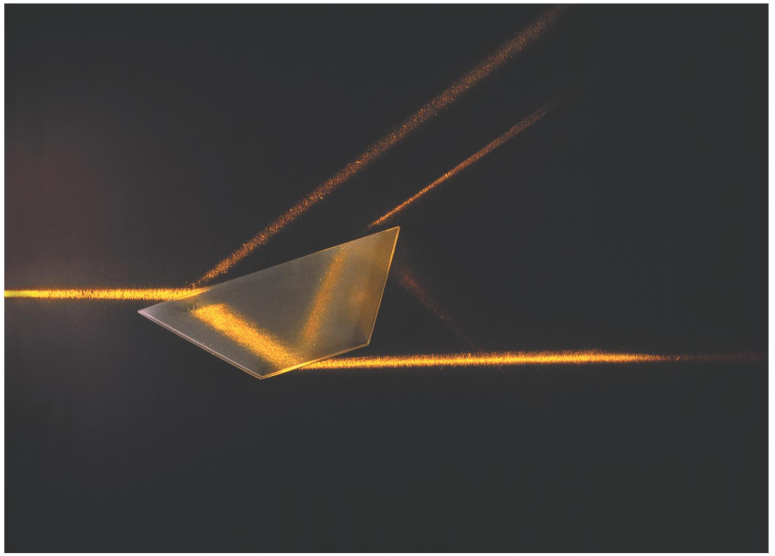
Refraction (23.3)



Two things happen when light hits the boundary between transparent materials

1. Part of the light reflects from the surface

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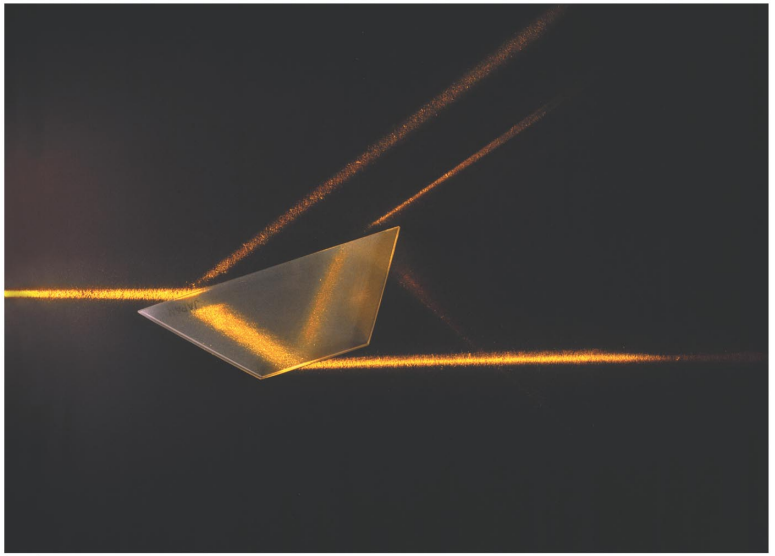
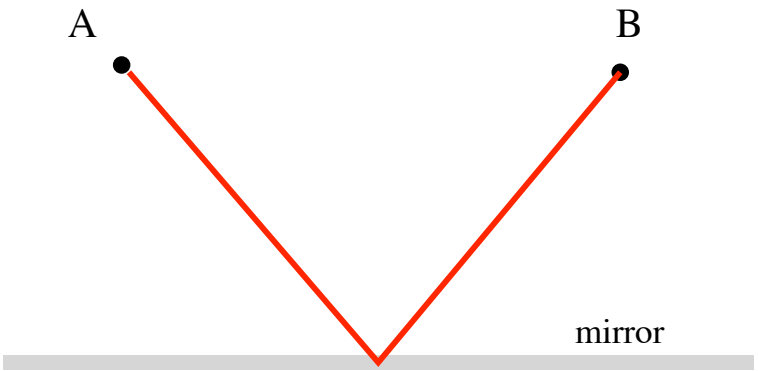


Two things happen when light hits the boundary between transparent materials

1. Part of the light reflects from the surface
2. Part of the light is transmitted through the second medium with a change of direction. This is called refraction

Fermat's Principle for Reflection



- When light travels from A to B what path will it take?

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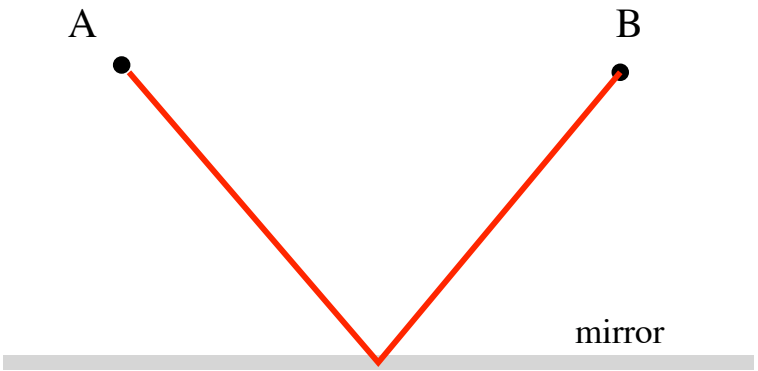

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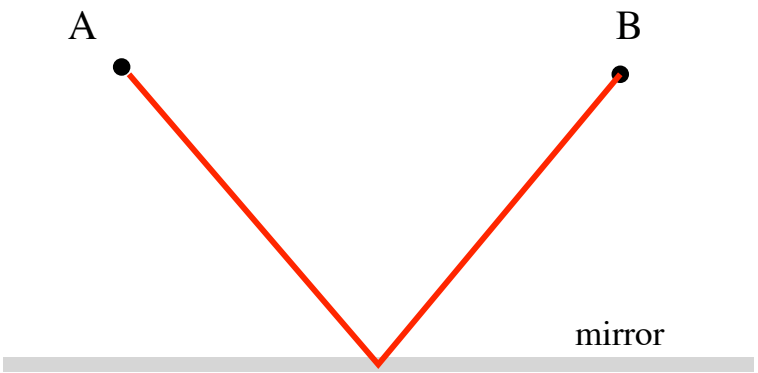

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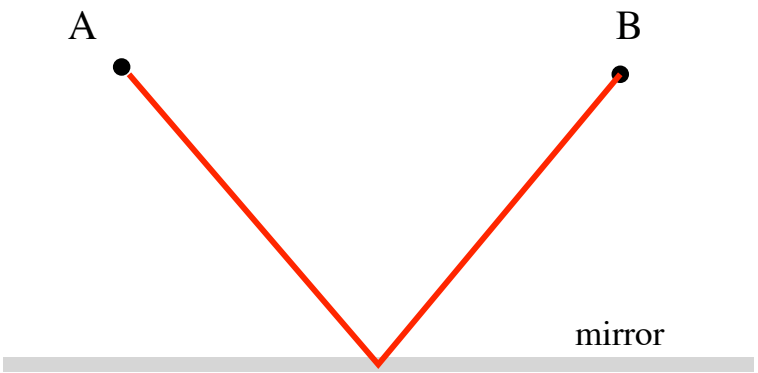

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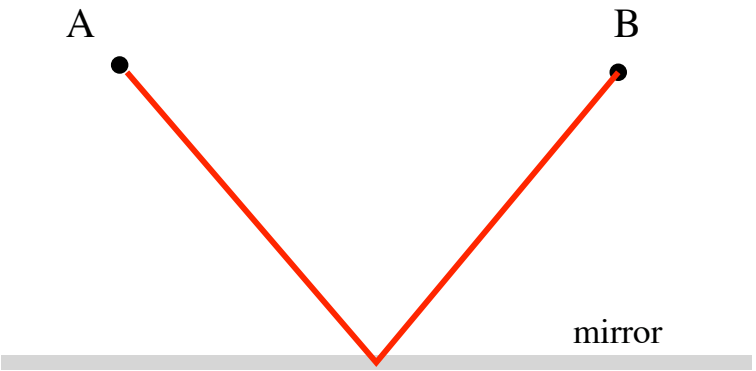

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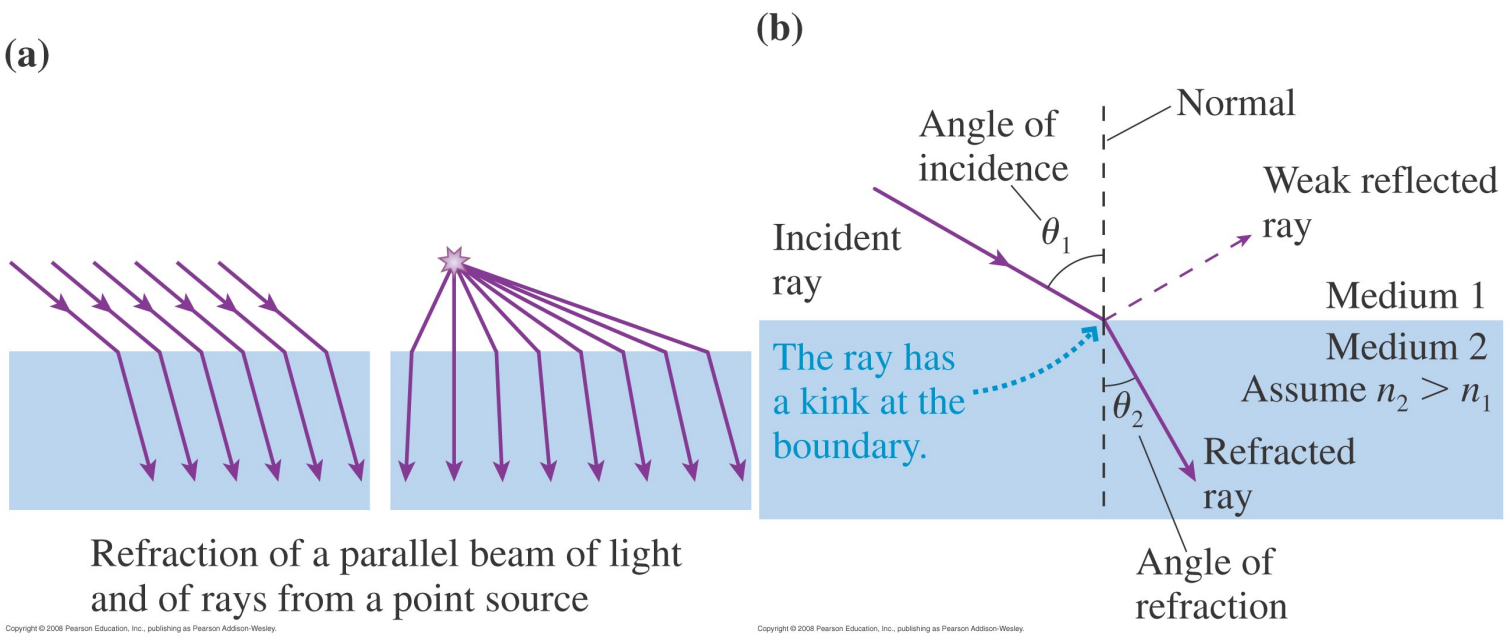
- Answer: The shortest.
- This is also the path that takes the least time.
- For reflection, the shortest path is the path of least time and this is consistent with the law of reflection.
- Fermat's principle says: Light travelling between two points takes the path of least time.

