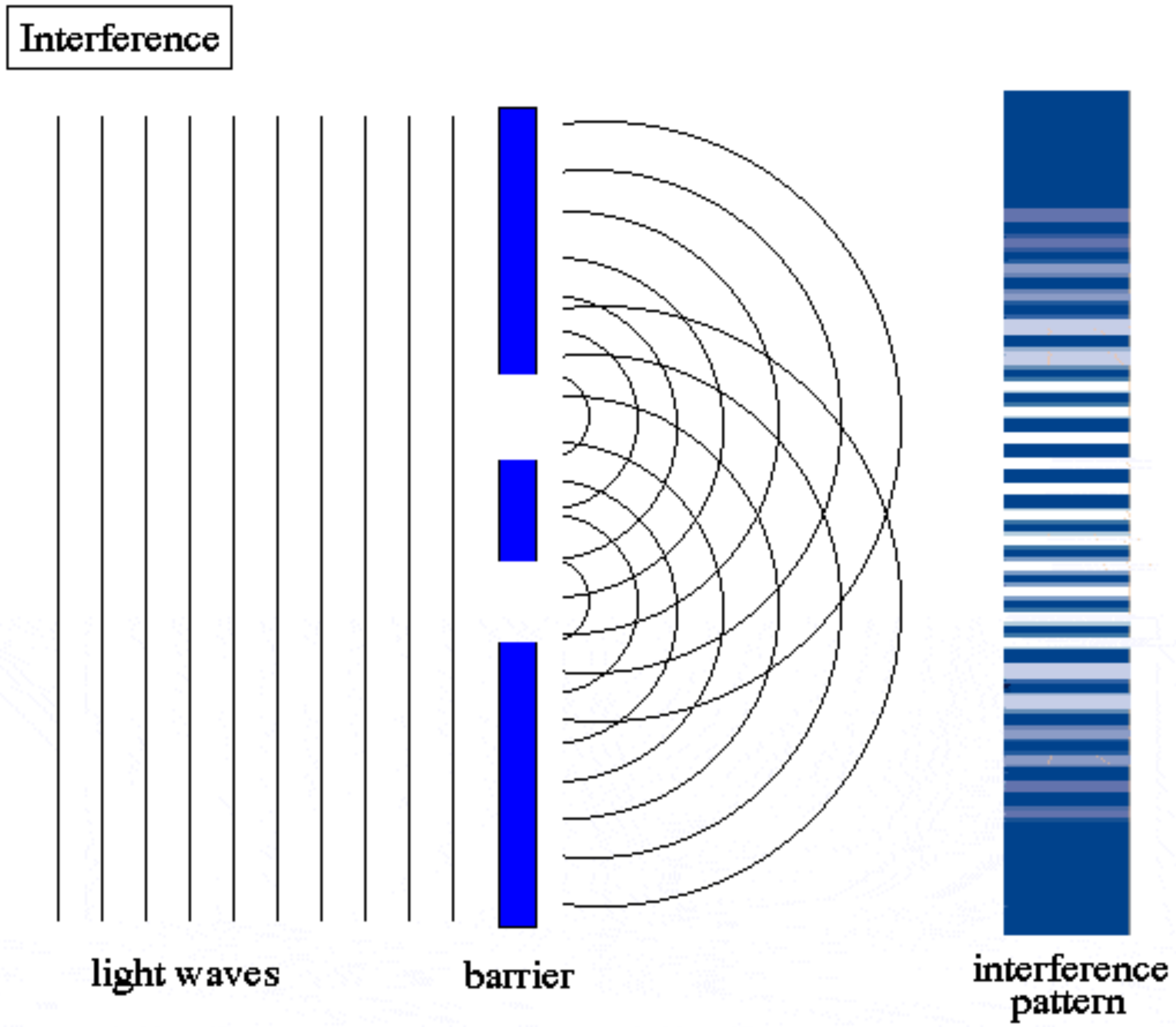
Month	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
April	6 Midterm 2 ✅	7	8 HWG due	9	10 Lecture 15 ✅	11	12
	13 Lecture 16 ✅	14	15 HWH due	16	17 Lecture 17 ✅	18	19
	20 Lecture 18 ✅	21	22 HWI due	23	24 Lecture 19	25	26
May	27 Lecture 20	28	29 HWJ due	30	1 Lecture 21	2	3
	4 Lecture 22	5 Lecture 23	6	7	8	9	10



Halliday & Resnick: 35.1-35.3


Interference
light waves
barrier
interference
pattern

Key concepts: Refraction

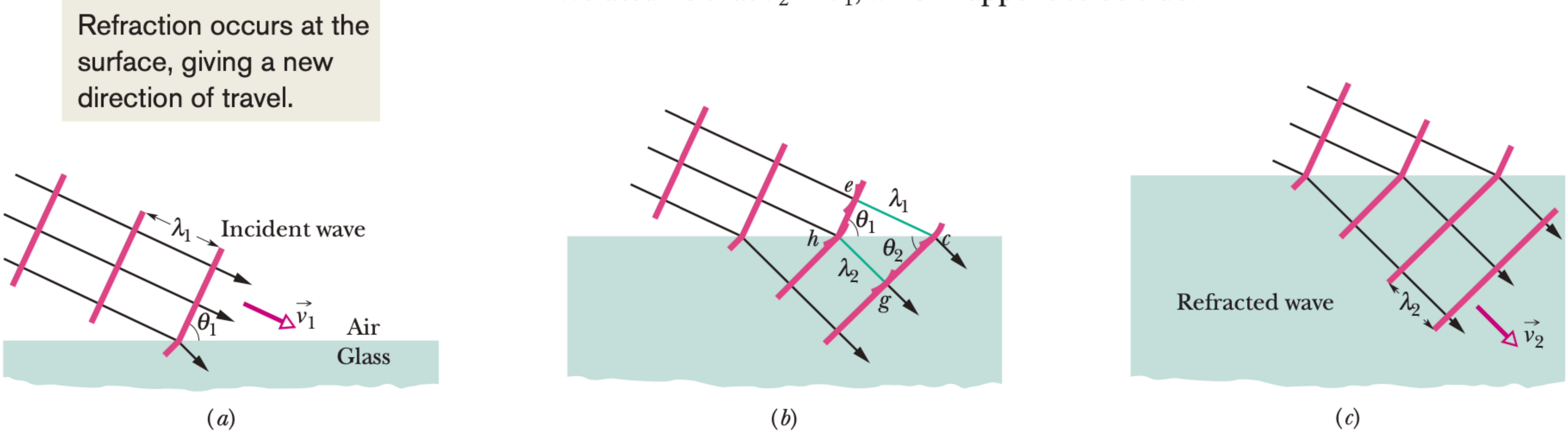


Figure 35-3 The refraction of a plane wave at an air–glass interface, as portrayed by Huygens' principle. The wavelength in glass is smaller than that in air. For simplicity, the reflected wave is not shown. Parts (*a*) through (*c*) represent three successive stages of the refraction.

