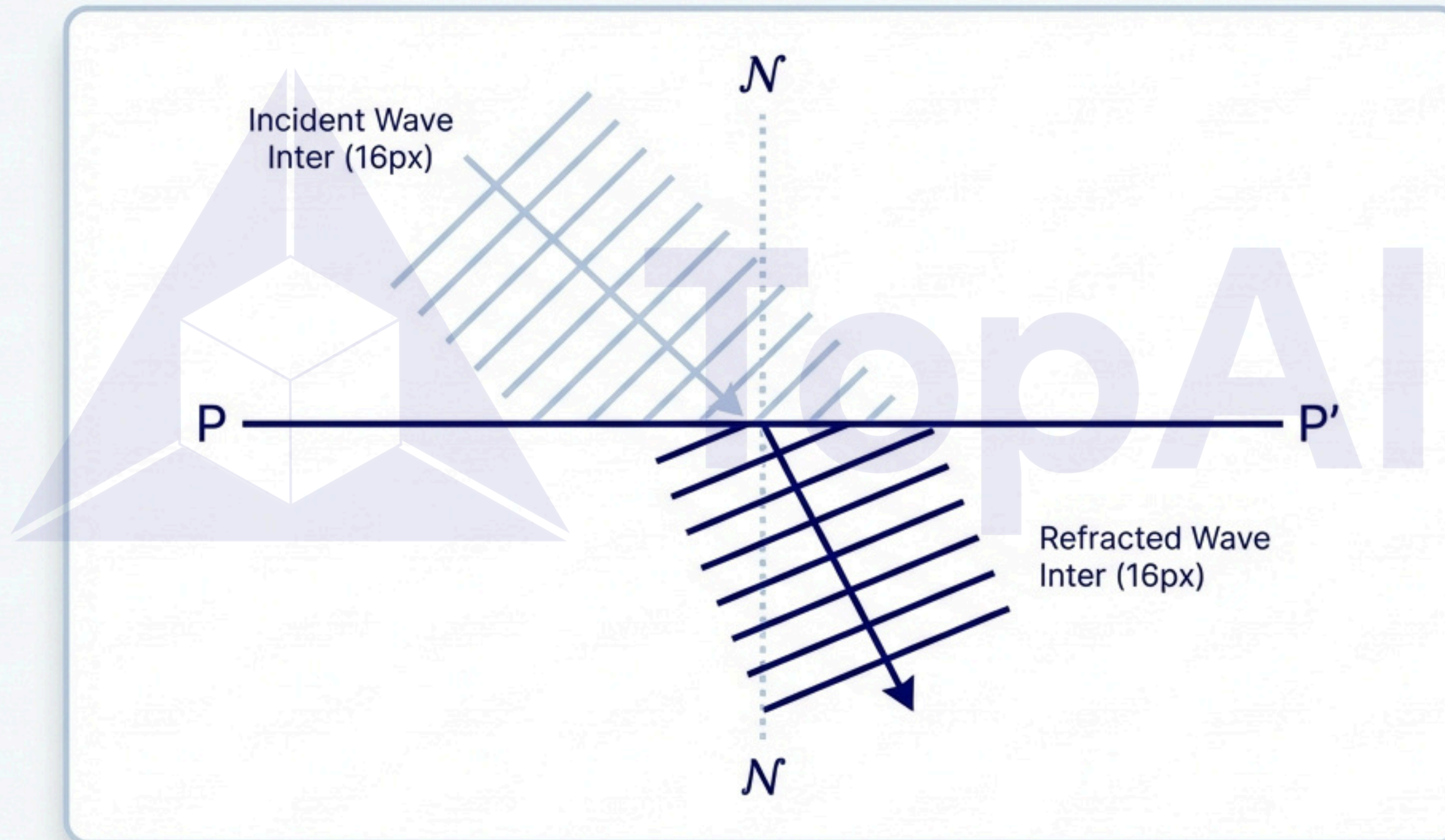