Refraction



- Simplify by drawing a single ray

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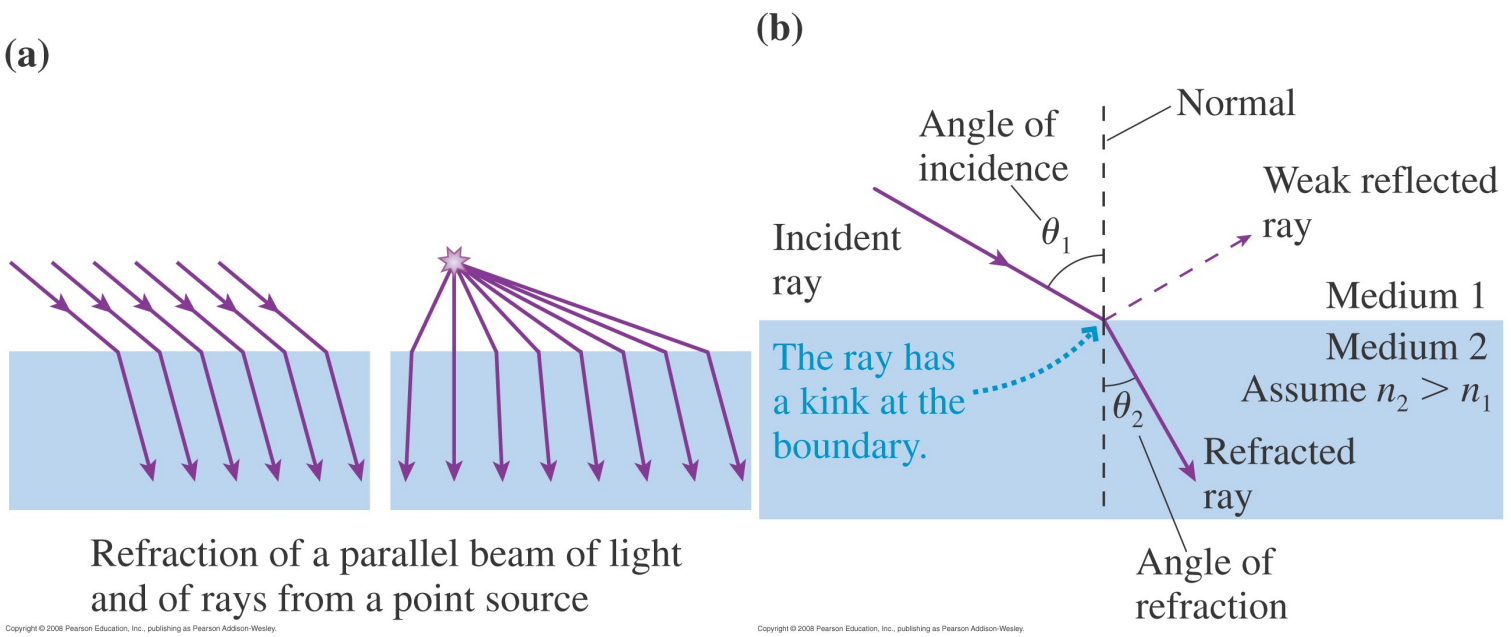

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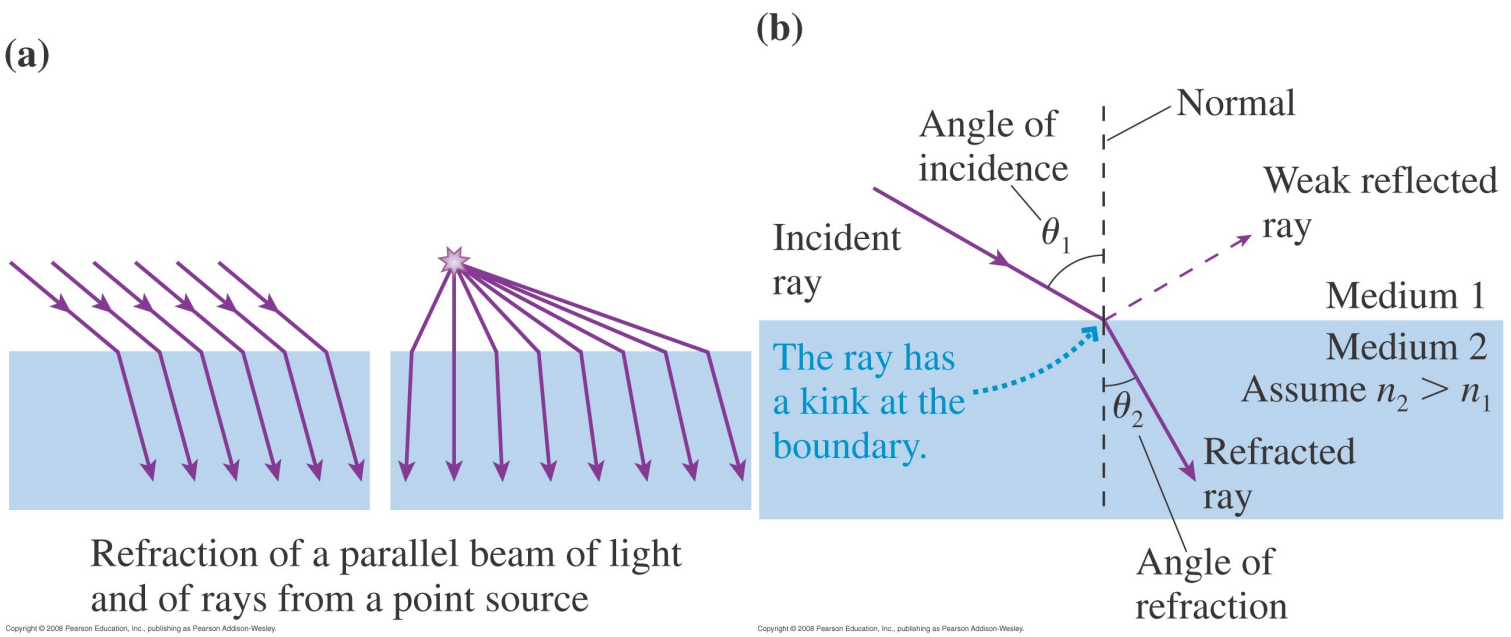

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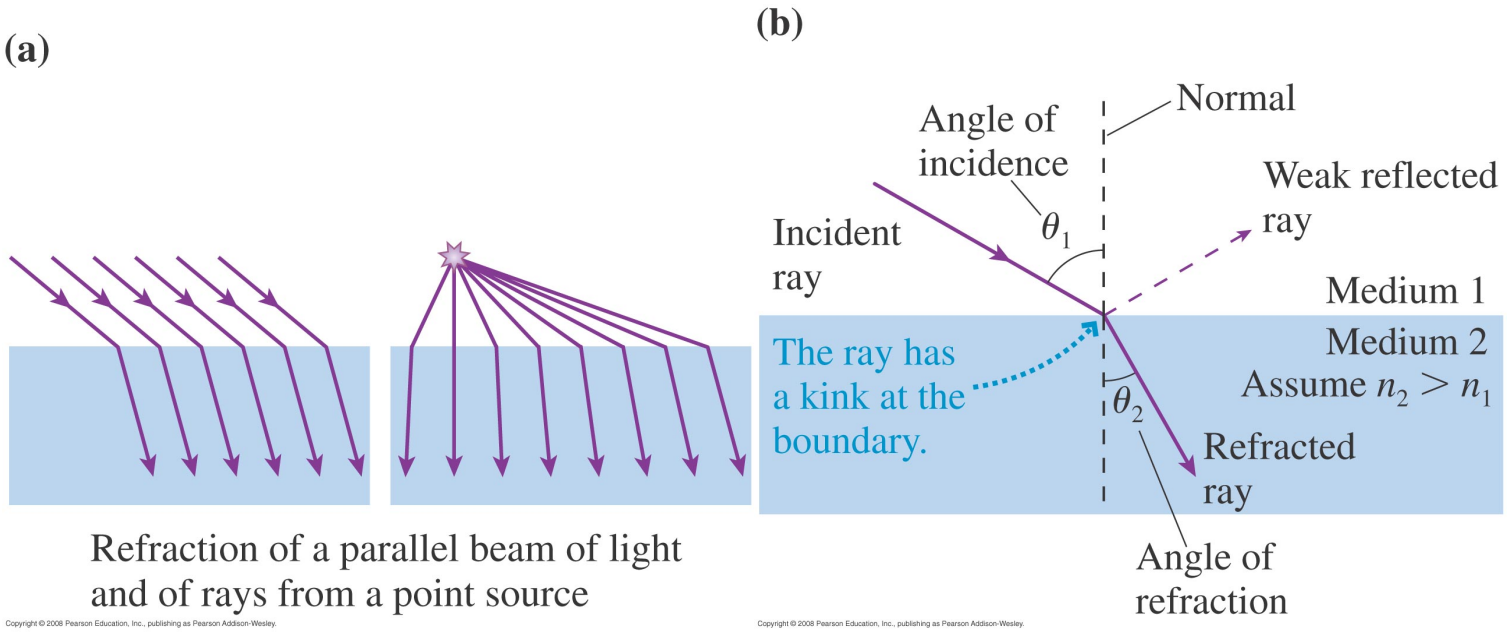

- Simplify by drawing a single ray
- The angle between the incoming ray and the normal is the angle of incidence. In medium 1, use θ_1.
- The angle on the transmitted side from the normal is the angle of refraction. In medium 2, use θ_2.
- Snell's Law tell us that

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

Index of Refraction

We have already mentioned the index of refraction a couple of times in the course...but a quick reminder:

$$n = \frac{c}{v_{medium}}$$

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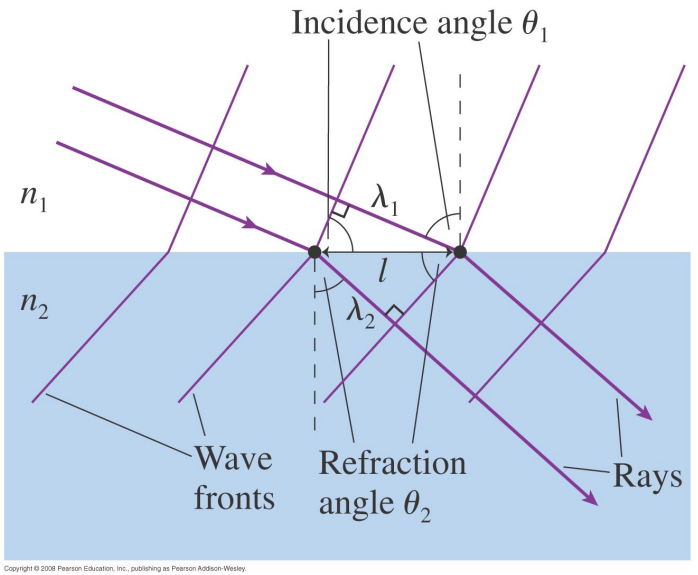

- Wave fronts are crests of waves

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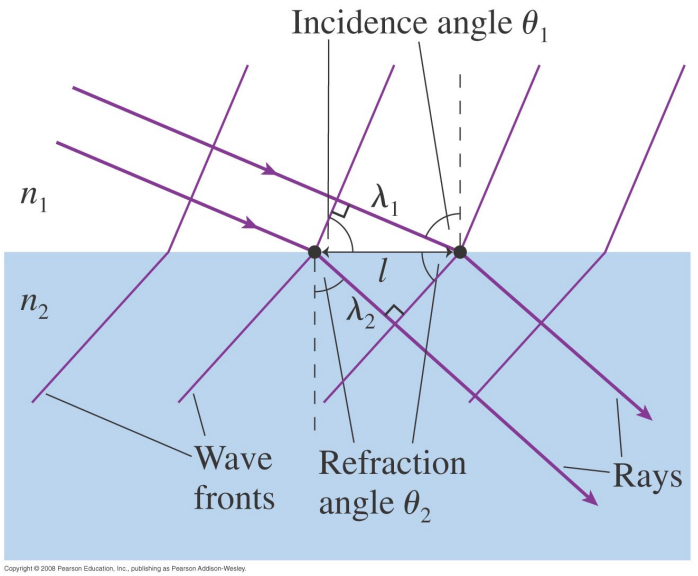

- Wave fronts are crests of waves
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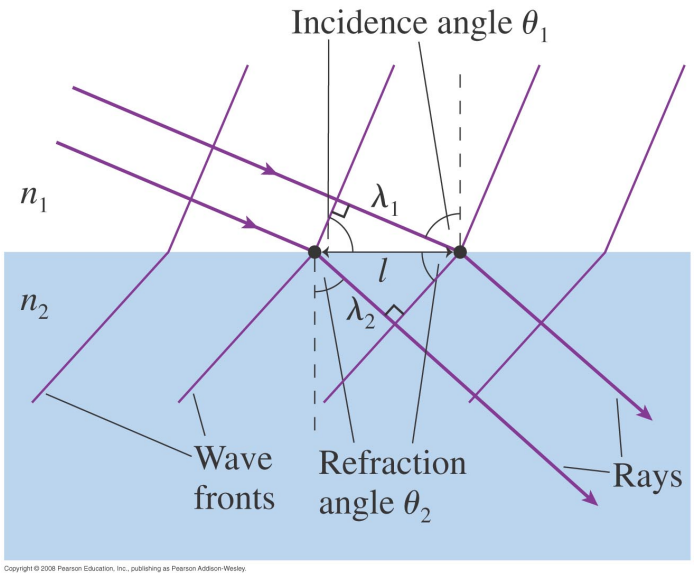