$$\frac{\lambda_1}{\lambda_2} = \frac{v_2}{v_1}$$

$$\sin\theta_1 = \frac{\lambda_1}{hc}, \sin\theta_2 = \frac{\lambda_2}{hc}$$

Key concepts: Intensity in double slit interference

- $E_1 = E_0 \sin \omega t$
- $E_1 = E_0 \sin(\omega t + \phi)$
- Intensity:
  - $I = 4I_0 \cos^2 \frac{1}{2}\phi$
  - $\phi = \frac{2\pi d}{\lambda} \sin \theta$
  - Condition for maxima: $d \sin \theta = m\lambda \; (m = 0,1,2)$
  - Condition for minima: $d \sin \theta = (m + \frac{1}{2})\lambda \; (m = 0,1,2)$

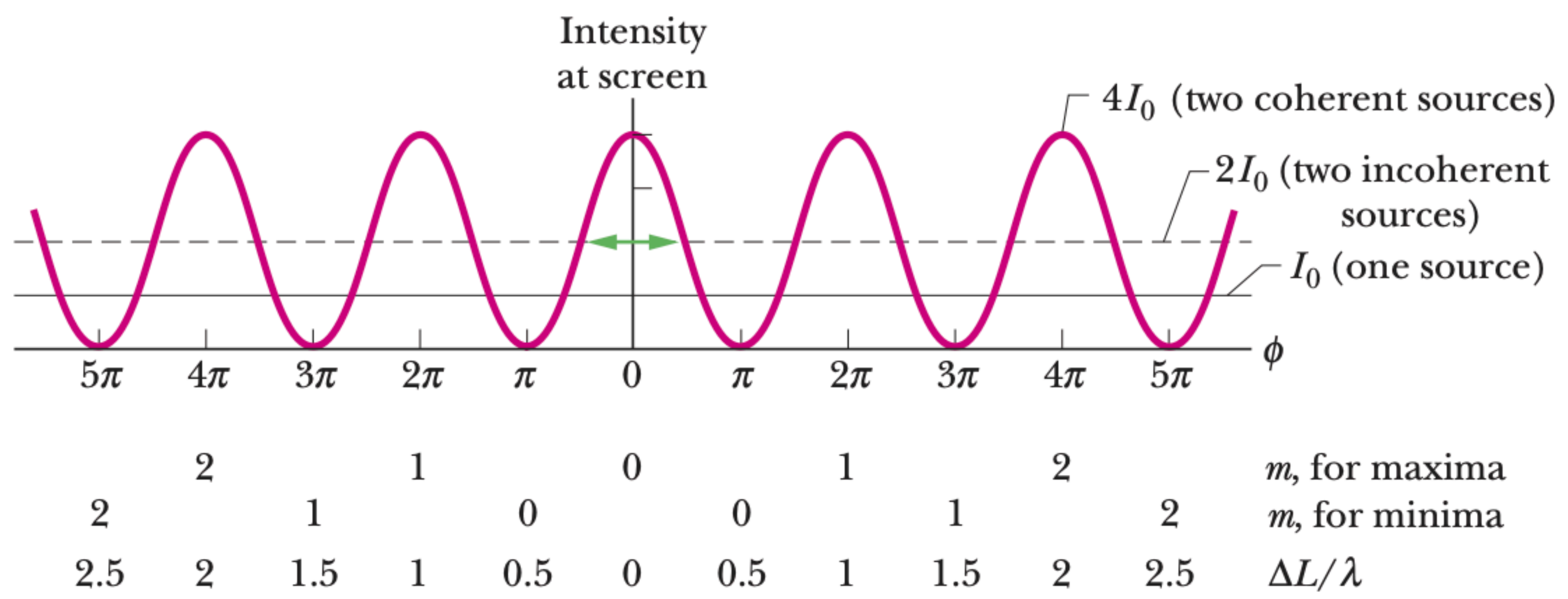


Figure 35-12 A plot of Eq. 35-22, showing the intensity of a double-slit interference pattern as a function of the phase difference between the waves when they arrive from the two slits. I_0 is the (uniform) intensity that would appear on the screen if one slit were covered. The average intensity of the fringe pattern is $2I_0$, and the *maximum* intensity (for coherent light) is $4I_0$.

What is the correct expression for the index of refraction in terms of wave speed v and wavelength λ?

a) $v \lambda$

b) v / λ

c) λ / v

d) c / v

e) $v \lambda / c$

f) v / c

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d) c / v

e) $v \lambda / c$

f) v / c

$$n = c/v$$

Which of these is Snell's law?

a) $n_1 \sin \theta_2 = n_2 \sin \theta_1$

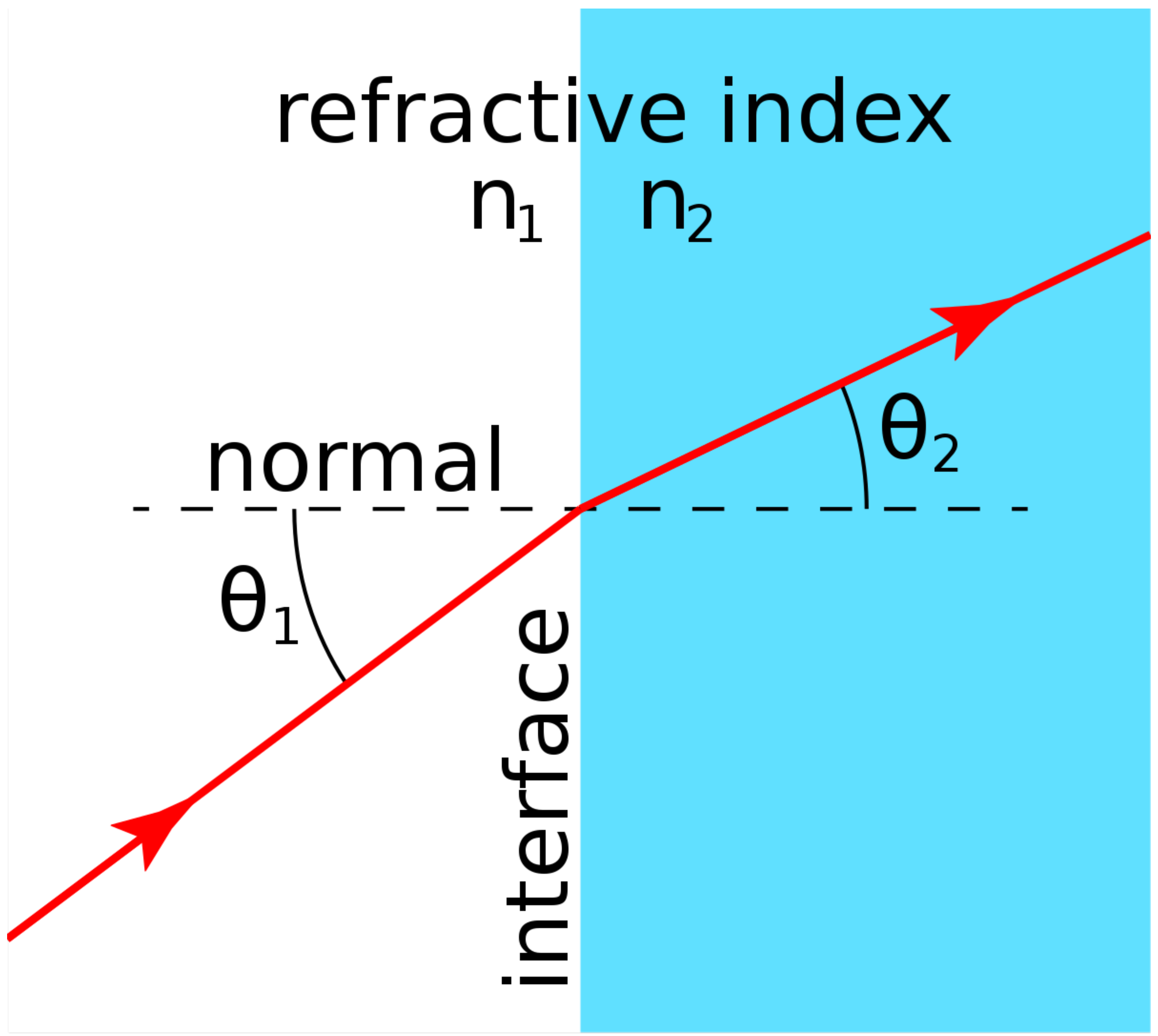
b) $n_1 \sin \theta_1 = n_2 \sin \theta_2$

