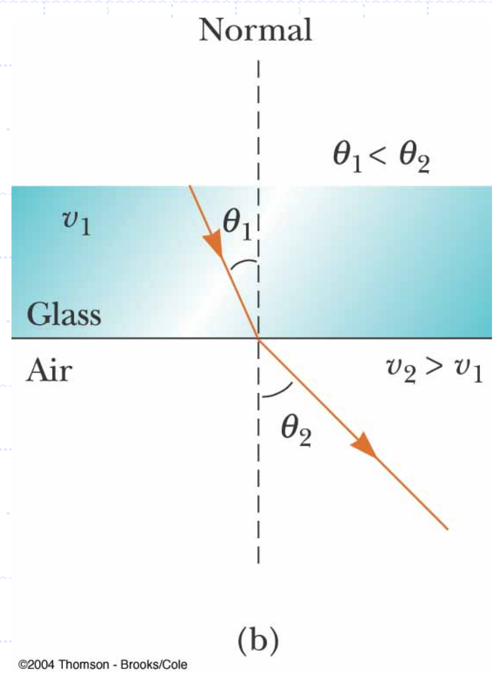
Example problem 1

- Light with a frequency of 5.80×10^{14} Hz propagates in a block of glass that has an index of refraction of 1.52. What is the wavelength of the light in (a) vacuum and (b) the glass?

Example problem 2

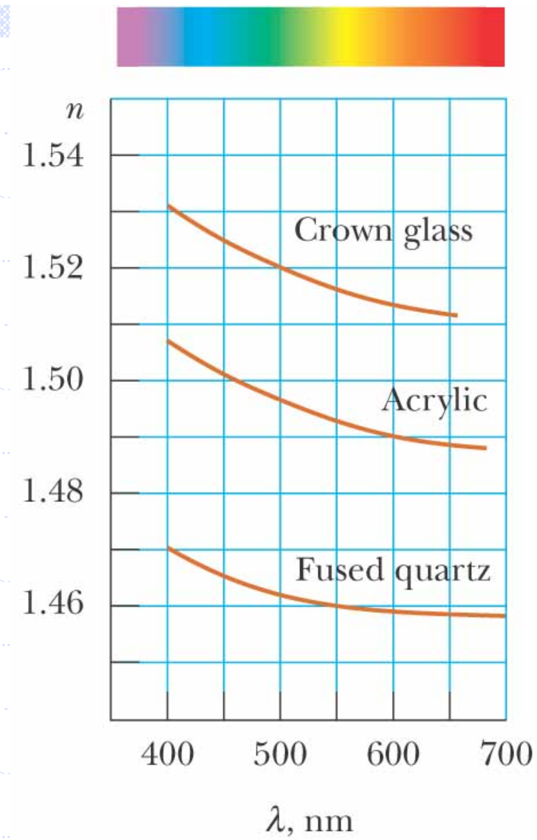
- A light ray is incident on a plane surface separating two sheets of glass with $n_1=1.70$ and $n_2=1.58$. The angles of incidence is 62.0°, and the ray originates in n_1. What is the angle of refraction?



Neat Index of Refraction Stuff

- Experiments done at Harvard in 1999 were able to slow light down to 17 m/s (compare to vacuum speed of $3x10^8$ m/s). The experiments involved the propagation of laser light into a Bose-Einstein condensate of gaseous Rb. Later experiments could actually stop the light momentarily (see http://en.wikipedia.org/wiki/Light_speed)
- Materials can be engineered to have a negative index of refraction. These materials have strange, but useful properties, e.g. the direction of light is reversed! (See Physics Today June 2004)

Dispersion and Prisms



- For a given material (and nearly all materials), the index of fraction is a function of the wavelength of the incident light, $n = n(\lambda)$
- This implies that the speed of light inside the medium depends on λ
- The dependence of wave speed v and n on λ is called ***dispersion***
- Since $n = n(\lambda)$, Snell's law of refraction implies that different wavelength light is bent at different refraction angles $\theta_2(\lambda)$ for a given θ_1