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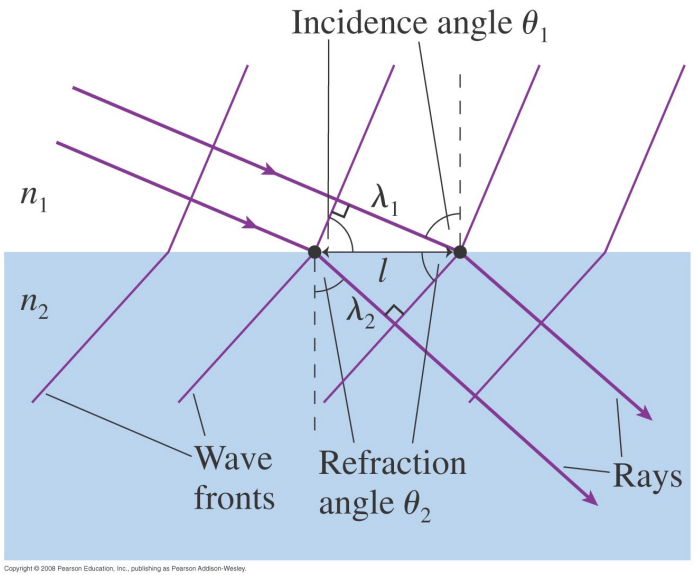

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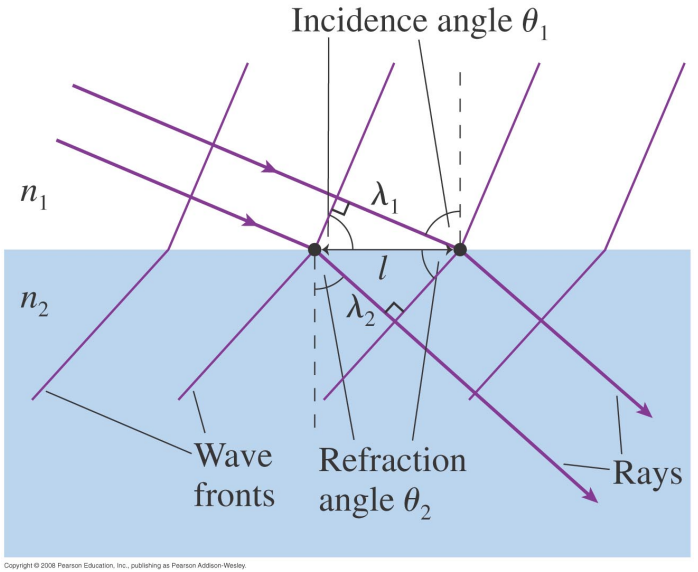

- Using upper and lower triangles:

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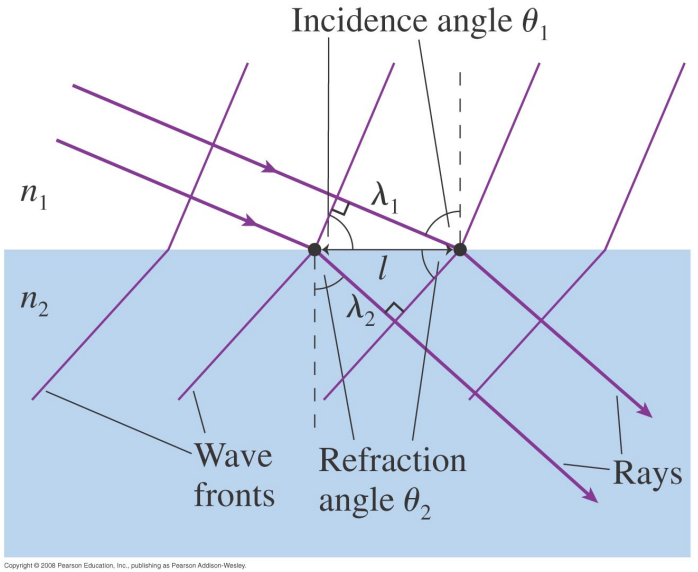

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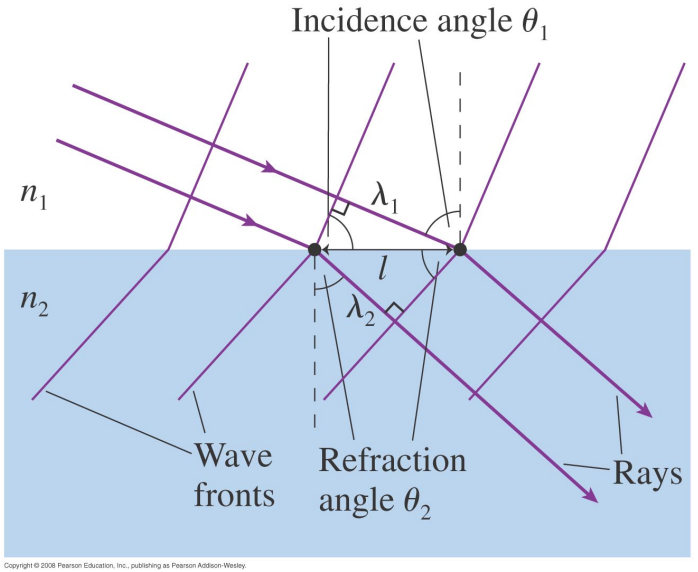

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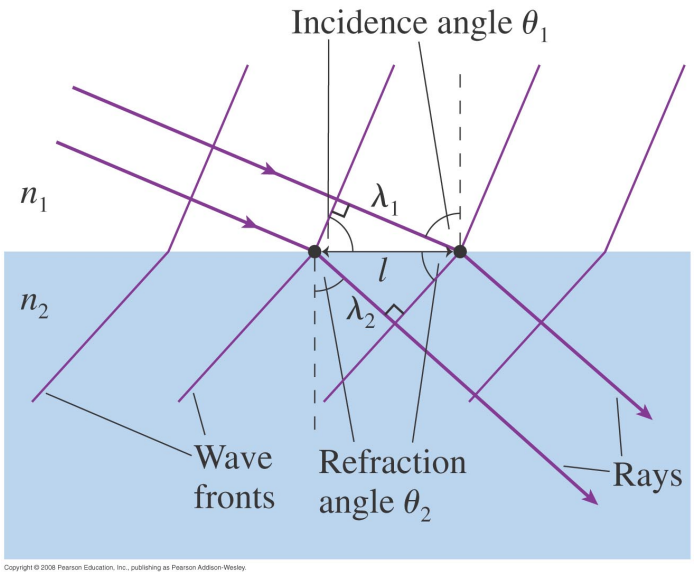

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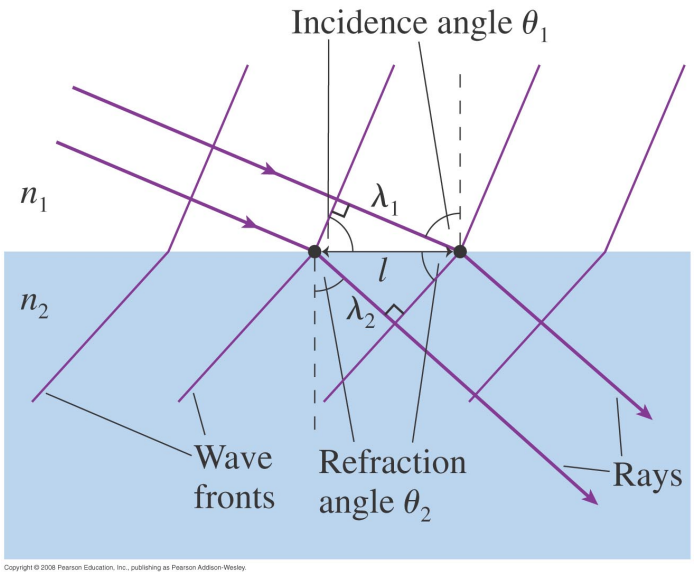

- Using upper and lower triangles:

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- Setting these equal to each other and using $\lambda_1 = \lambda_0/n_1$, $\lambda_2 = \lambda_0/n_2$ gives

$$\frac{\lambda_0}{n_1 \sin\theta_1} = \frac{\lambda_0}{n_2 \sin\theta_2}$$
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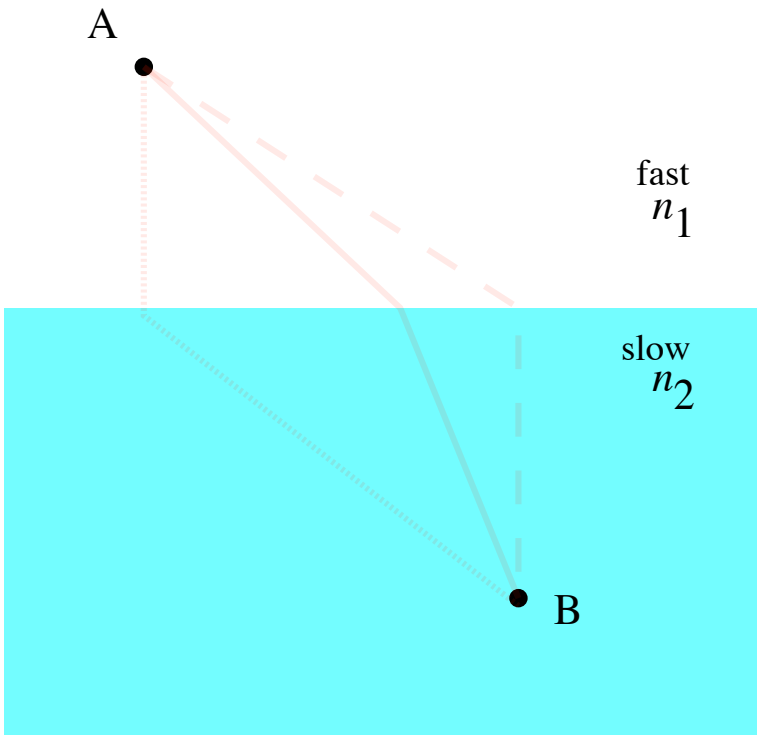
Fermat's Principle for Refraction



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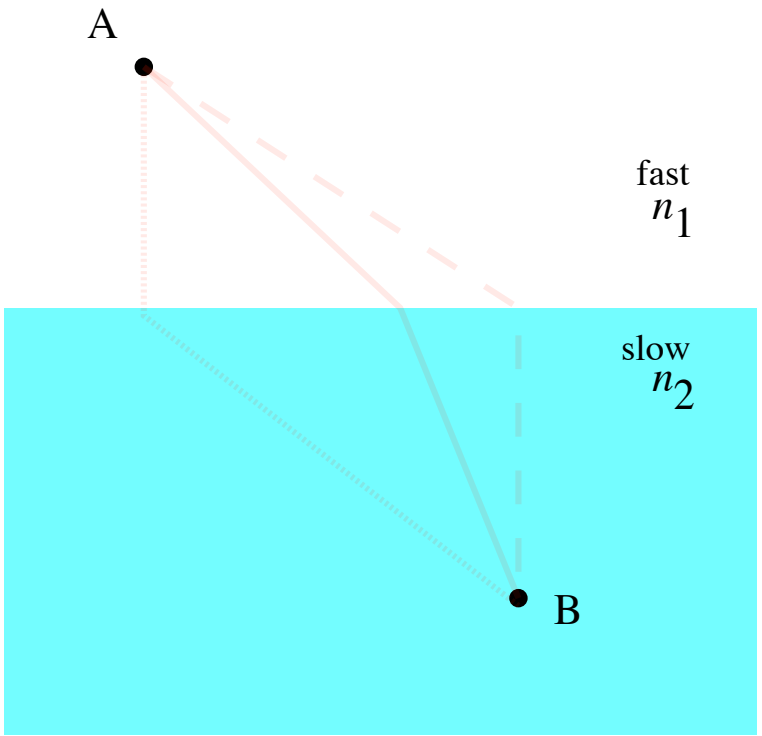