c) $n_1 \tan \theta_2 = n_2 \tan \theta_1$

d) $n_1 \tan \theta_1 = n_2 \tan \theta_2$

e) $n_1 \cos \theta_2 = n_2 \cos \theta_1$

f) $n_1 \cos \theta_1 = n_2 \cos \theta_2$



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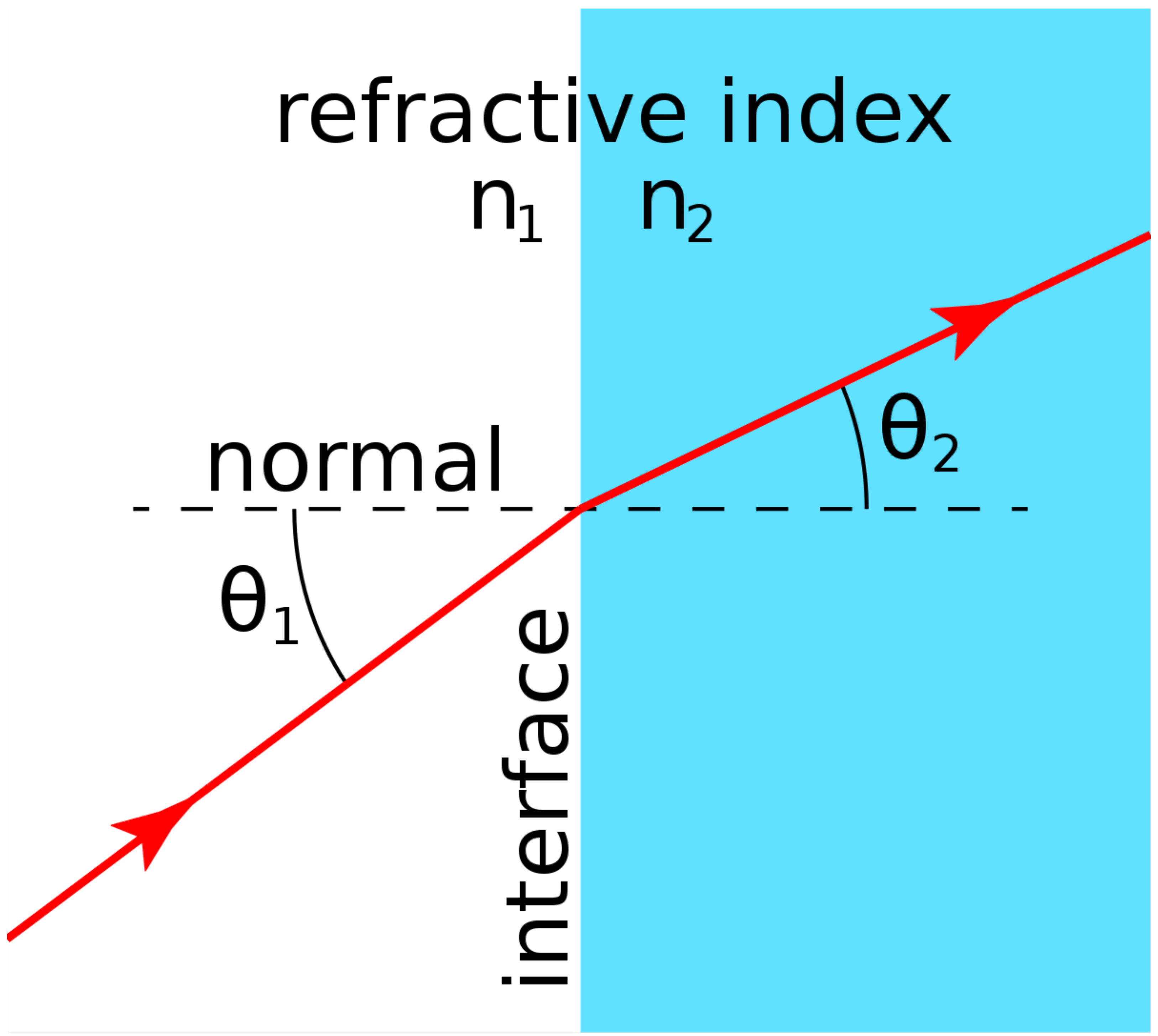

Which of the following are a coherent source of electromagnetic waves?

a)The Sun

b)A laser

c)An incandescent light bulb (now illegal)

d)A wavefront

e)A monochromatic source

f)Double slits illuminated by a laser

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The Correct Options:

- **b) A laser:** This is the quintessential coherent source. It operates via stimulated emission, meaning the emitted photons are identical in frequency, direction, and phase, resulting in highly coherent light.

- **f) Double slits illuminated by a laser:** According to Huygens' principle, the two slits act as secondary point sources. Because they are driven by the same coherent primary wavefront (the laser), the light emerging from both slits maintains a strict, constant phase relationship. This makes them perfectly coherent with respect to one another, which is required to produce a stable interference pattern.

Interference of waves can occur

a)Only with electromagnetic waves

b)With any kind of wave

c)Only with linear waves (superposition)