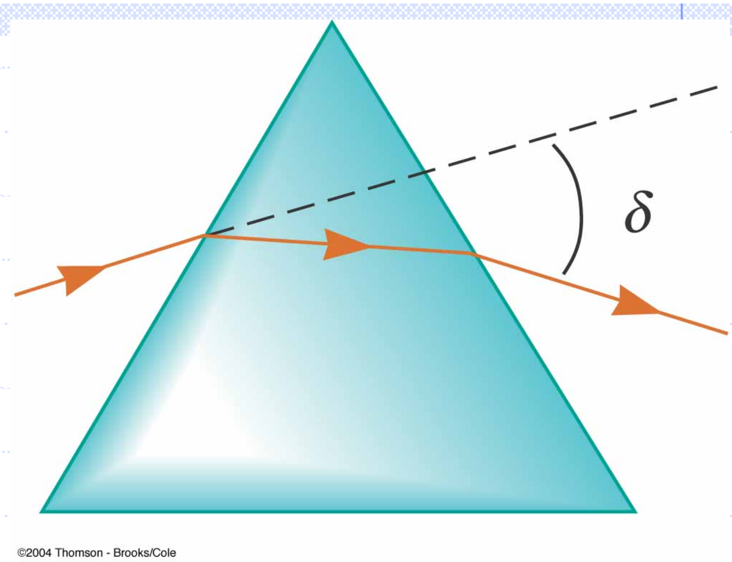
- In the *optical* region (or *visible*, i.e. 400-700 nm), *n* increases as λ decreases
- Therefore, violet light (low λ) is refracted more than red light (large λ)
- Outside of the optical region, *n* can be much greater than one (even less than one).
- Now, ordinary white light is composed of a superposition of light waves with different λ (and different intensities) extending over the optical region (and beyond) – *polychromatic light*
- Using transparent material to make a prism is a useful device to separate the various λ components

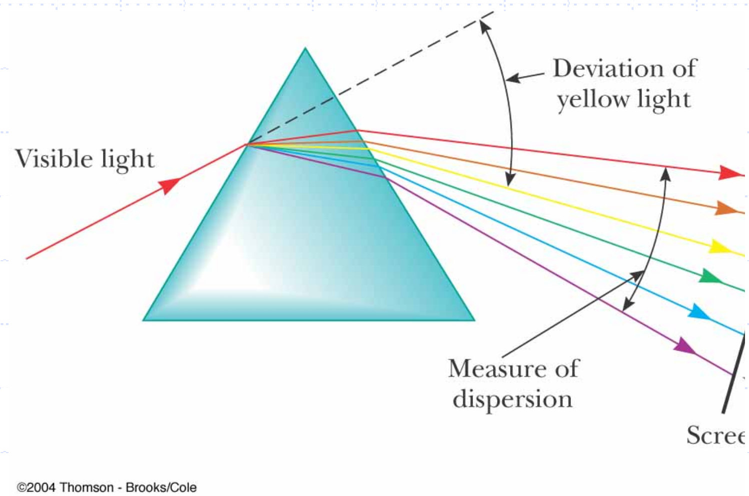
- Consider one λ component incident on a prism with apex angle Φ.
- The total deviation angle of the light is

$$\delta = (\theta_1 - \theta_2) + (\theta_1' - \theta_2')$$

where primes refer to the second interface.

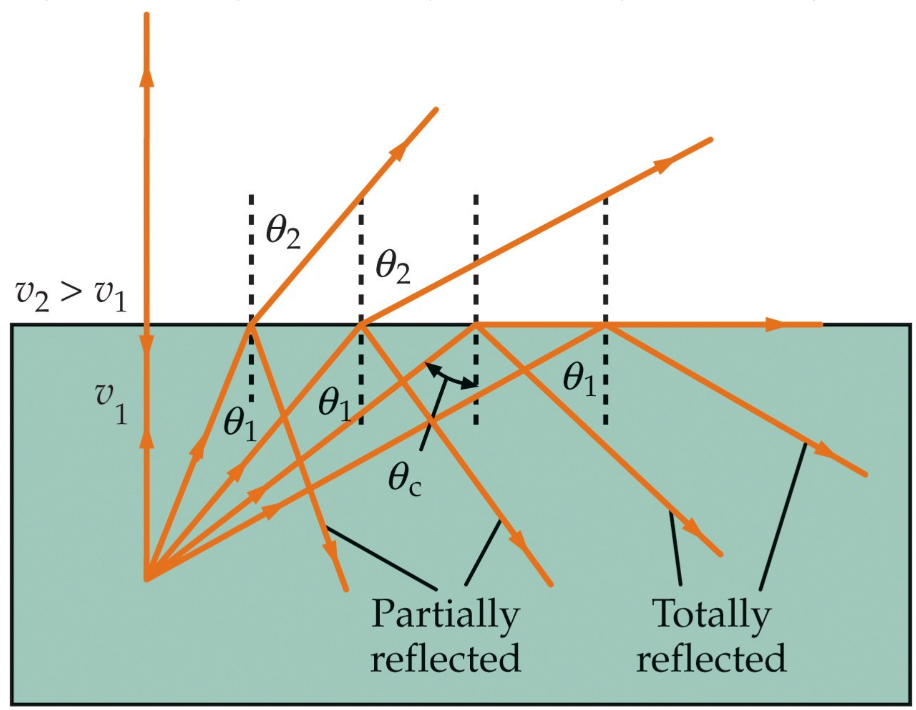
- δ increases with decreasing λ
- The larger the variation in n, the larger the range of δ