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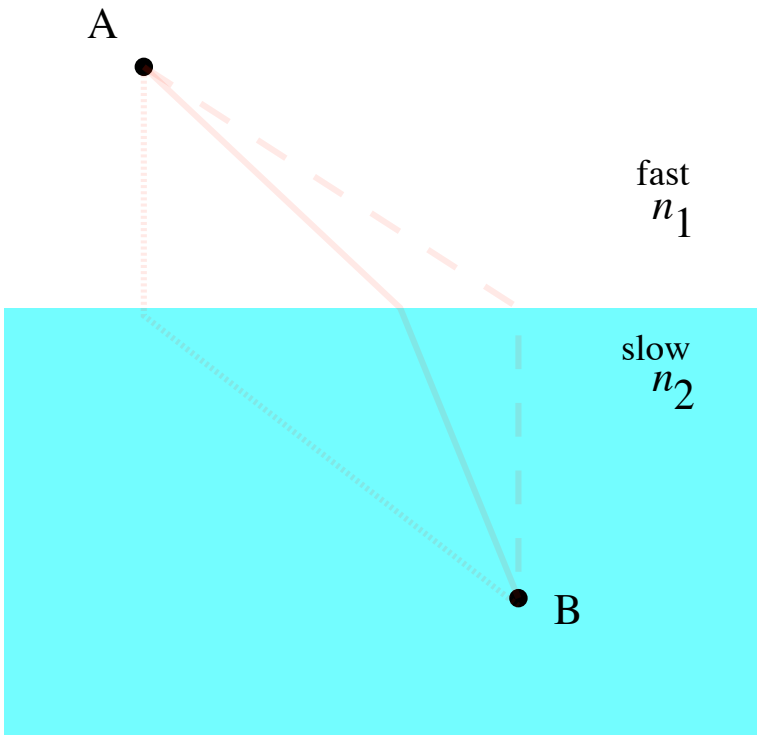

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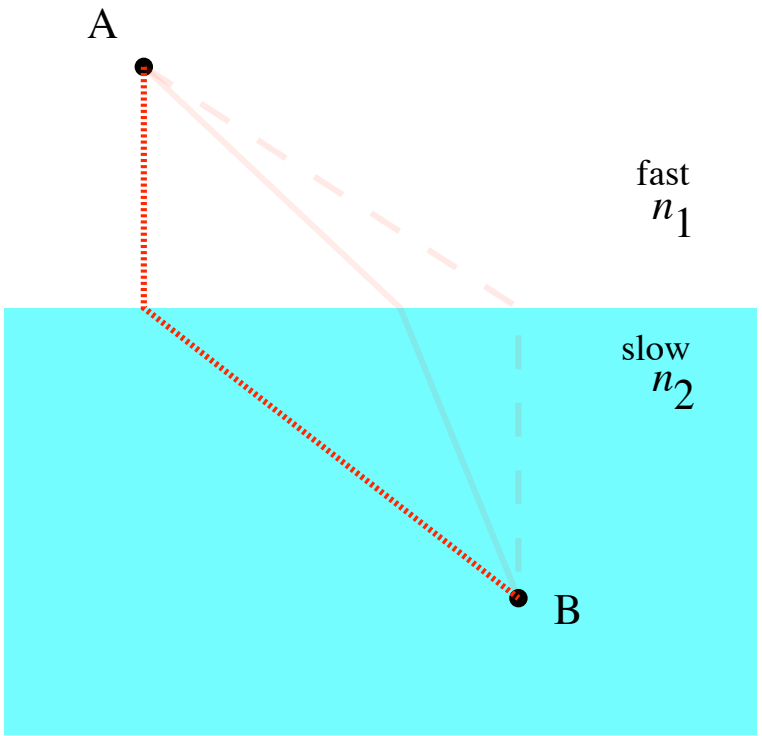

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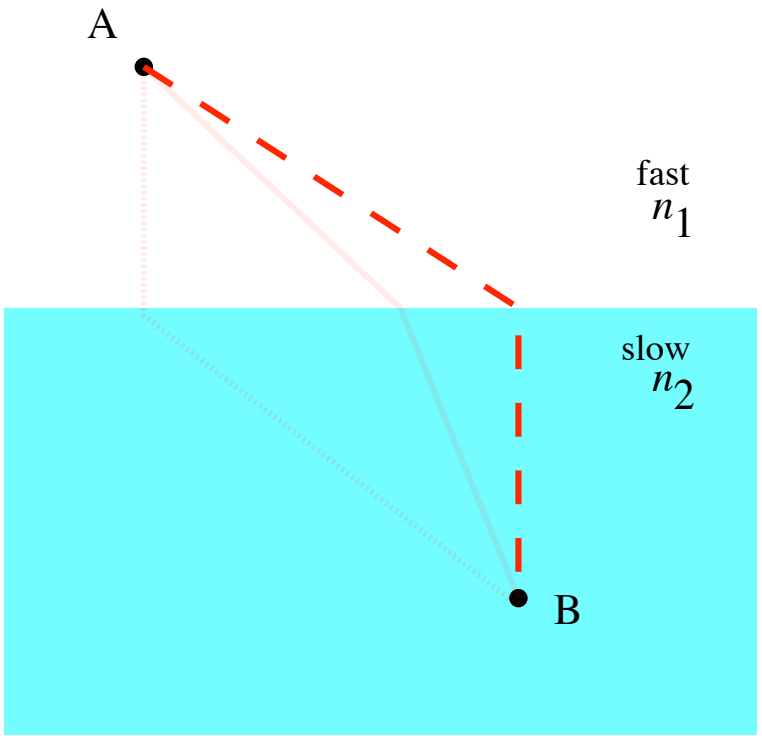

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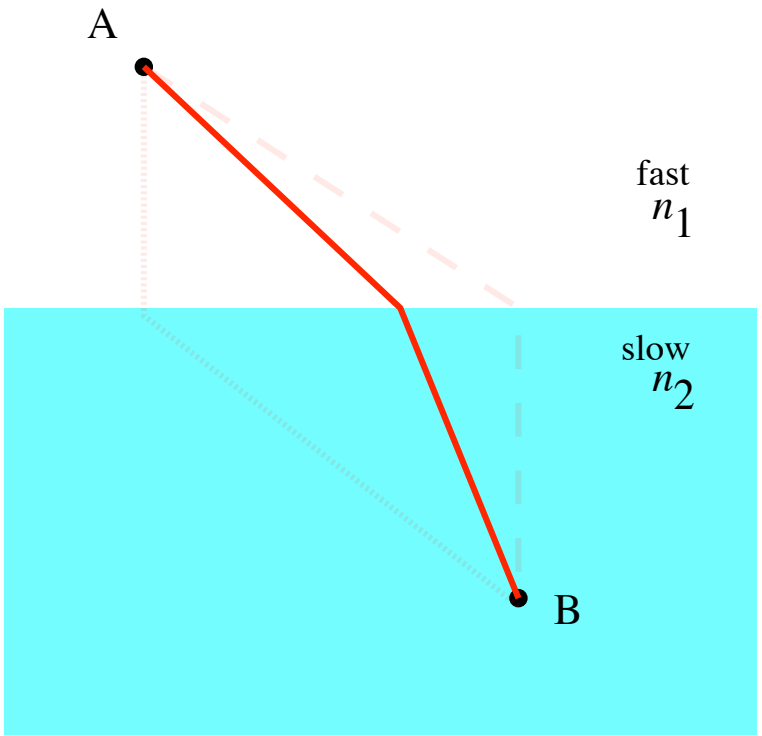

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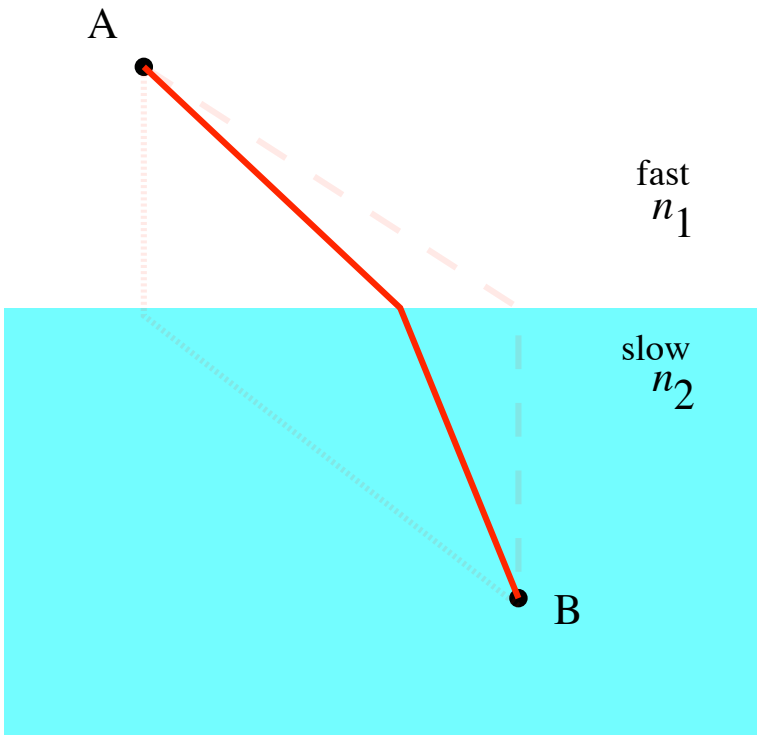

- It turns out that Fermat's Principle is consistent with Snell's law.
- See problem CP23.80 in the textbook.

Fermat's Principle, Philisophical Reflection

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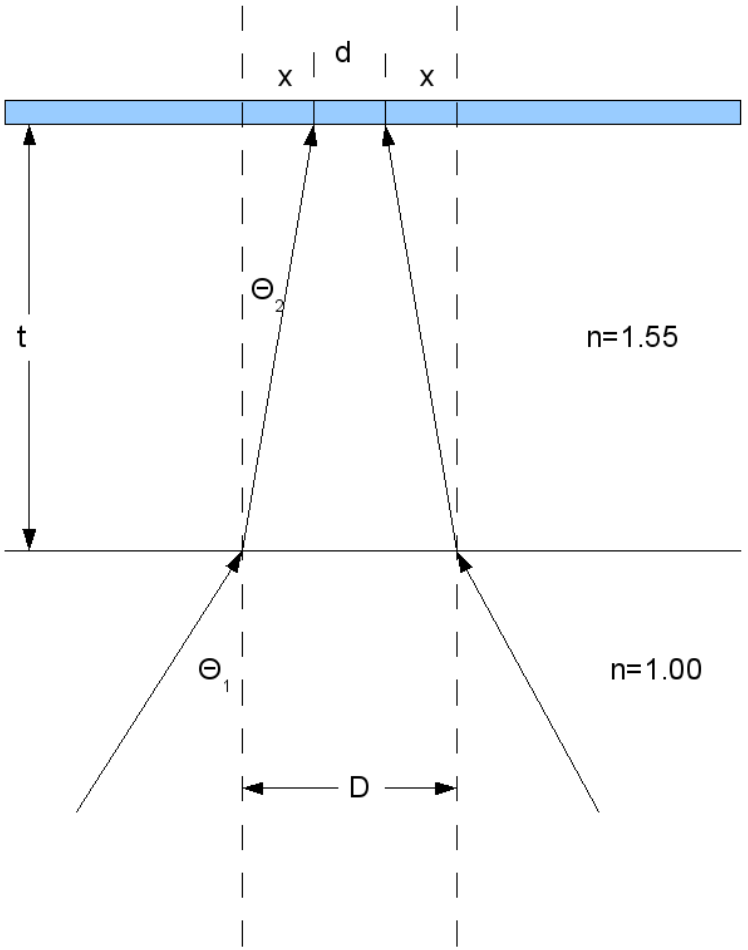
Example: Refraction and CDs



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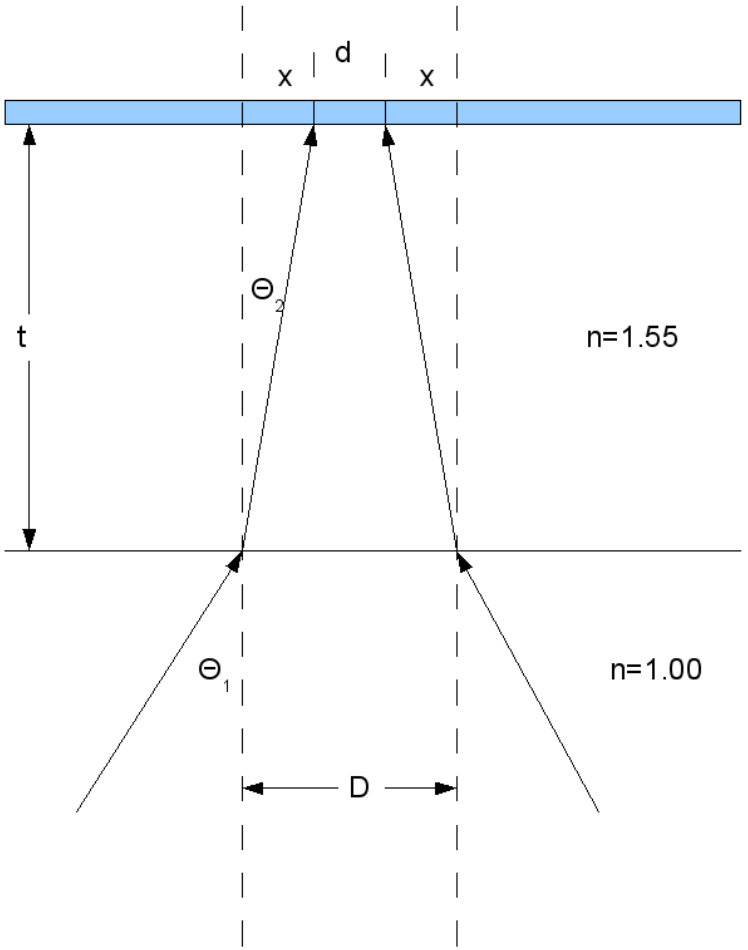