d)I am not sure…

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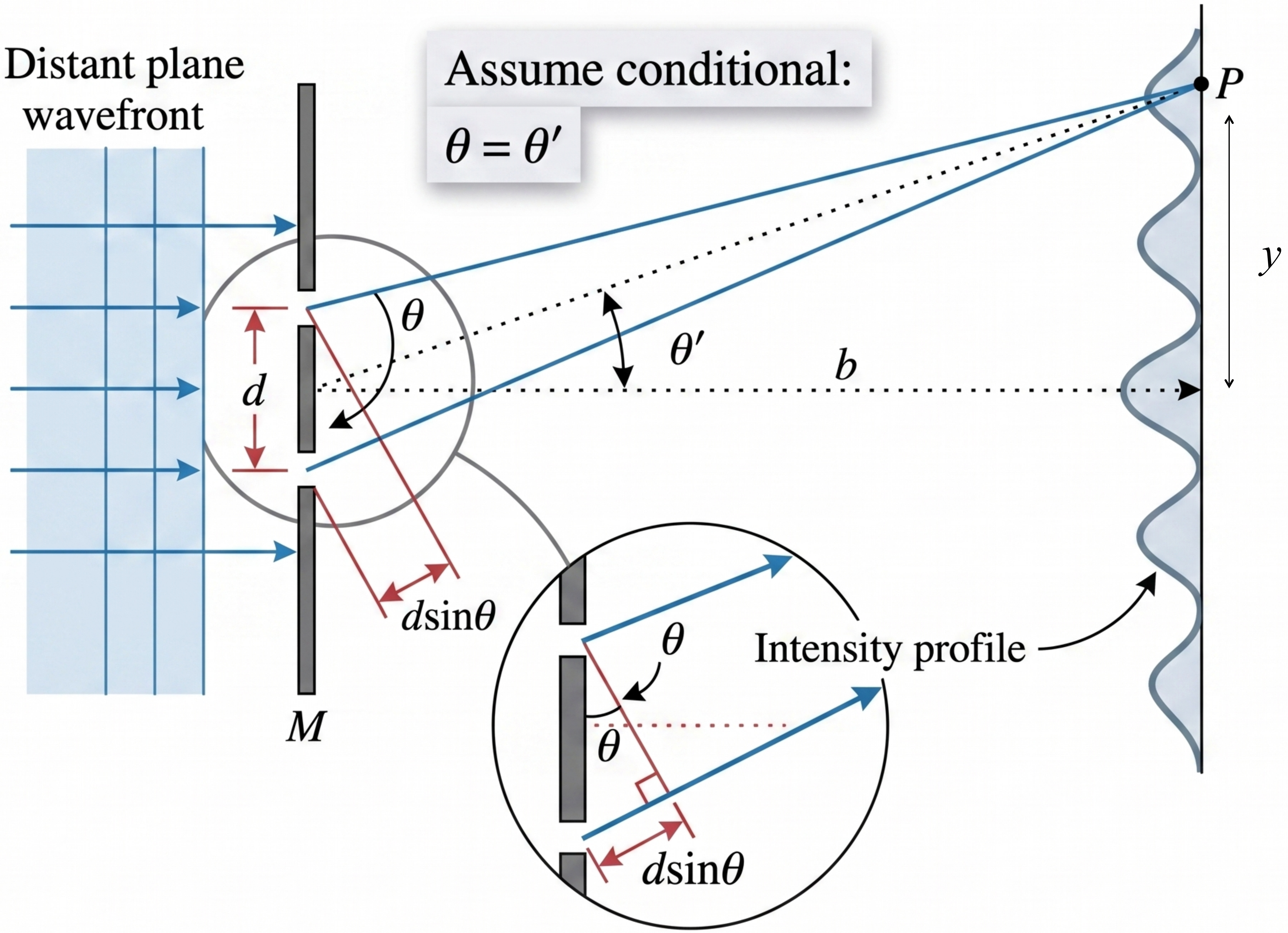
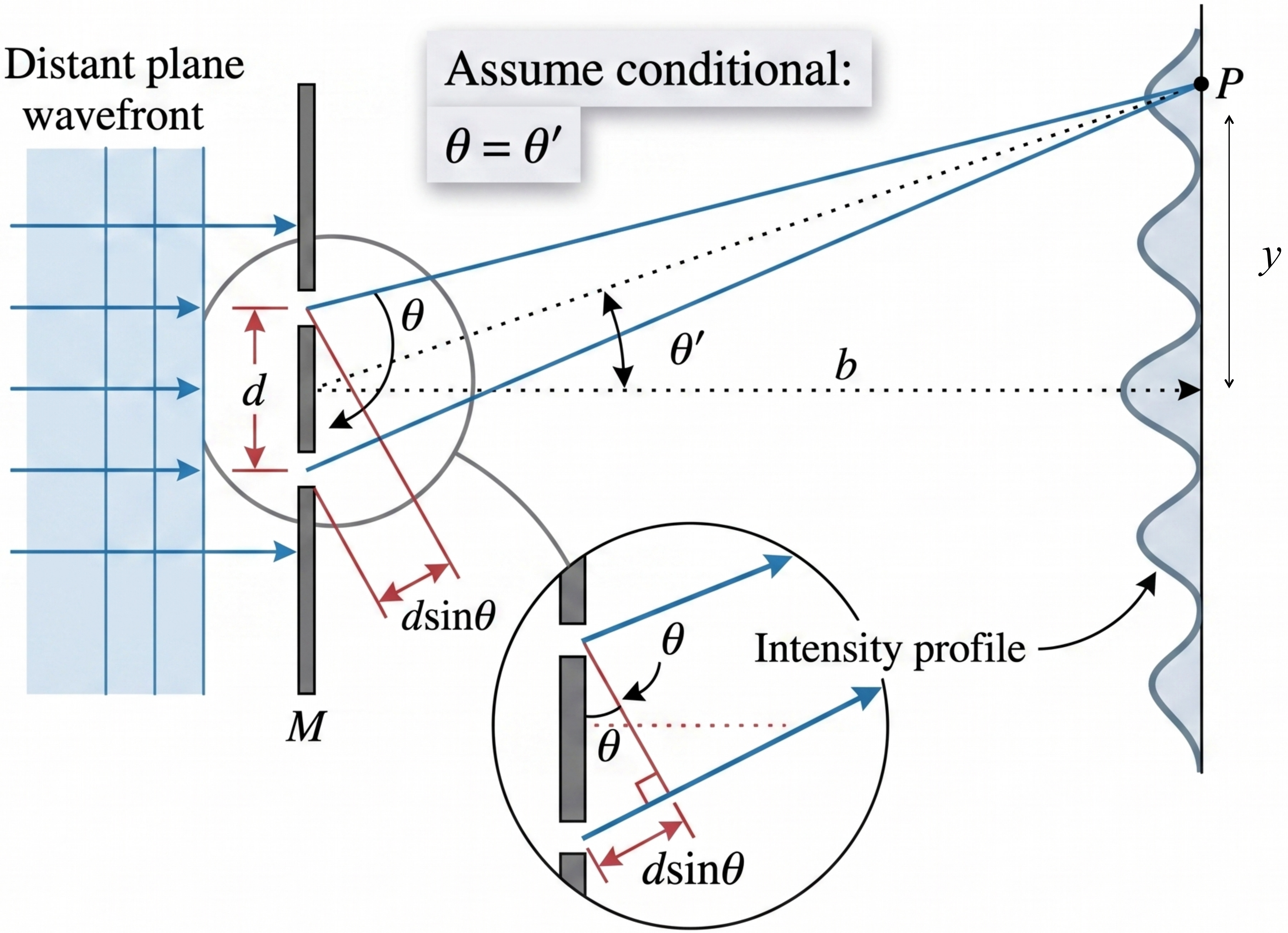
Key Assumption: $b \gg d$



Why is $\theta = \theta'$ in this diagram?

Key Assumption: $b \gg d$



Why is $\theta = \theta'$ in this diagram?

Similar triangles for large b

The core of this problem lies in the **far-field approximation**, which is explicitly pointed out at the top left of the diagram with the text: **Key Assumption:** $b \gg d$.

This means the distance to the screen (b) is extremely large compared to the distance between the two slits (d). Here is a step-by-step breakdown of why this assumption allows us to conclude that $\theta \approx \theta'$.

1. The Geometry of θ' (The Central Ray)

Let's assume the central point on the screen (directly across from the midpoint of the slits) is at a height of $y = 0$. Let's say point P is at some height y on the screen.

If we look at the right triangle formed by the central axis, the screen, and the path to point P, we can define the angle θ' using trigonometry:

$$\tan(\theta') = \frac{y}{b} \tag{1}$$

2. The Geometry of θ (The Bottom Slit Ray)

Now, let's look at the bottom slit. It is located at a distance of $d/2$ below the central axis. Therefore, the vertical distance from this bottom slit to point P is $y + \frac{d}{2}$.