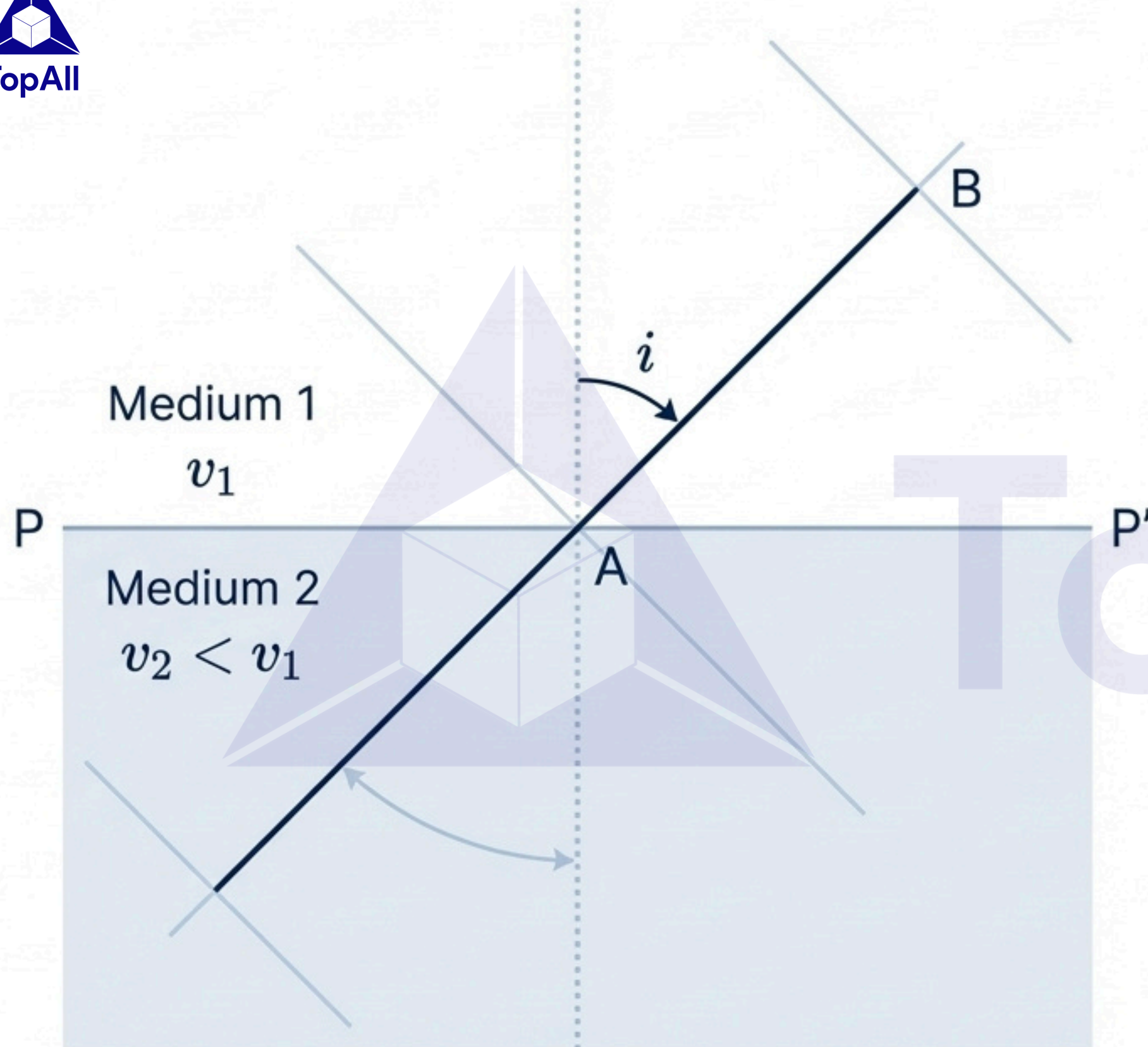