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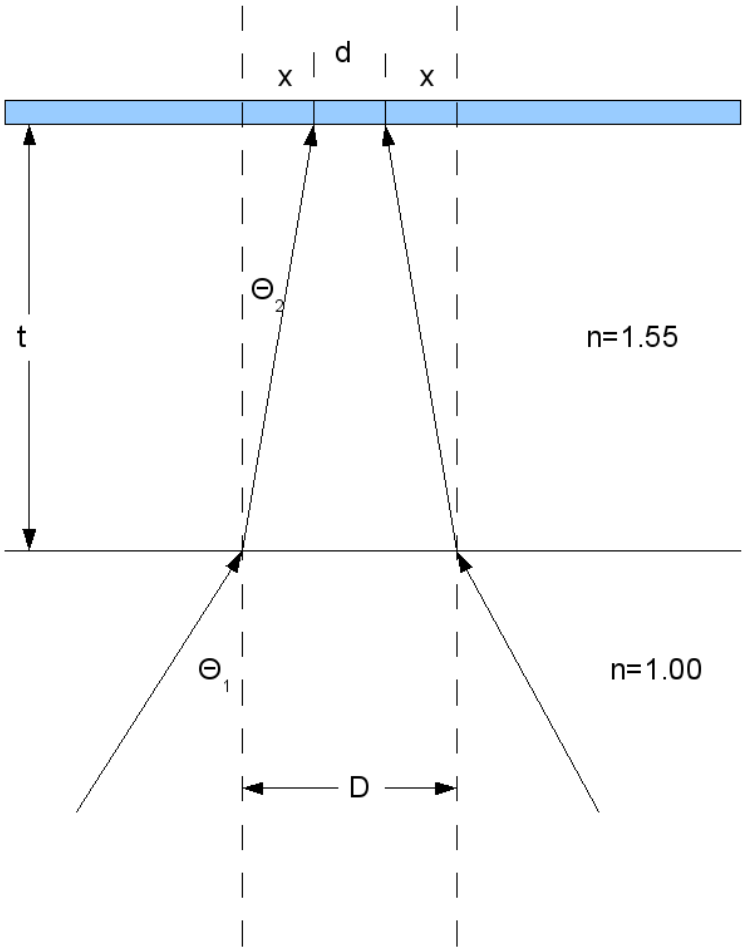

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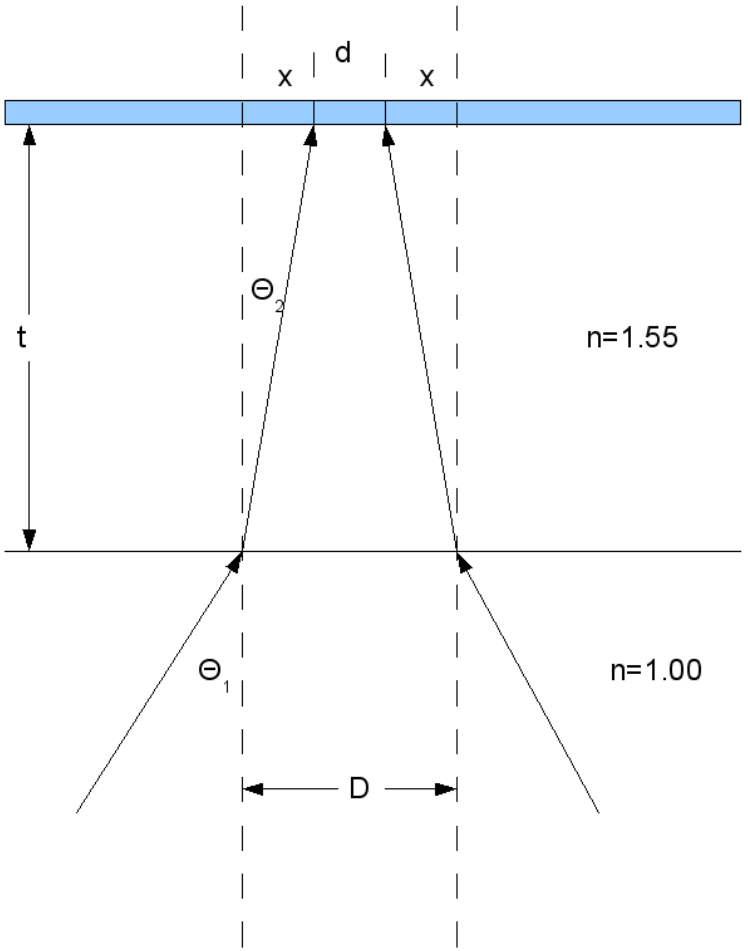

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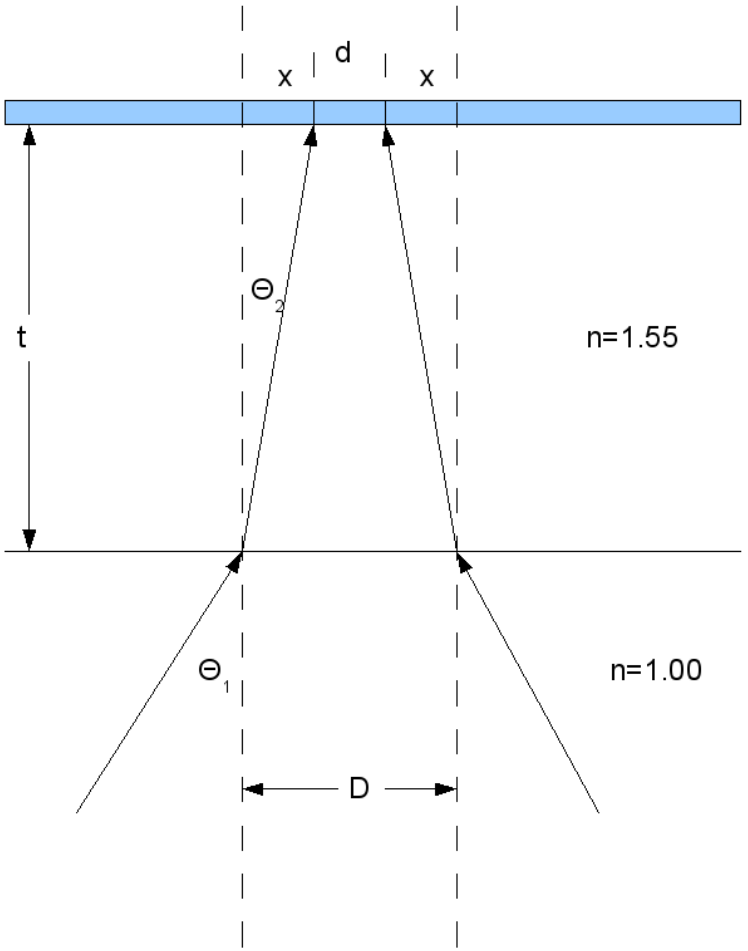

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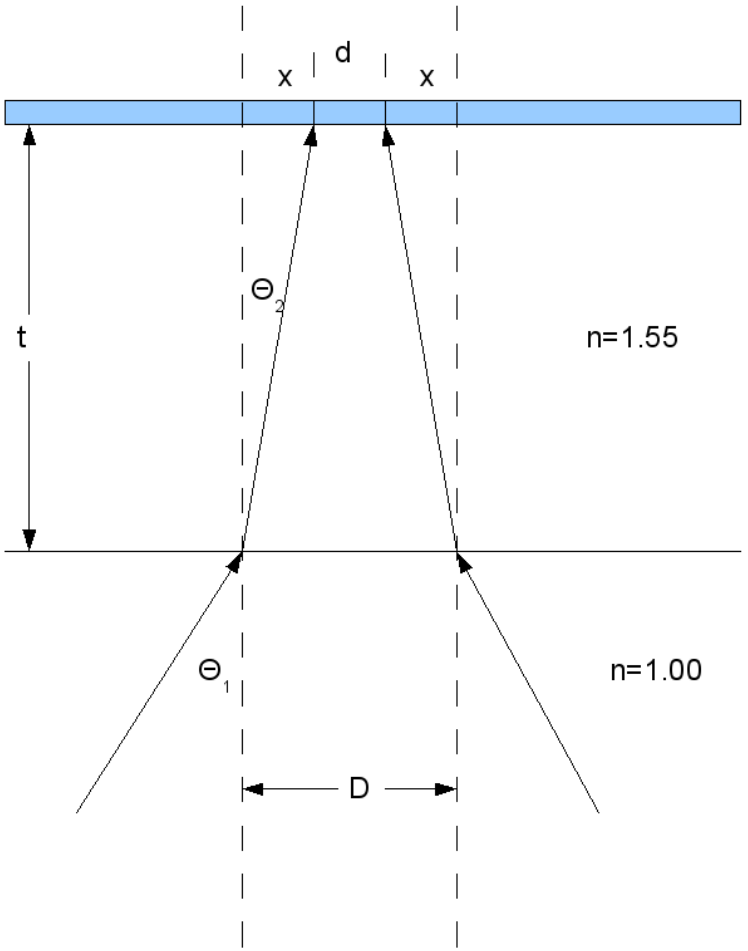

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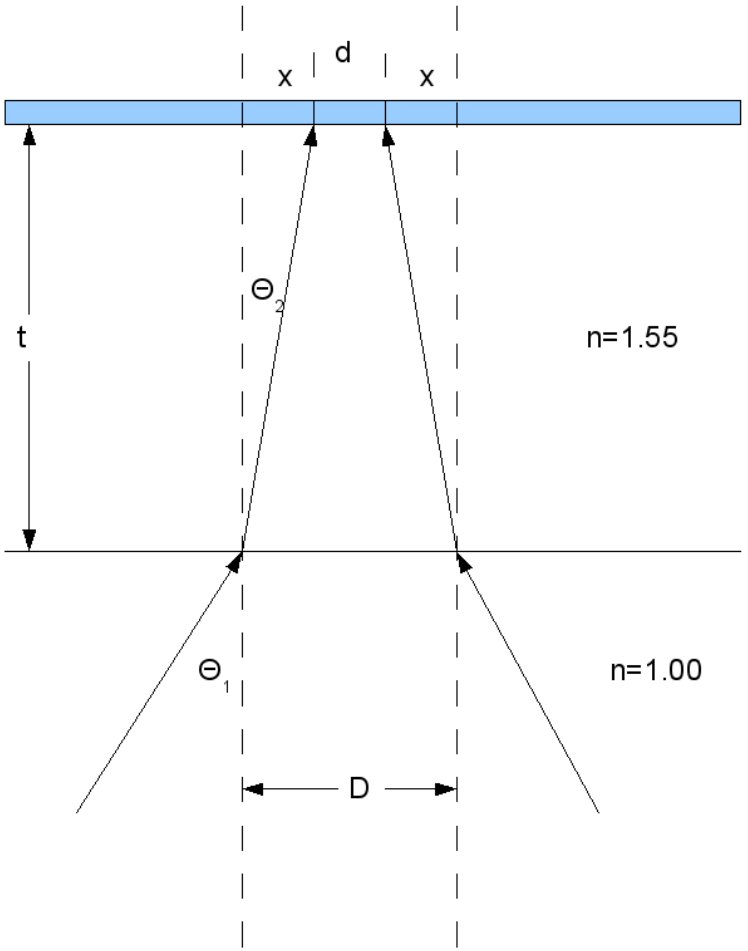