The right triangle formed by the bottom slit's path to point P gives us the angle θ:

$$\tan(\theta) = \frac{y + \frac{d}{2}}{b} = \frac{y}{b} + \frac{d}{2b} \tag{2}$$

3. Applying the Assumption ($b \gg d$)

Because the screen is vastly further away than the tiny distance between the slits (b is much, much larger than d), the fraction $\frac{d}{2b}$ becomes an infinitesimally small number—so close to zero that it becomes negligible in our calculations.

Because $\frac{d}{2b} \approx 0$, our equation for the bottom ray simplifies:

$$\tan(\theta) \approx \frac{y}{b} \tag{3}$$

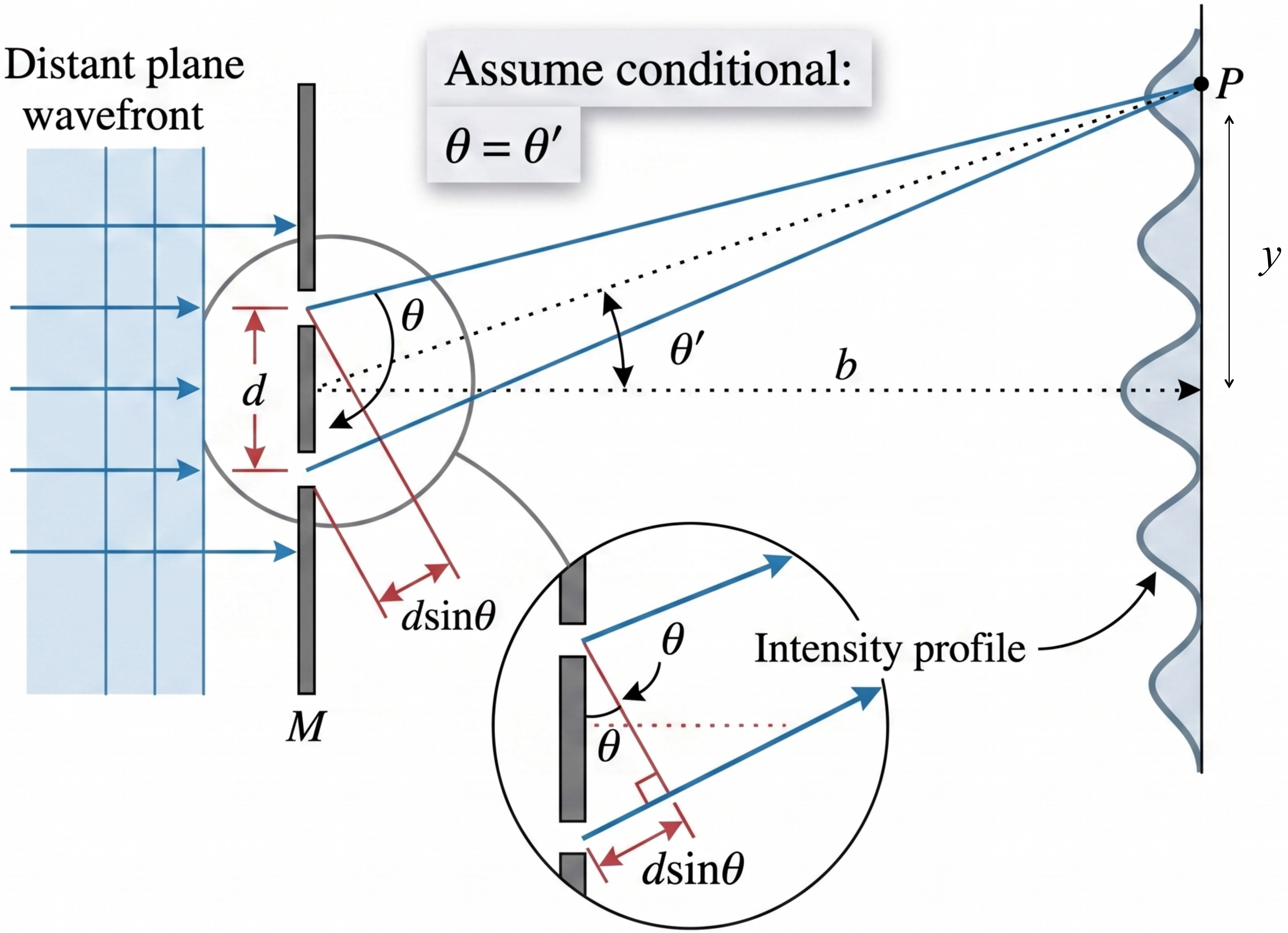
4. The Conclusion

Since $\tan(\theta') = \frac{y}{b}$ and $\tan(\theta) \approx \frac{y}{b}$, it logically follows that:

$$\tan(\theta) \approx \tan(\theta') \tag{4}$$

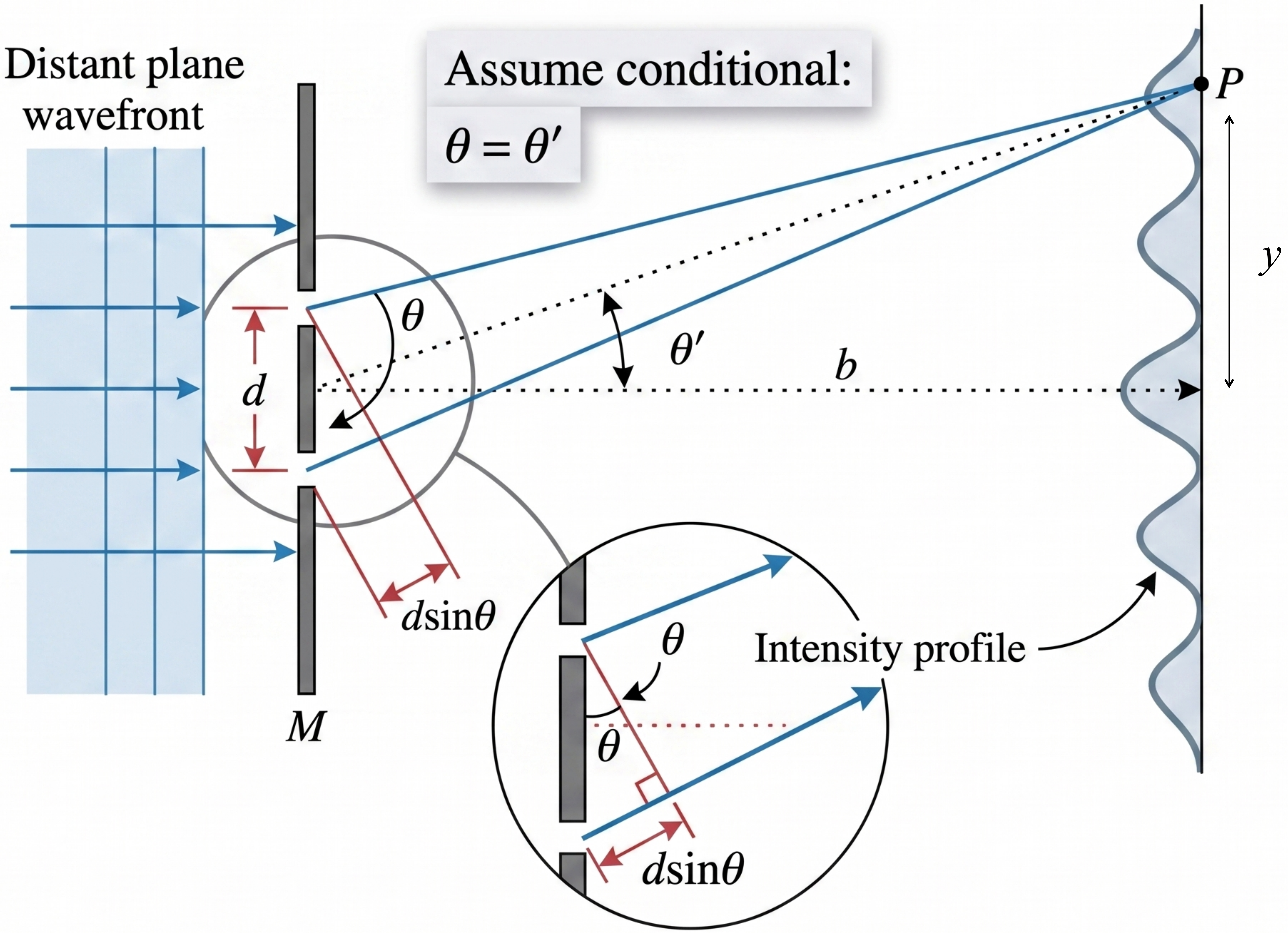
$$\theta \approx \theta' \tag{5}$$

Key Assumption: $b \gg d$



Why is $d \sin \theta = 2\lambda$ in this diagram?

Key Assumption: $b \gg d$



Why is $d \sin \theta = 2\lambda$ in this diagram?

Sine = opp/hyp and n = 2 constructive interference

1. Why is $d \sin \theta = 2\lambda$ at point P in this diagram?

In a double-slit interference setup, the path difference between the light rays from the two slits determines whether constructive or destructive interference occurs at a given point on the screen. The path difference is geometrically given by $\Delta L = d \sin \theta$.

For constructive interference (a bright fringe or intensity maximum), the path difference must be an integer multiple of the wavelength:

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

where $m = 0, \pm 1, \pm 2, \ldots$

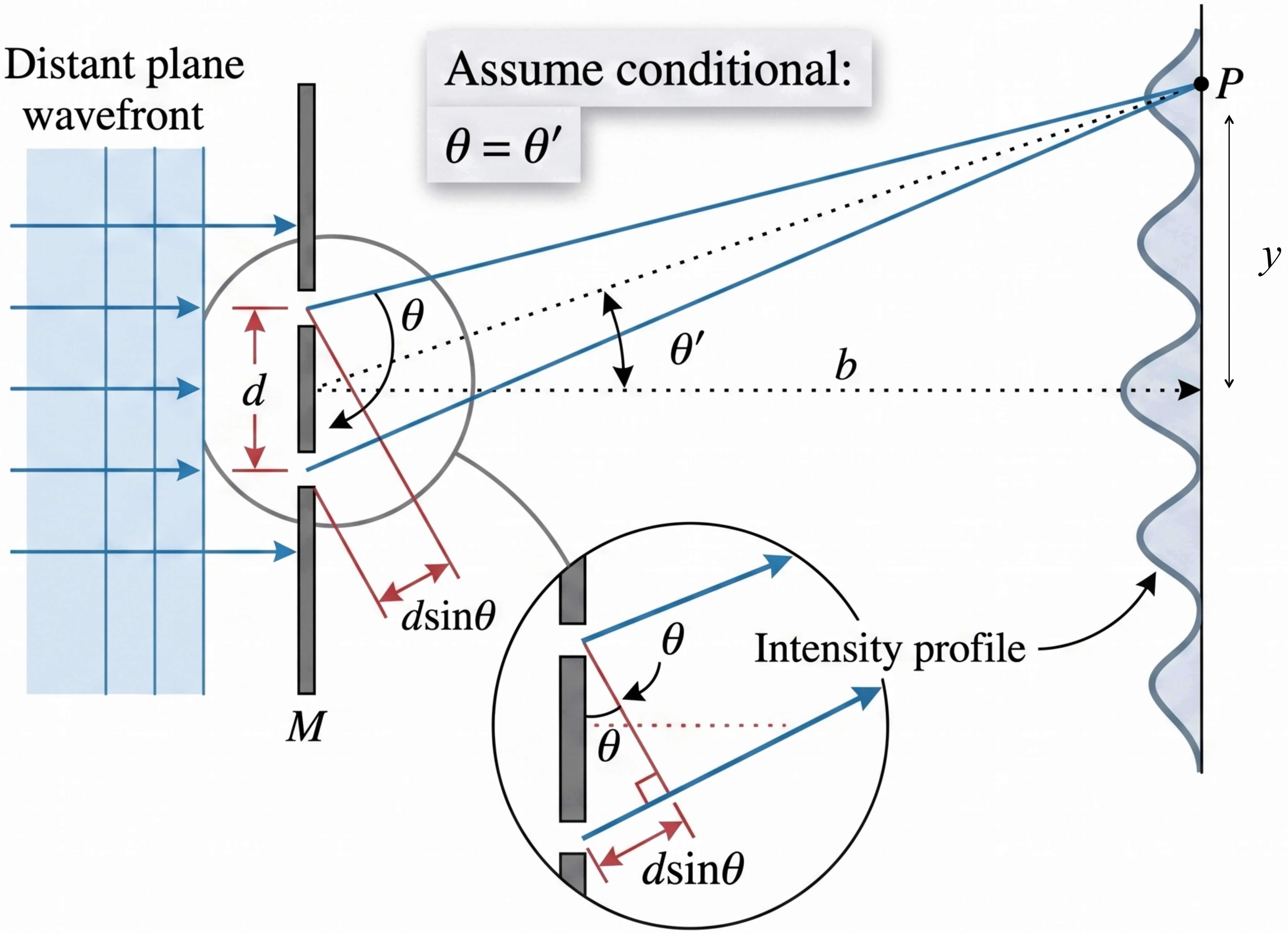
If we examine the intensity profile on the right side of the diagram, the central maximum (where path difference is zero) is directly aligned with the center axis. Counting the peaks outwards from the central maximum:

- The first peak from the center is the first-order maximum ($m = 1$).
- Point P is located exactly at the **second peak** from the center.