Refraction of a Plane Wave

Deriving Snell's law using Huygens principle

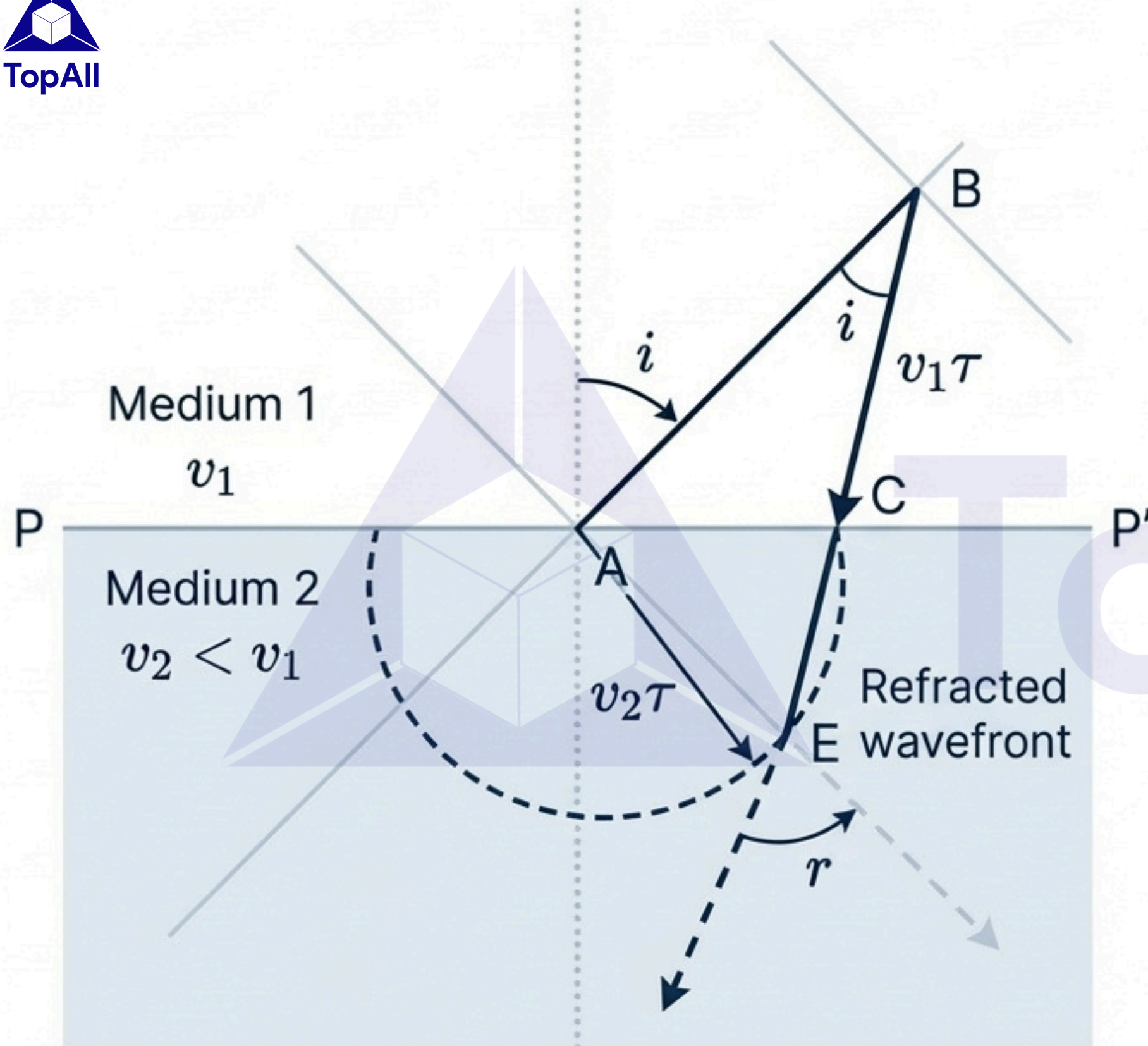




Defining the Initial State at the Interface

A plane wavefront AB propagates toward the surface PP' separating two distinct optical media.

- Medium 1: Light travels at speed v_1 .
- Medium 2: Light travels at a slower speed v_2 .
- The wavefront strikes the interface at an angle of incidence i .