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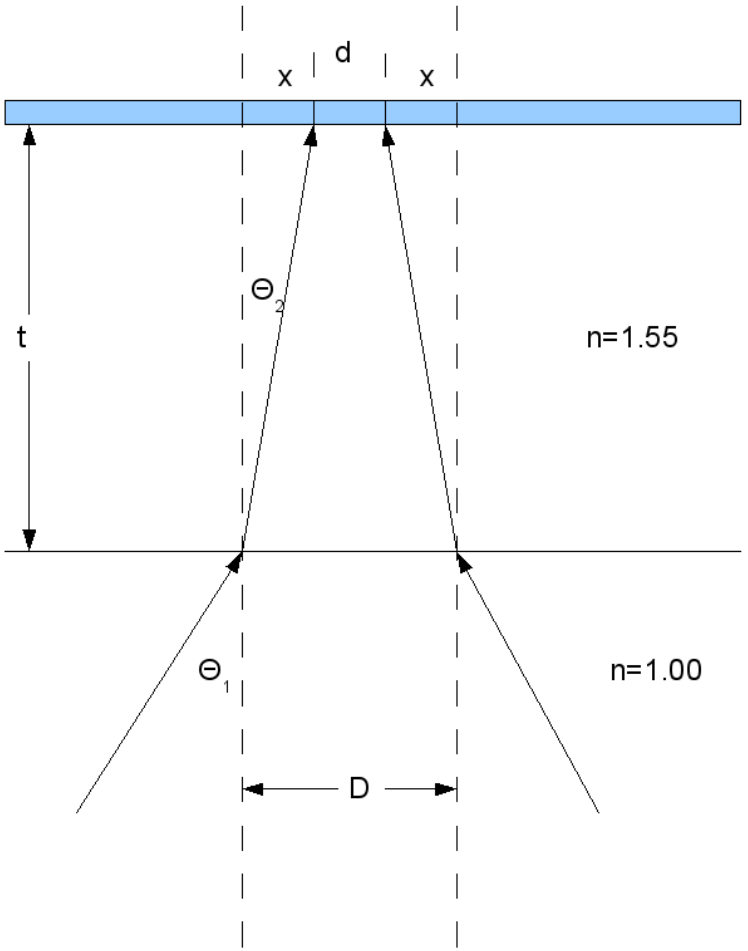

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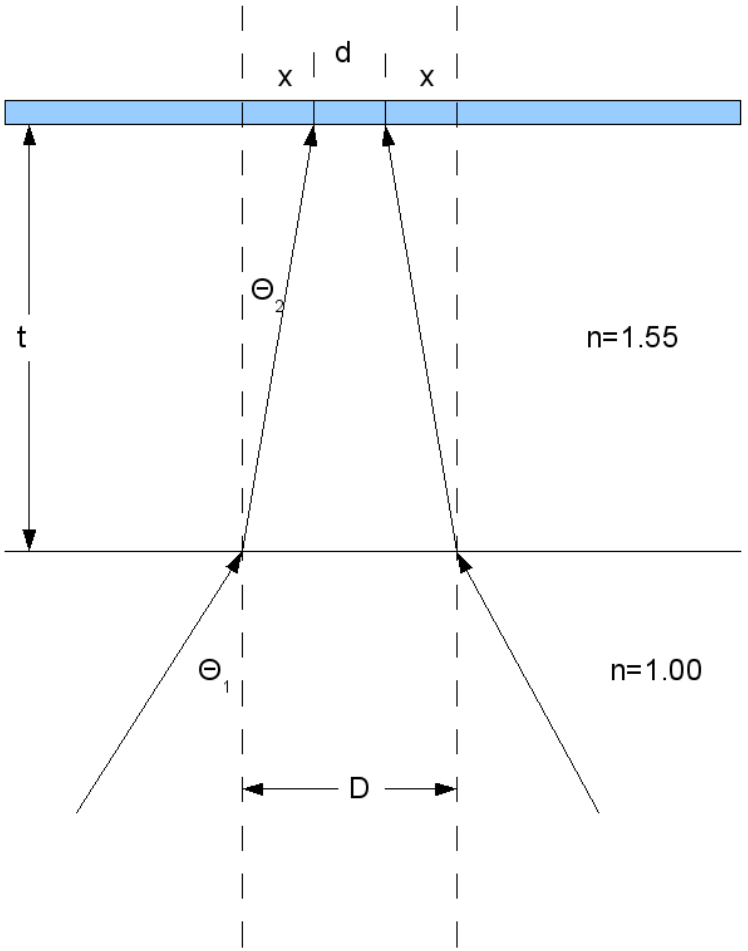

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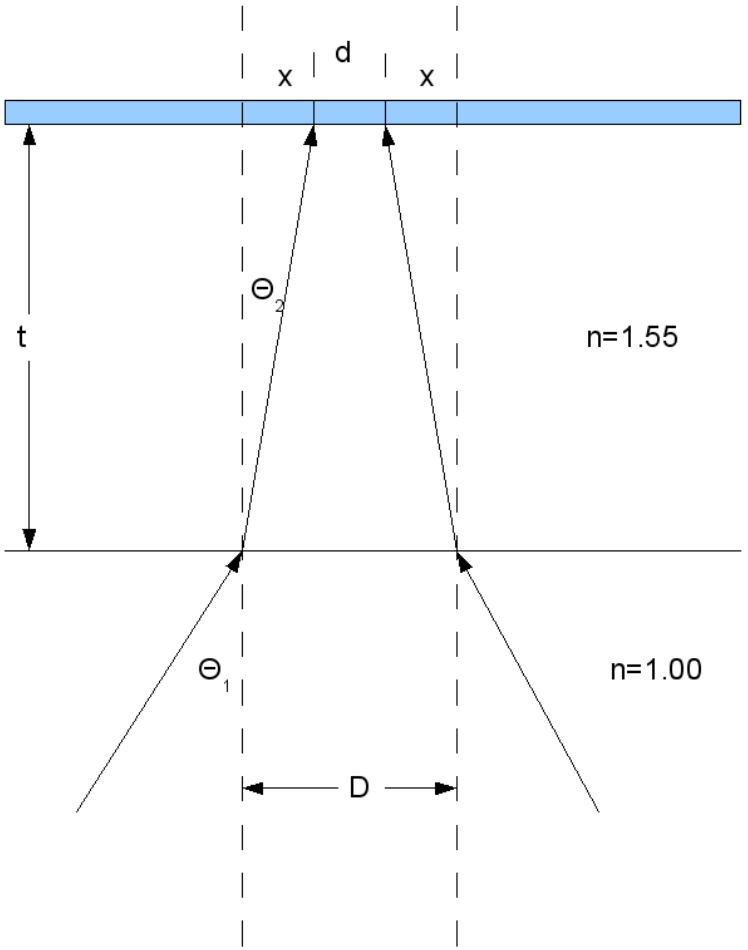

- The bumps in a CD are about 0.6 μm wide, 0.9 to 3.3 μm long and 0.12 μm deep.

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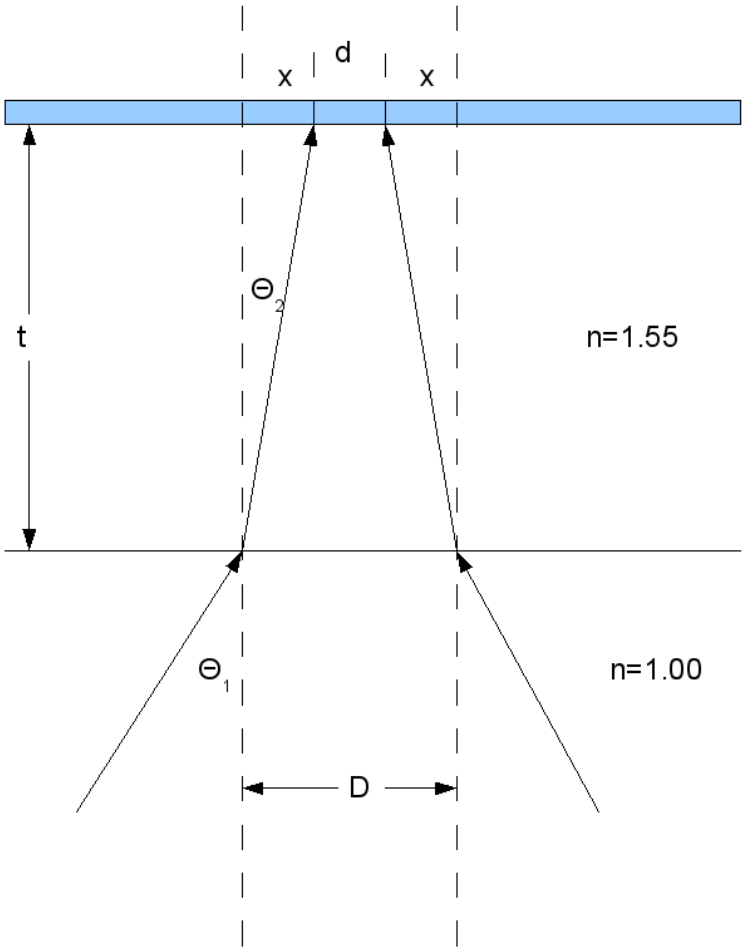

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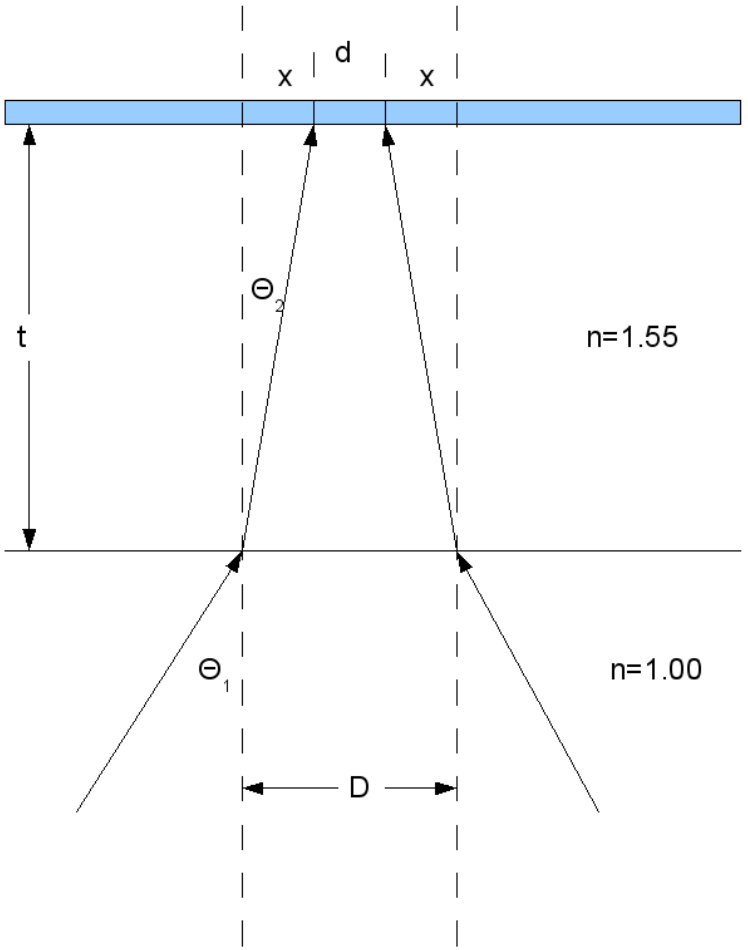