Total Internal Reflection

- Under certain circumstances, light traveling through a transparent media can be completely reflected (i.e. no transmission) when it encounters an interface
- This occurs when $n_1 > n_2$ and for some critical incident angle θ_c
- From Snell's law there is "no transmission" with $\theta_2 = 90°$

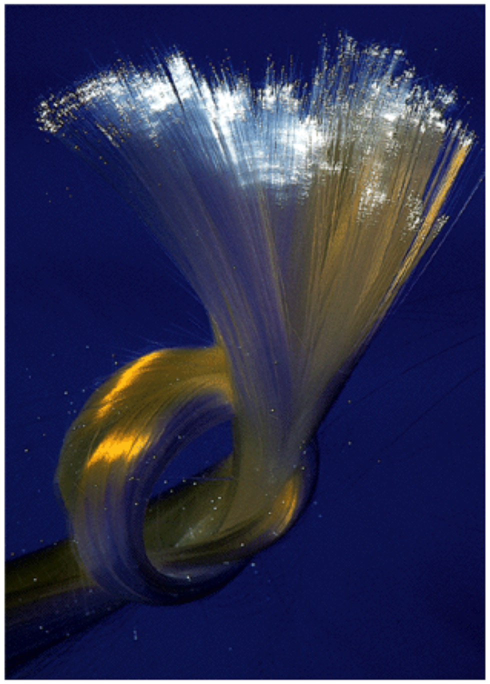


$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

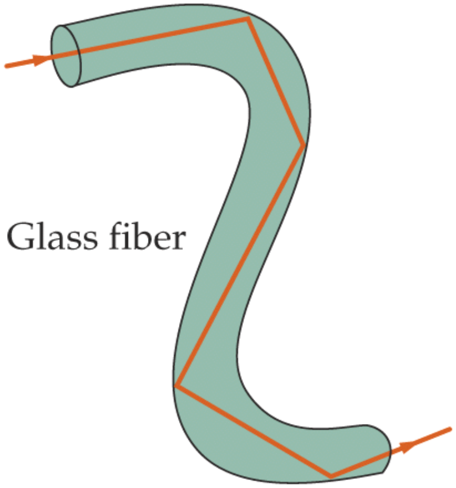
$$n_1 \sin\theta_1 = n_2 \sin 90^\circ$$

$$\sin\theta_1 = n_2 / n_1 \qquad (n_1 > n_2)$$

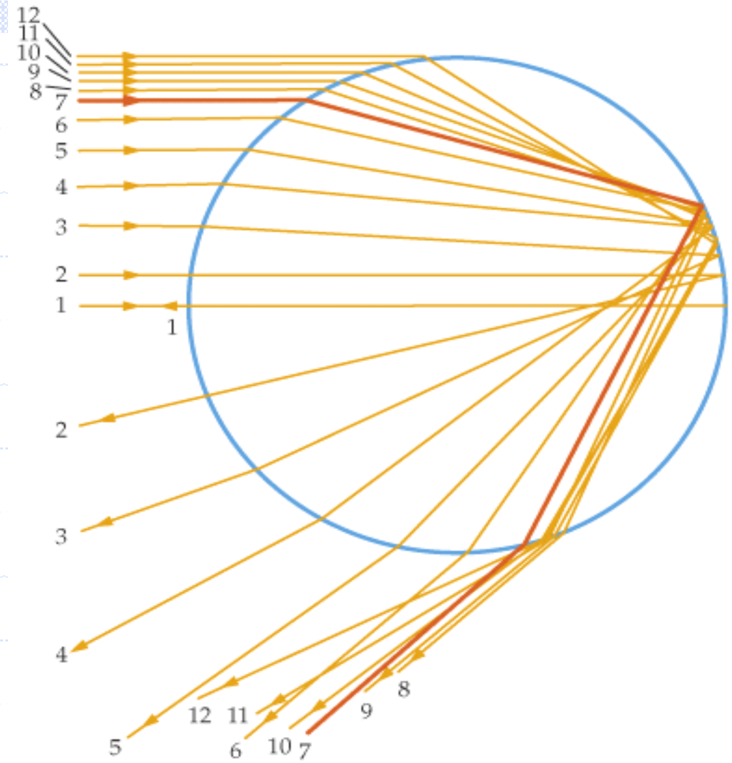
$$\theta_1 = \boxed{\theta_c = \sin^{-1}(n_2 / n_1)}$$