The Passing of Time: Constructing the New Wavefront

In Medium 1: As the wave advances, point B travels to C over time τ . The distance covered is $BC = v_1\tau$.

In Medium 2: Simultaneously, point A acts as a secondary source, emitting a spherical wavelet into the denser medium with radius $AE = v_2\tau$.

Conclusion: Drawing a tangent from C to the wavelet at E gives the new, refracted wavefront CE.



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$$E=mc^2$$



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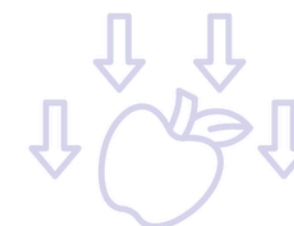
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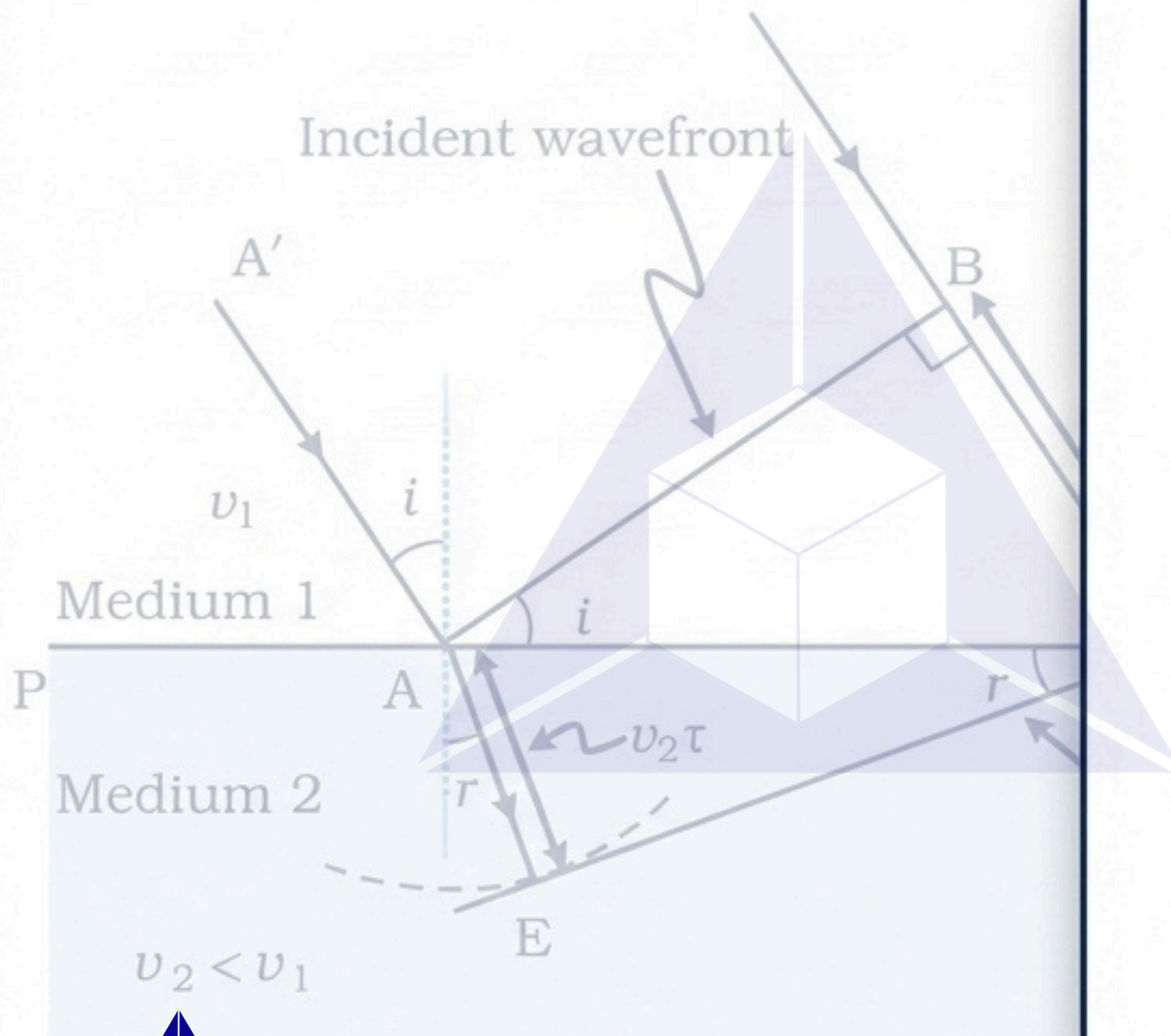