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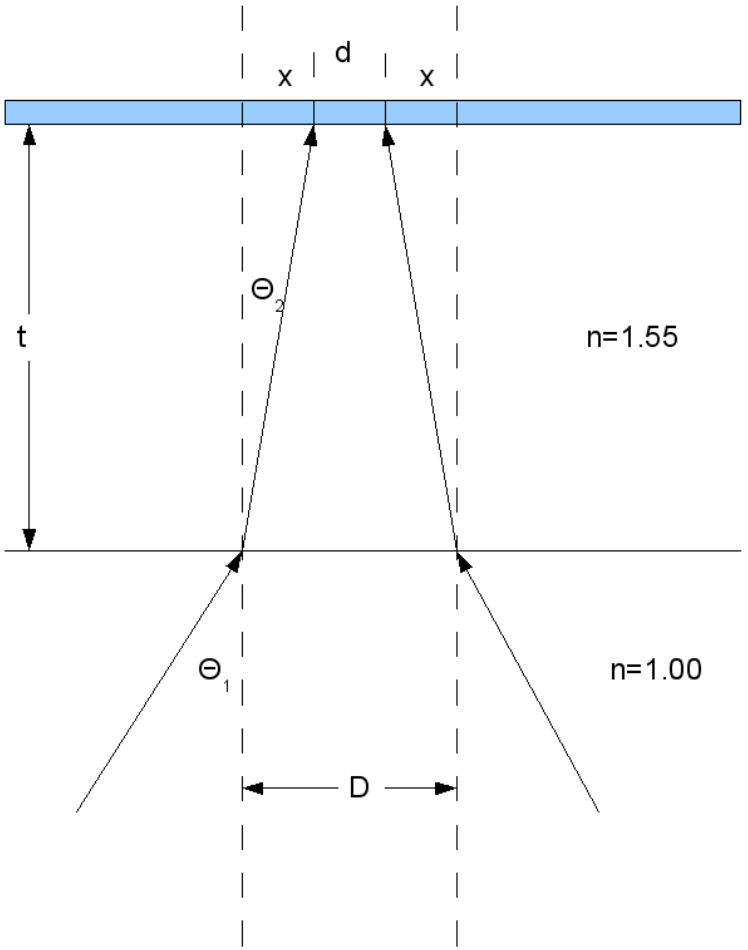

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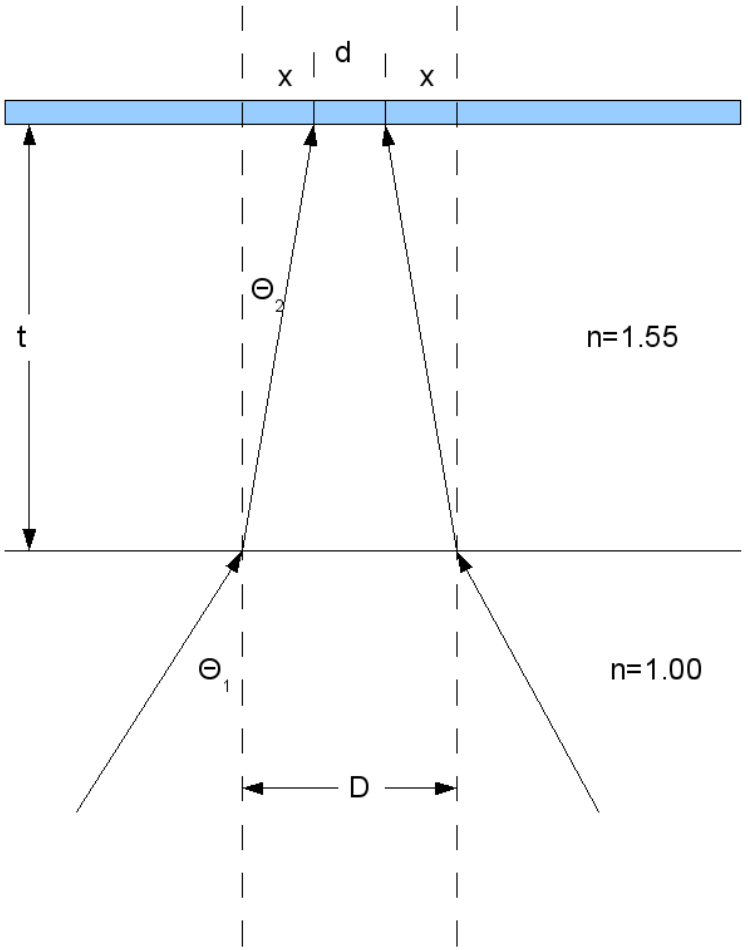

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- The beam needs to be narrowed in order to work!
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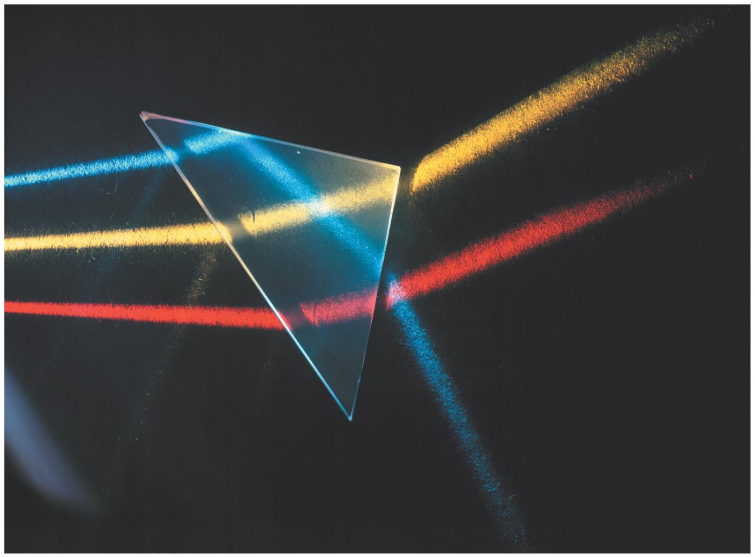
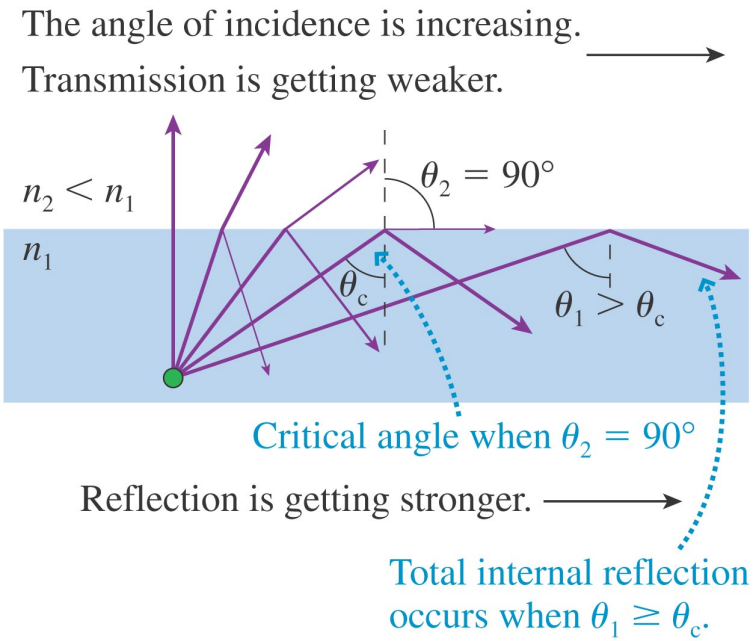
Total Internal Reflection (23.3)





- If light strikes a boundary in which it transitions from a high index of refraction to a lower one, it can undergo Total Internal Reflection (TIR).

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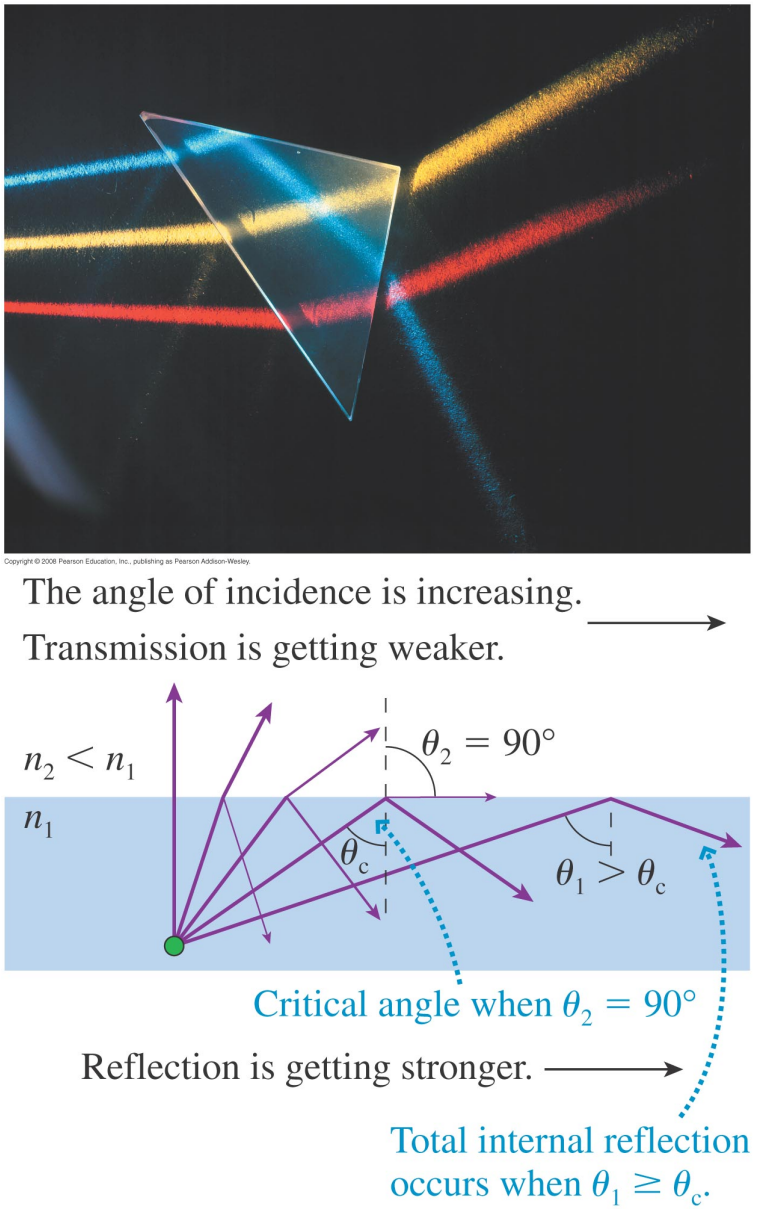

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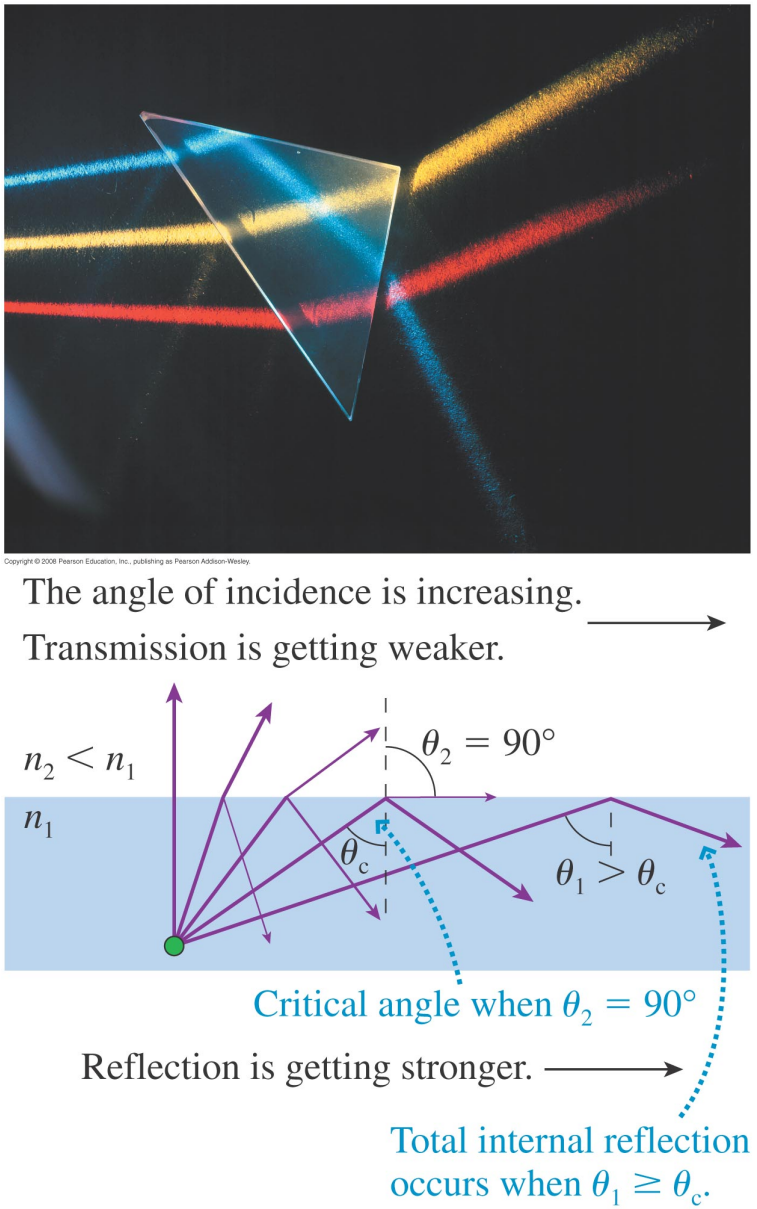

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- The figure on the left shows several rays leaving a source inside a high-n medium. As the angle of incidence gets larger the angle of refraction gets closer and closer to 90°.
- When the angle of refraction (θ_2) is exactly 90 degrees we reach the critical angle. Above the critical angle there is no transmitted light.