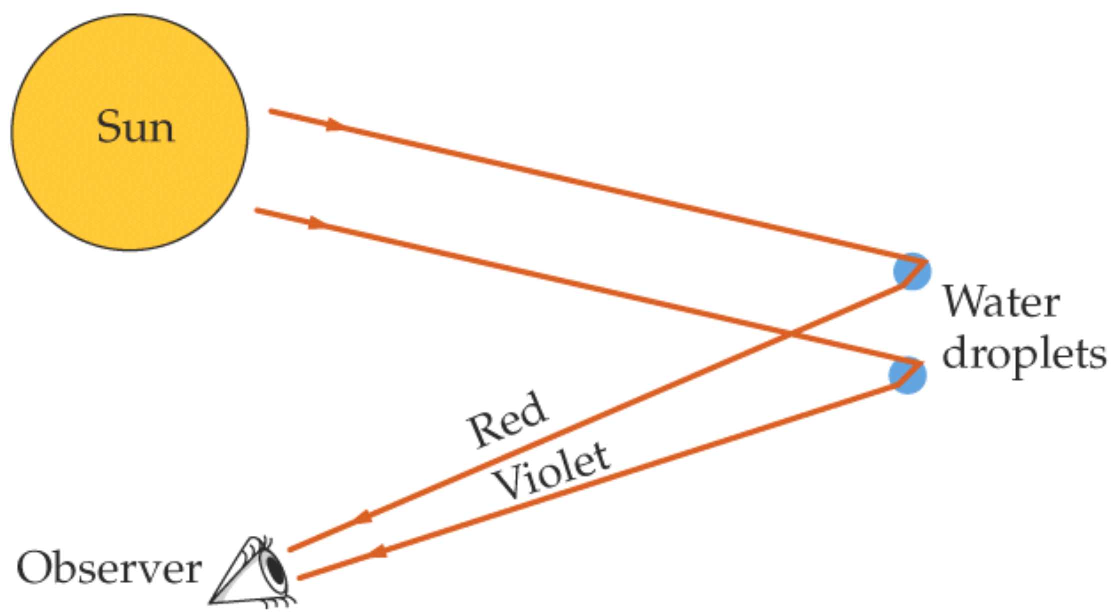


- For all angles, the reflection angle equals the incident angle
- Light travels along fiber optic cables as a consequence of many multiple total internal reflections