Key Highlights



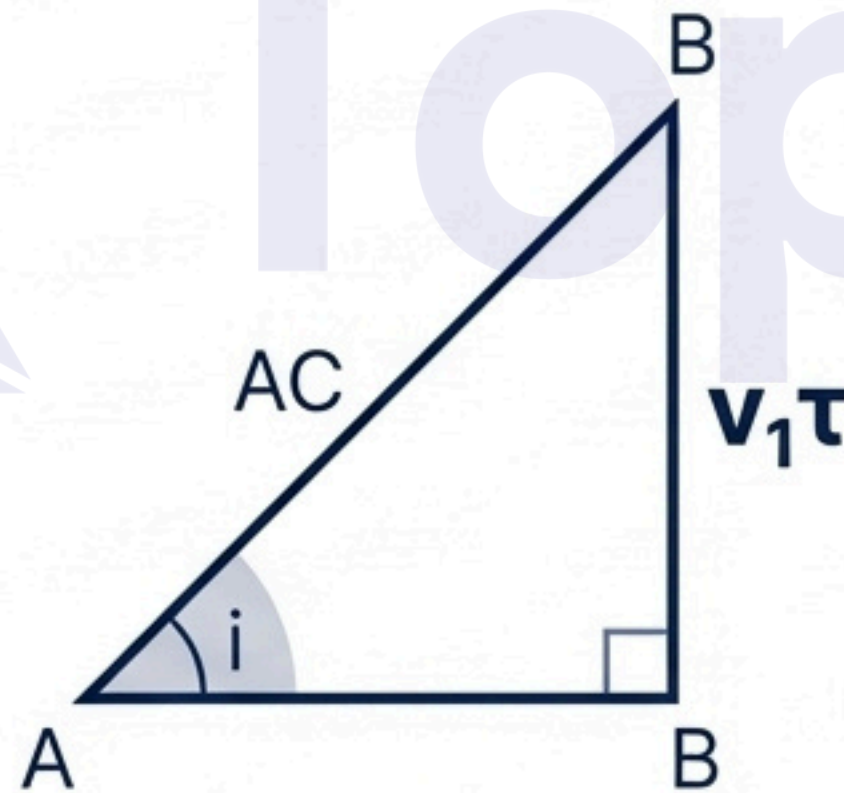
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Extracting the Trigonometry from the Physics