Because point P sits at the second-order maximum, we substitute $m = 2$ into the interference equation, yielding:

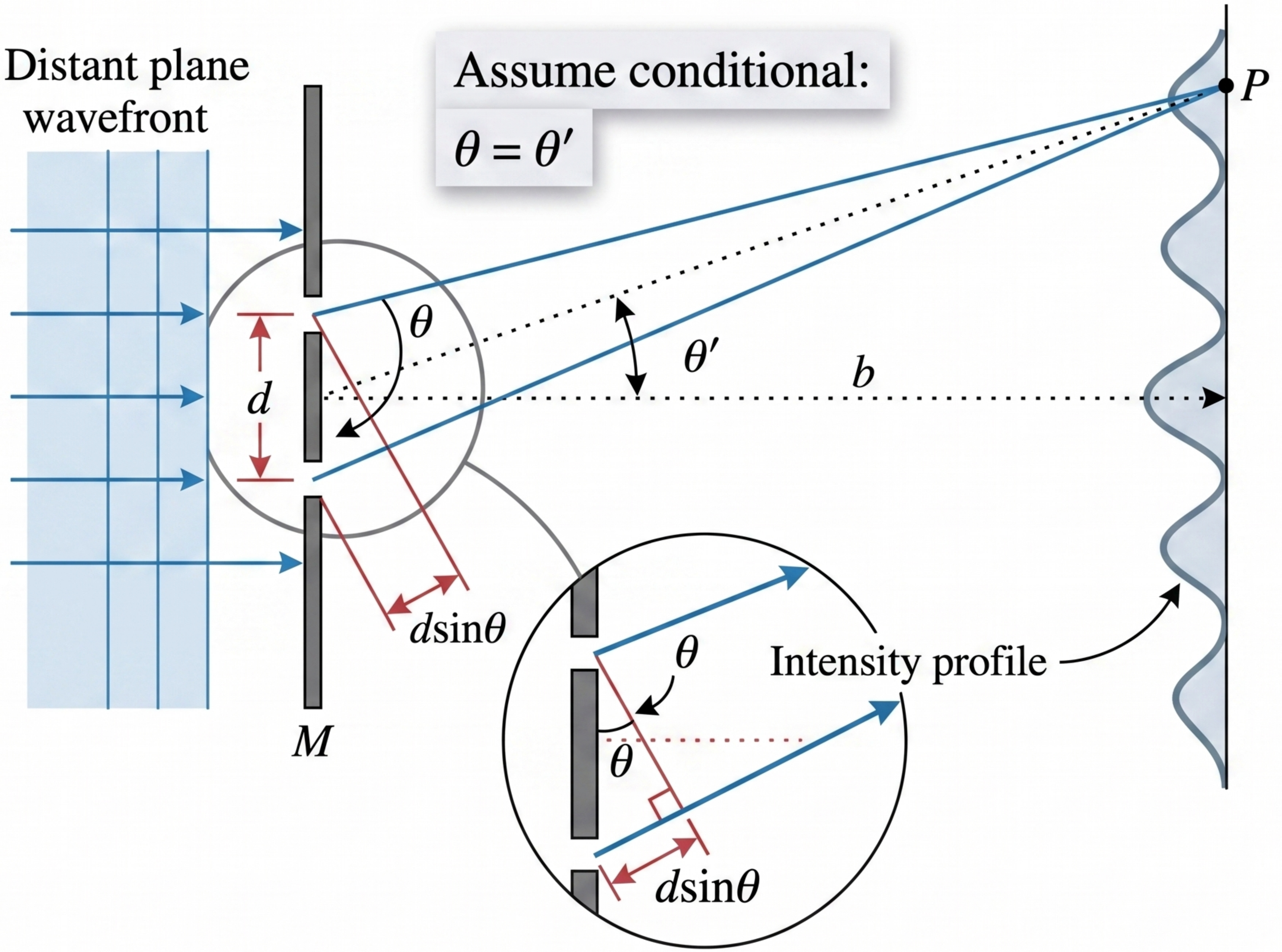
$$d \sin \theta = 2\lambda$$

Key Assumption: $b \gg d$



What is y in terms of θ, b, λ and d in this diagram?

Key Assumption: $b \gg d$



What is y in terms of θ, b, λ and d in this diagram?

$y = 2b\lambda/d$

2. What is y in terms of θ, b, λ, and d?

Let y be the vertical distance along the screen from the central axis to point P. From the large right triangle formed by the central axis (length b), the screen (height y), and the line of sight to P (angle θ'), we have:

$$y = b\tan\theta'$$

Based on the far-field approximation ($b \gg d$) established in the diagram, $\theta \approx \theta'$. Therefore:

$$y = b\tan\theta$$

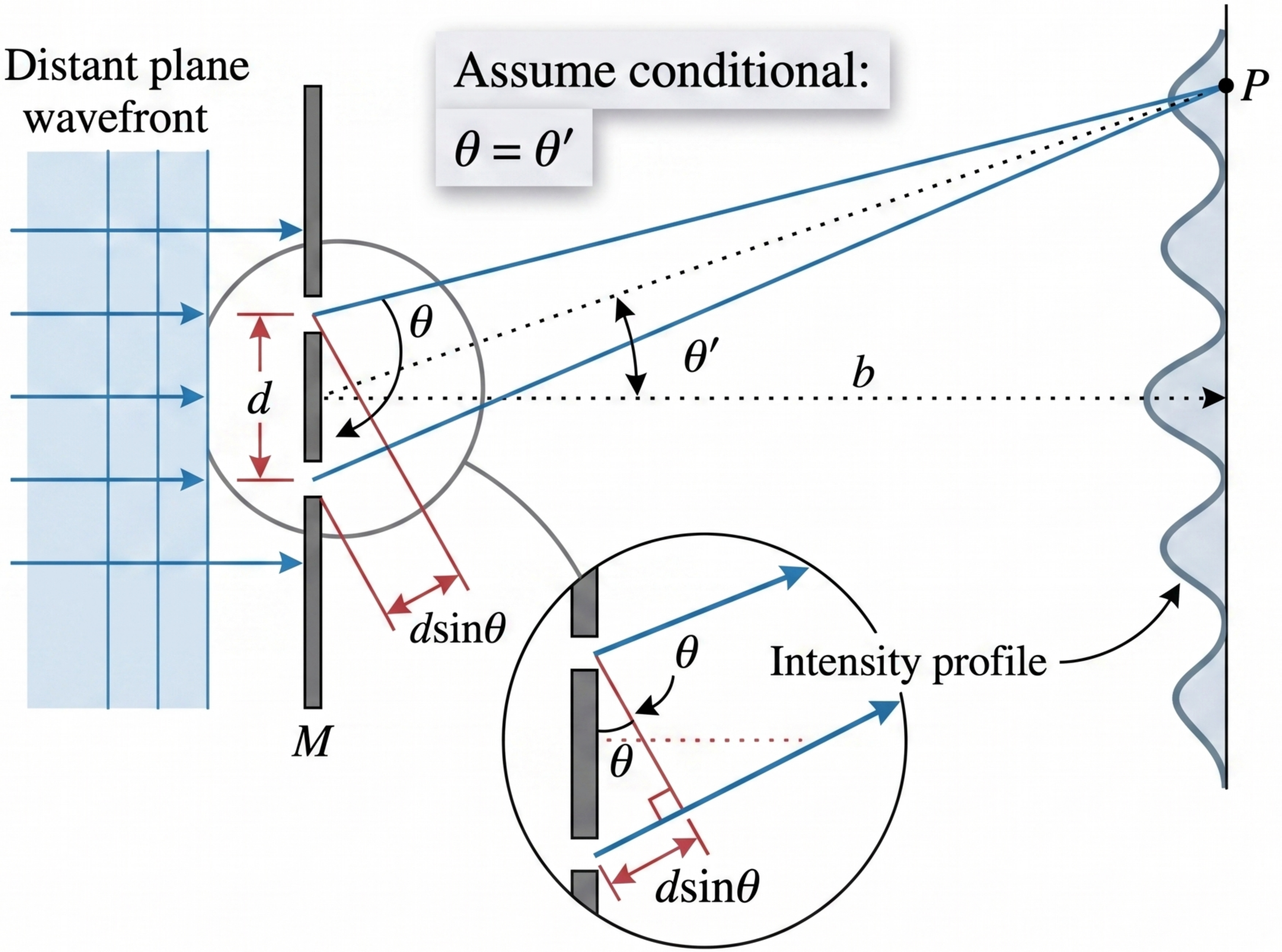
Since we know that at point P, $d\sin\theta = 2\lambda$, we can express θ as $\theta = \arcsin\left(\frac{2\lambda}{d}\right)$. Thus, the exact geometric expression for y at point P is:

$$y = b\tan\left(\arcsin\left(\frac{2\lambda}{d}\right)\right)$$

Small-Angle Approximation: If the angle θ is very small (which is typical when $b \gg y$), we can approximate $\tan\theta \approx \sin\theta$. Substituting $\sin\theta = \frac{2\lambda}{d}$ directly into the approximated equation gives:

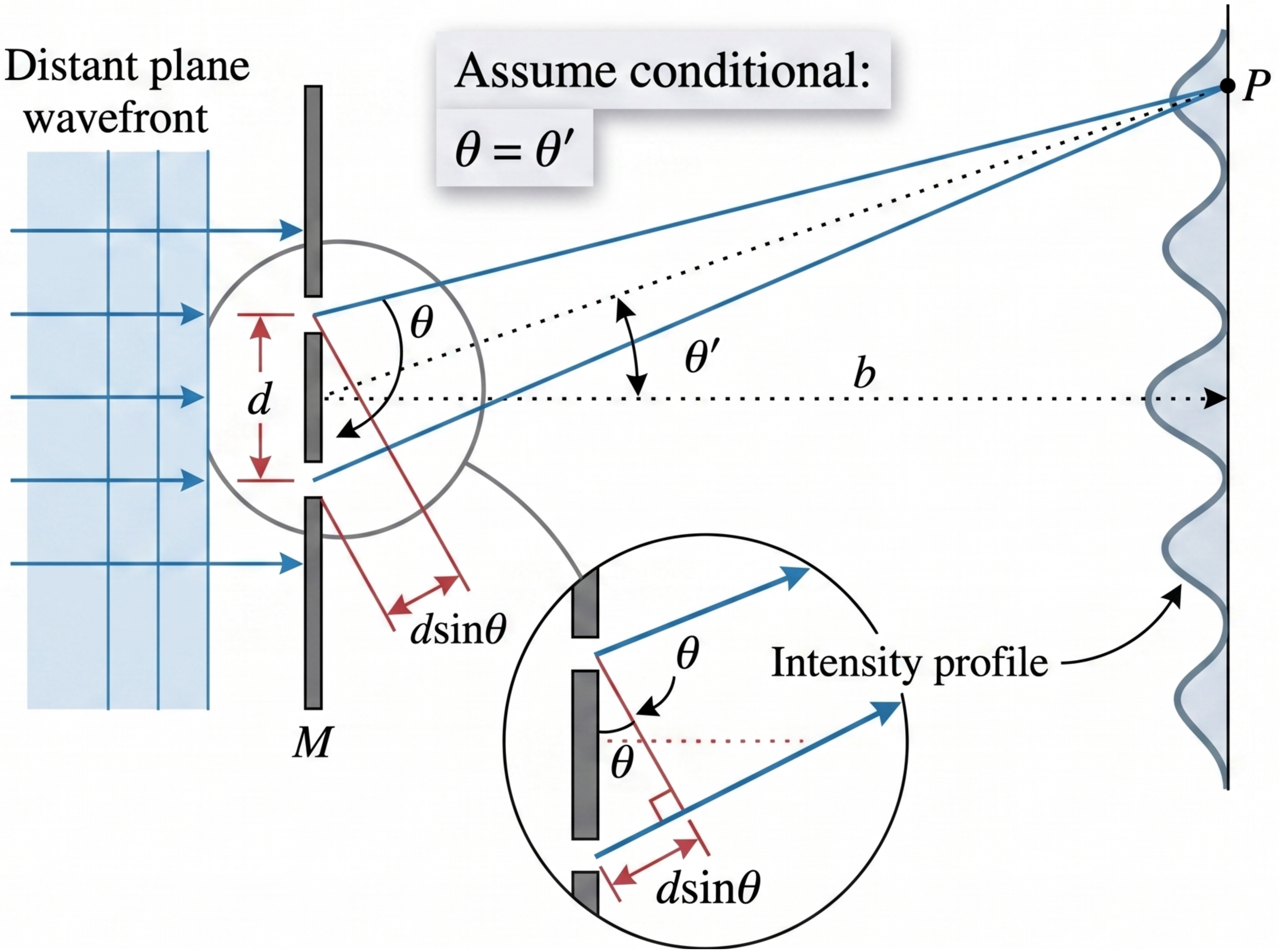
$$y \approx b\sin\theta = \frac{2\lambda b}{d}$$

Key Assumption: $b \gg d$



Why do you think the intensity maxima are not the same height?

Key Assumption: $b \gg d$



Why do you think the intensity maxima are not the same height?

Maxima at higher n are further from the point sources, we assumed it was plane waves in every direction from sources, made small angle approximation,…

3. Why are the intensity maxima not the same height?

In an ideal, oversimplified model where the slits are infinitely thin point sources, all constructive interference fringes would have the exact same peak intensity.

However, real physical slits have a finite width (let's denote it as a). Because of this finite width, the light passing through each individual slit also undergoes **single-slit diffraction**.

The overall intensity pattern observed on the screen is the product of two factors:

1. The rapidly oscillating **double-slit interference** pattern.
2. A broader **single-slit diffraction envelope** that acts as a modulating boundary.

As you move further away from the central axis (increasing θ), the single-slit diffraction envelope tapers off, which suppresses the intensity of the higher-order double-slit interference fringes. This is why the central maximum is the tallest, and subsequent maxima progressively decrease in height.

What is the separation d between two very narrow slits that just eliminates all the but the central maximum of intensity from the interference pattern?

a)½ λ

b)λ

c)2 λ

d)The other maxima cannot be eliminated

What is the separation *d* between two very narrow slits that just eliminates all the but the central maximum of intensity from the interference pattern?

a)½ λ

b)λ

c)2 λ

d)The other maxima cannot be eliminated

4. What separation d just eliminates all but the central maximum?

To eliminate all side maxima from the interference pattern, we must ensure that even the first-order maximum ($m = 1$) cannot physically appear on the screen.

The condition for the first-order maximum is:

$$d \sin \theta = 1\lambda$$

Solving for $\sin \theta$, we get:

$$\sin \theta = \frac{\lambda}{d}$$

For a maximum to be visible, there must be a real angle θ that satisfies this equation, which requires $\sin \theta \leq 1$. The maximum possible angle for a fringe to propagate toward the screen is $\theta = 90°$ (where $\sin(90°) = 1$).

If we set the first maximum to occur exactly at $90°$ (which means it travels parallel to the screen and never lands on it), we find the critical separation distance:

$$d(1) = \lambda \implies d = \lambda$$

If the slit separation d is less than or equal to the wavelength of the light ($d \leq \lambda$), then $\frac{\lambda}{d} \geq 1$. For $d < \lambda$, $\sin \theta > 1$, which has no real mathematical solution for θ. Thus, no side fringes can form, and **only the central maximum will exist** in the interference pattern.

Wave-particle duality