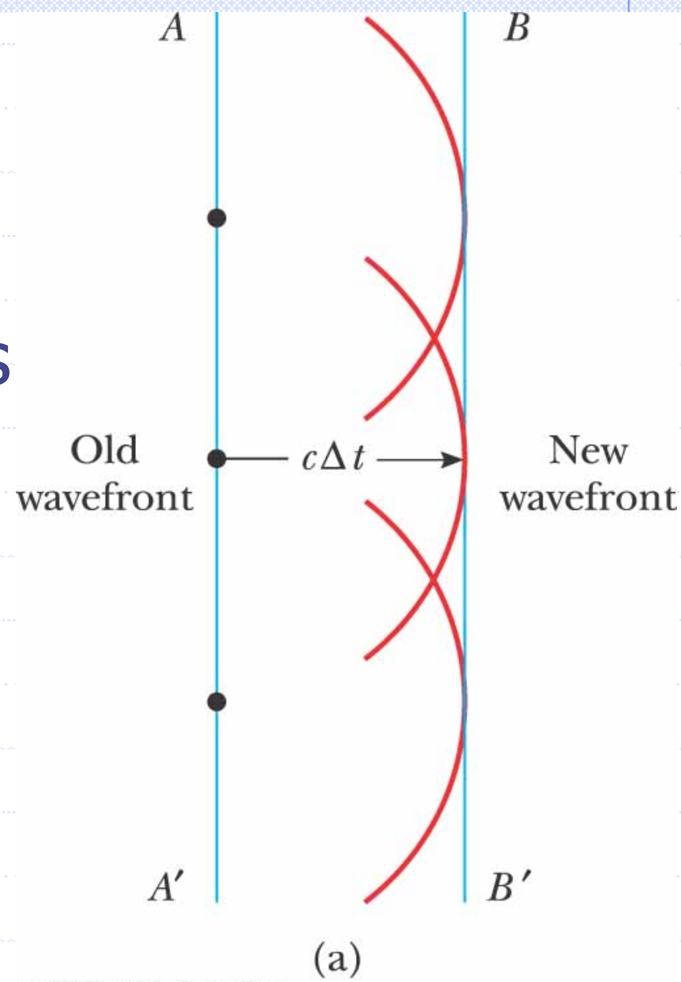
- The combination of *total internal reflection* and *dispersion* in a raindrop is responsible for the creation of a rainbow





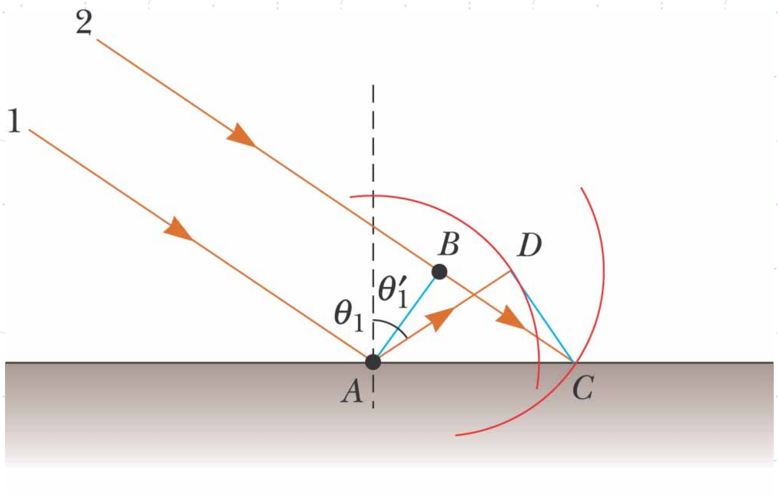
Huygen's Principle

- In our development of the laws of reflection and refraction, we did not need to know light is a wave
- Let's consider a way to derive them using wave fronts
- Huygen's principle states that