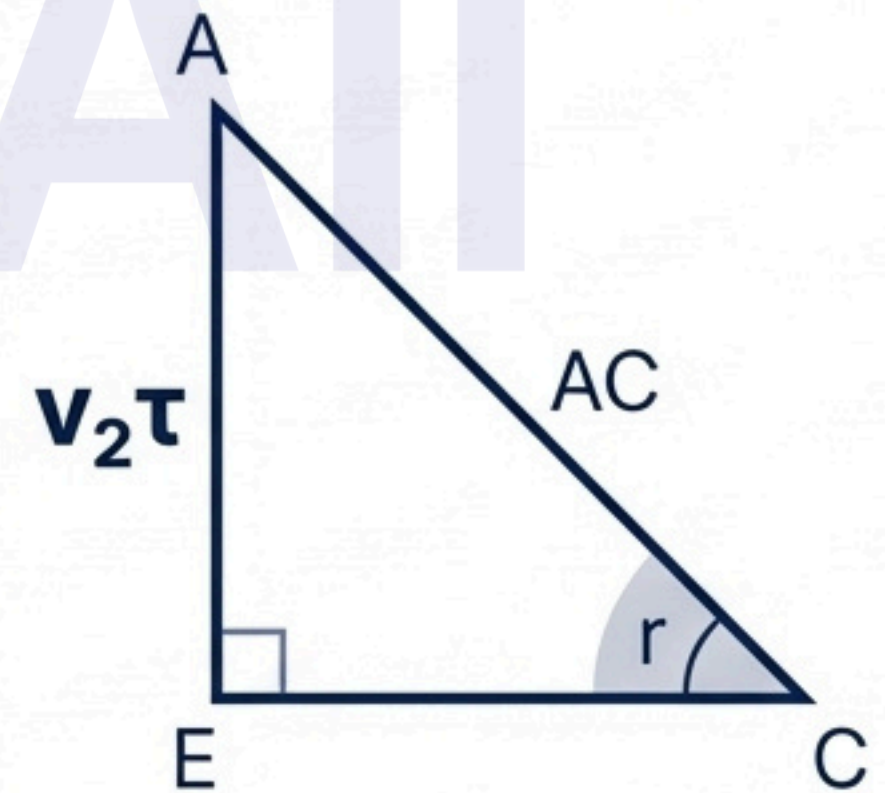
**Incident Triangle
($\triangle ABC$)**

$$\sin i = \frac{BC}{AC} = \frac{v_1\tau}{AC}$$



**Refracted Triangle
($\triangle AEC$)**

$$\sin r = \frac{AE}{AC} = \frac{v_2\tau}{AC}$$



Synthesizing the Ratios into a Single Law

Divide the two sine equations to eliminate the common hypotenuse (AC) and time (τ).

$$\frac{\sin i}{\sin r} = \frac{v_1 \tau / AC}{v_2 \tau / AC} = \frac{v_1}{v_2}$$



Introduce the absolute refractive index ($n = c/v$), where c is the speed of light in vacuum.

$$\begin{aligned} n_1 &= \frac{c}{v_1} \Rightarrow v_1 = \frac{c}{n_1} \\ n_2 &= \frac{c}{v_2} \Rightarrow v_2 = \frac{c}{n_2} \end{aligned}$$



Substitute and cross-multiply to reach the final form:

$$\begin{aligned} \frac{\sin i}{\sin r} &= \frac{c/n_1}{c/n_2} = \frac{n_2}{n_1} \\ \mathbf{n_1 \sin i} &= \mathbf{n_2 \sin r} \end{aligned}$$

Snell's Law of Refraction

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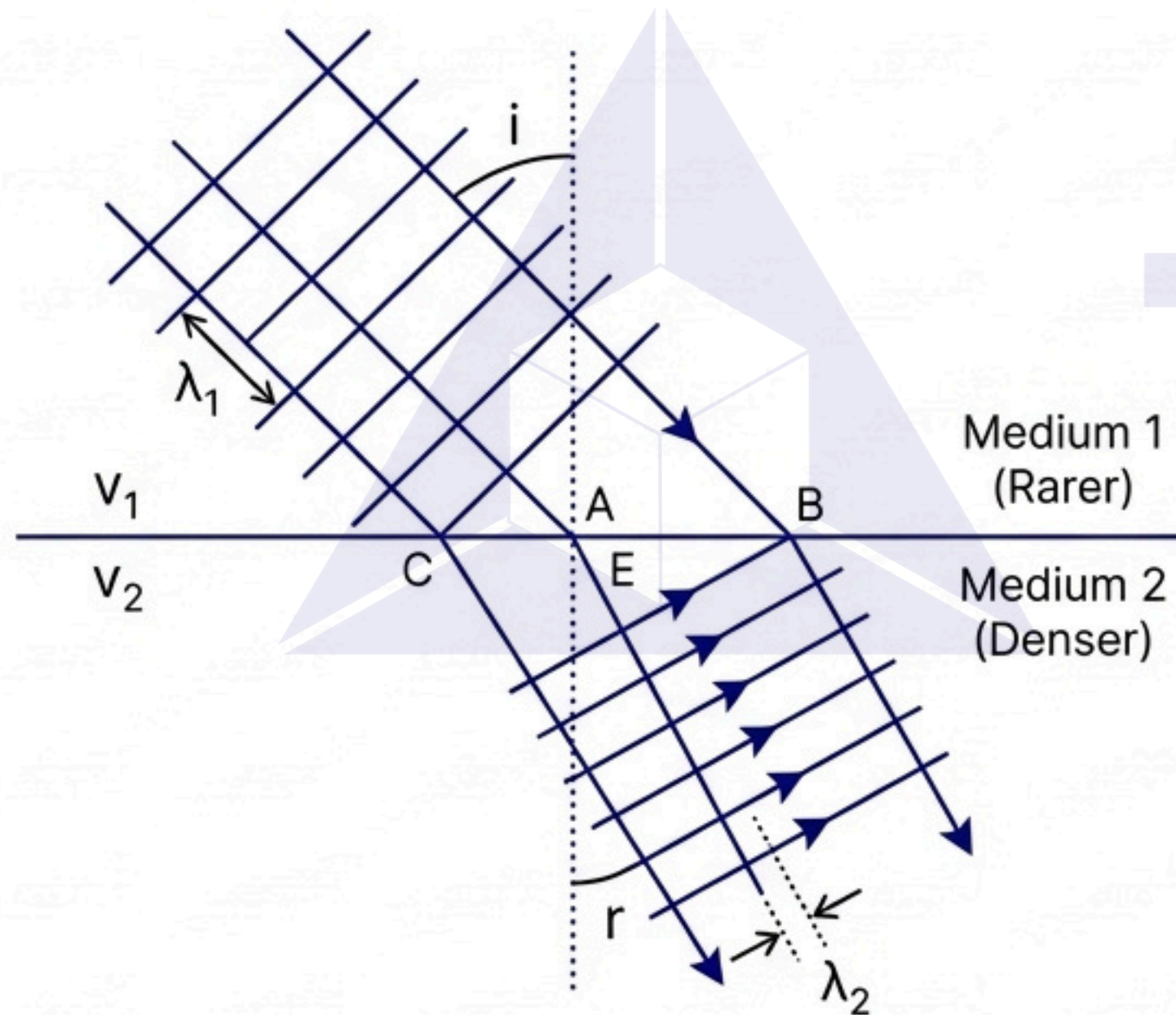
$$n_1 \sin i = n_2 \sin r$$

What does this physically mean?

- When light enters a denser medium, its speed decreases ($v_2 < v_1$).
- Because $(\sin i) / (\sin r) = v_1 / v_2$, the angle of refraction must be smaller than the angle of incidence ($r < i$).
- Conclusion: The light ray naturally bends toward the normal.

The Impact on Wavelength and Speed

The geometric construction reveals that distance $BC = \lambda_1$ and $AE = \lambda_2$. Therefore, $\lambda_1/\lambda_2 = v_1/v_2$.



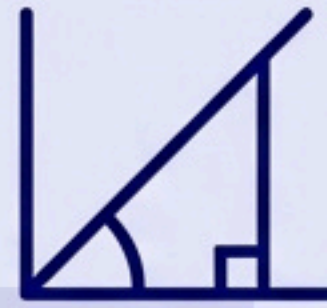
Property	Medium 1 (Rarer)	Medium 2 (Denser)
Speed	v_1	v_2 (Decreases) ↓
Wavelength	λ_1	λ_2 (Decreases proportionally) ↓
Frequency	ν	ν (Remains absolutely constant)

The Blueprint of Wave Refraction



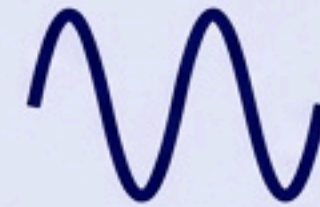
The Cause

Refraction is not arbitrary; it is the physical consequence of a wave changing speed as it crosses the boundary between two different media.



The Proof

Snell's Law ($n_1 \sin i = n_2 \sin r$) is not just an empirical observation. It emerges naturally from the geometry of Huygens' expanding secondary wavelets.



The Rule

When entering a denser medium, wave speed and wavelength decrease proportionally. However, the wave's frequency (ν) remains strictly constant.



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