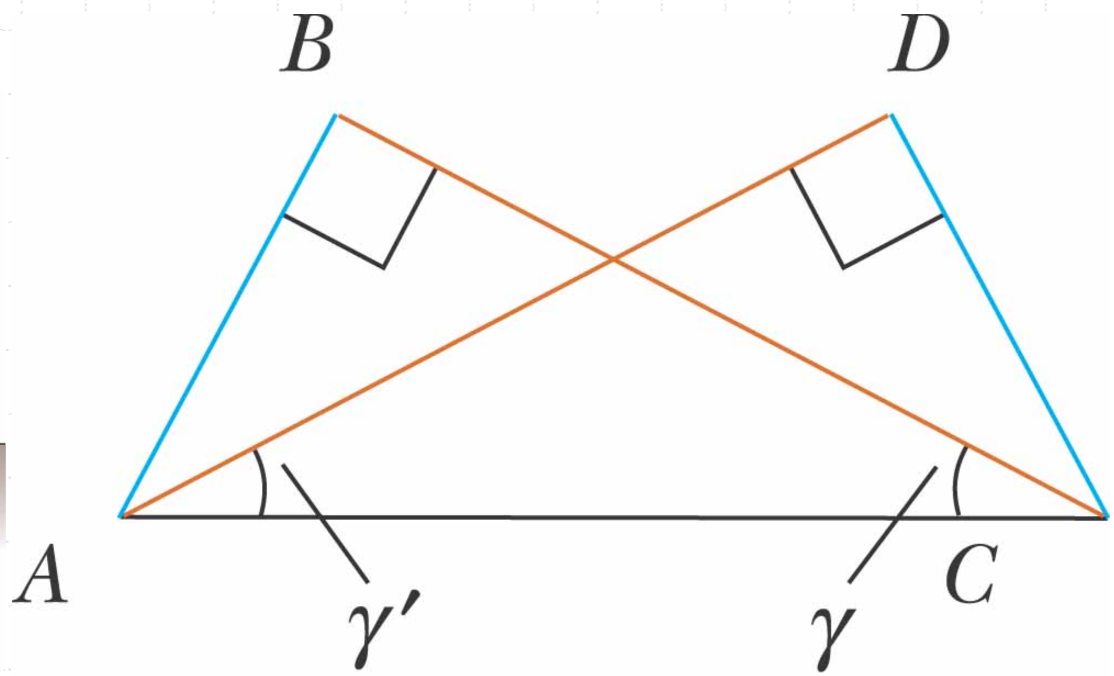


every point on a wave front may be considered the source of a secondary spherical wavelet that spreads out in all directions with the speed equal to the speed of the wave propagation

- After some period of time, the new wave front is found by constructing a surface tangent to the secondary wavelets
- Now, lets prove the law of reflection

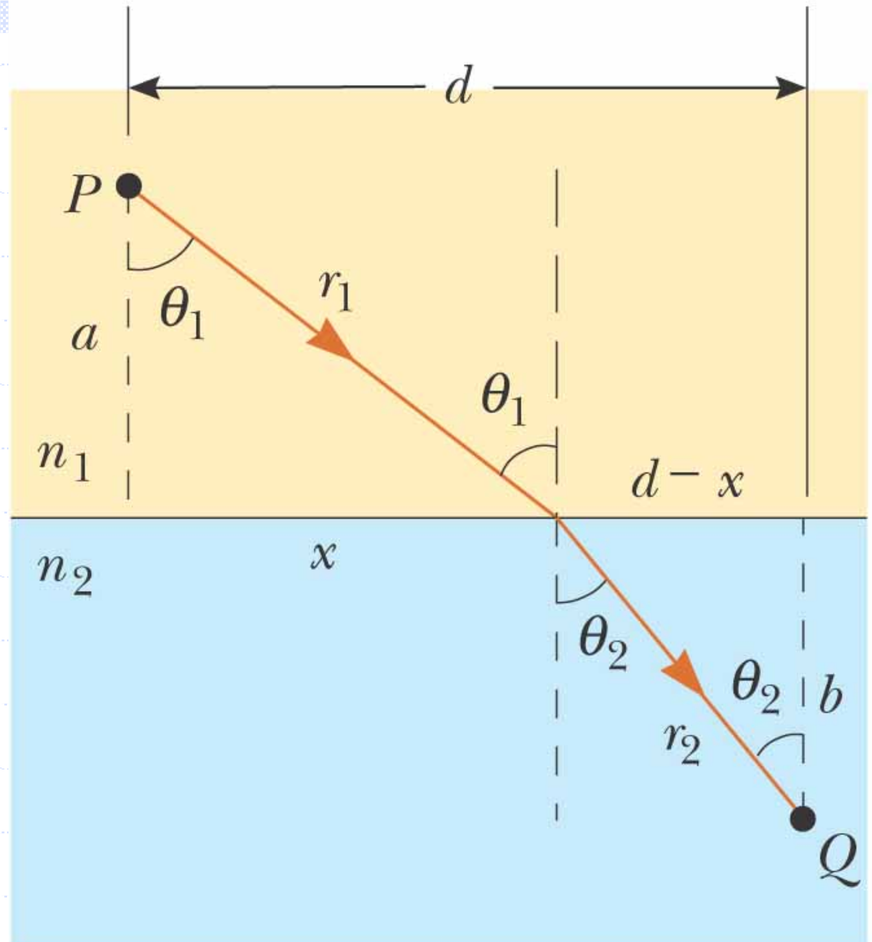


(a)



Fermat' s Principle

- Another way to formulate the laws of optics
- *The actual path (out of all possible paths) between two points taken by a beam of light is the one that is traversed in the least time*



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- Also called the *principle of least time*

Example Problem

- A narrow white light beam is incident on a block of fused quartz at an angle of 30.0°. Find the angular width of the light beam inside the quartz.

Example Problem (you do)

- A prism that has an apex angle of 50.0° is made of cubic zirconia with $n=2.20$. What is the angle of minimum deviation? (Answer = 86.8°)