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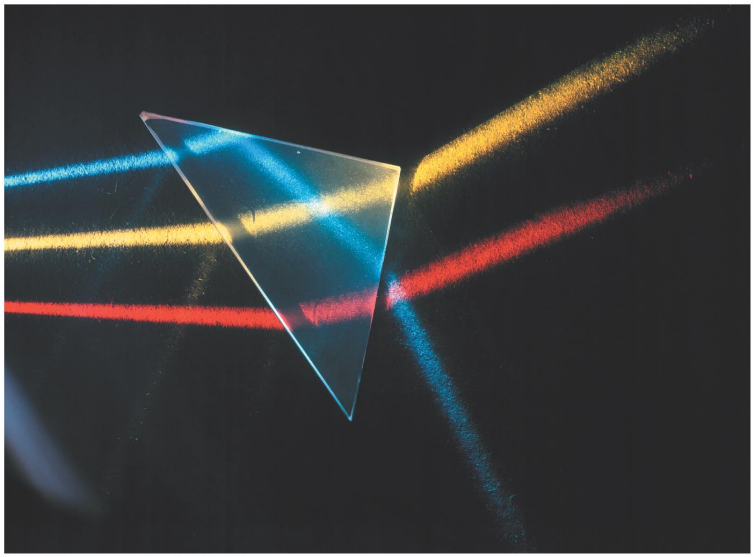

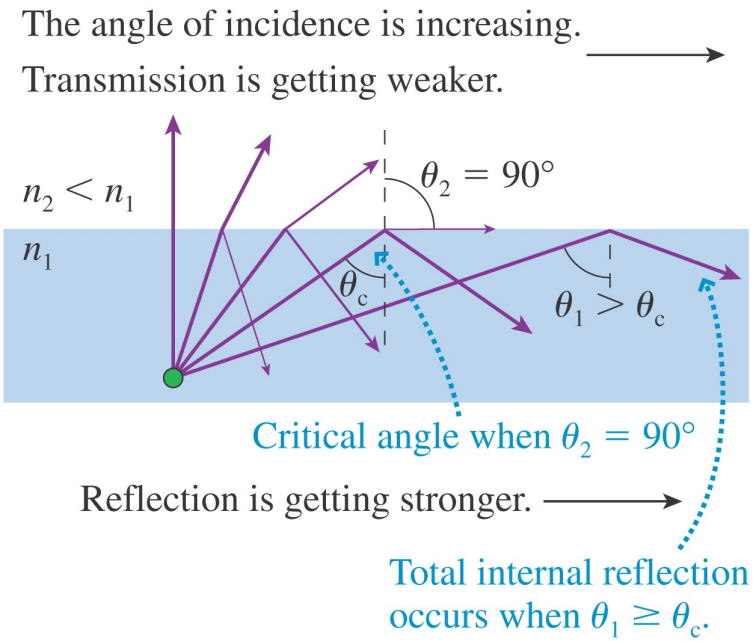

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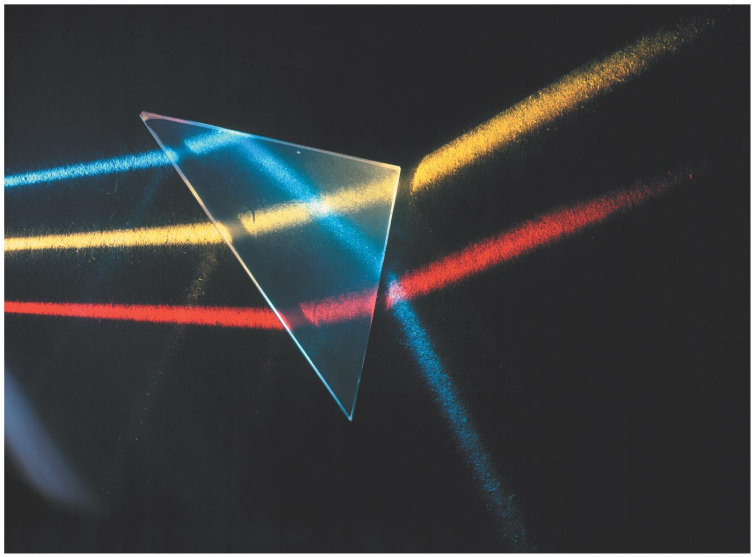

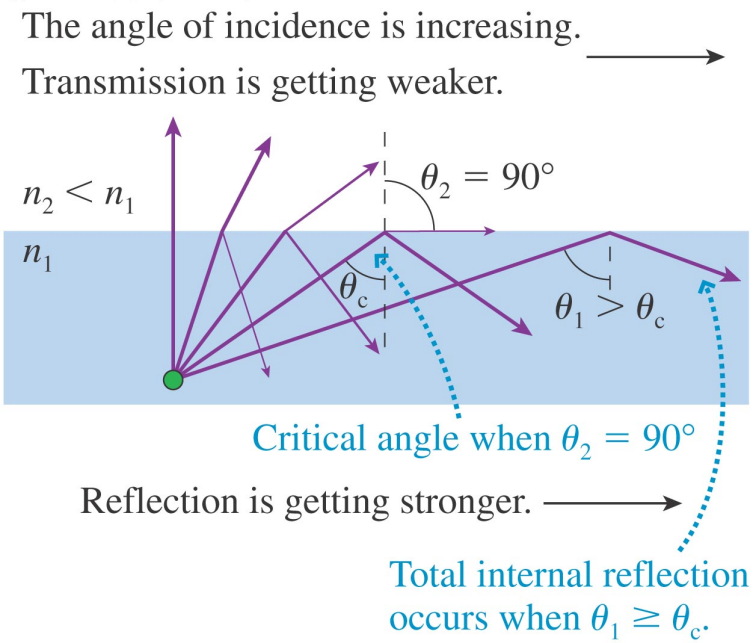

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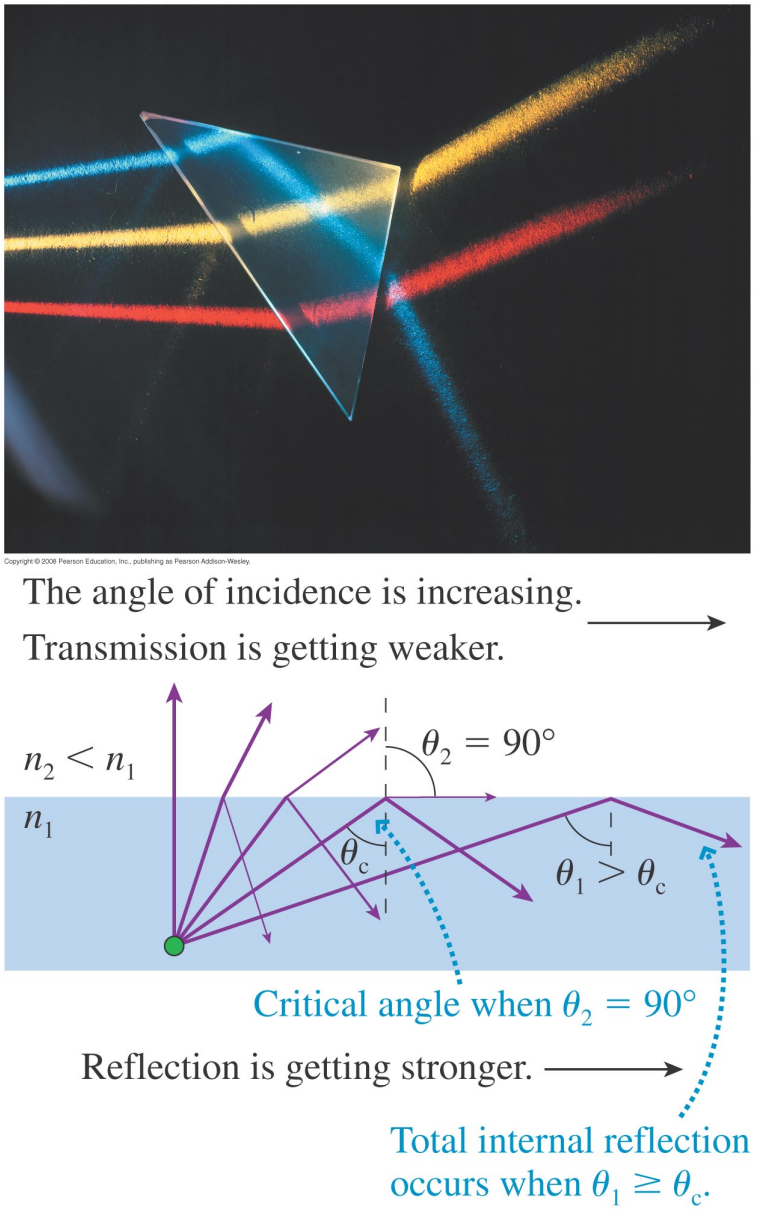

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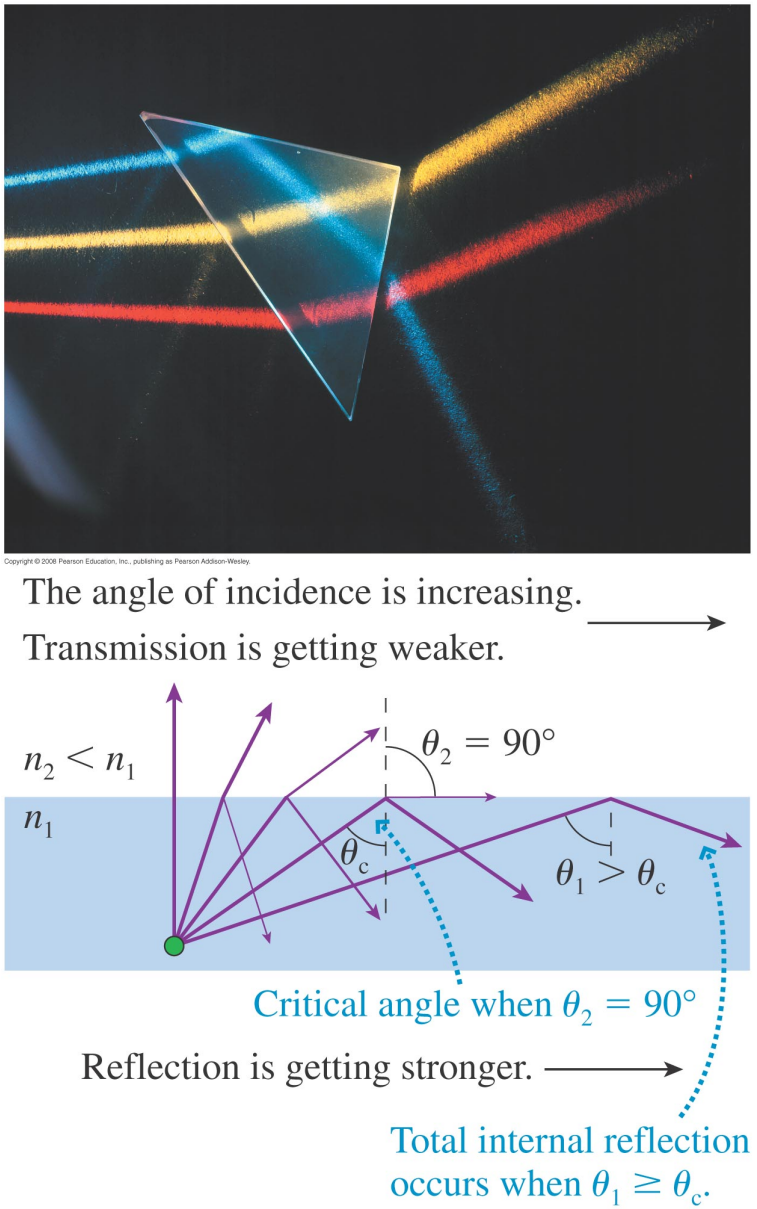

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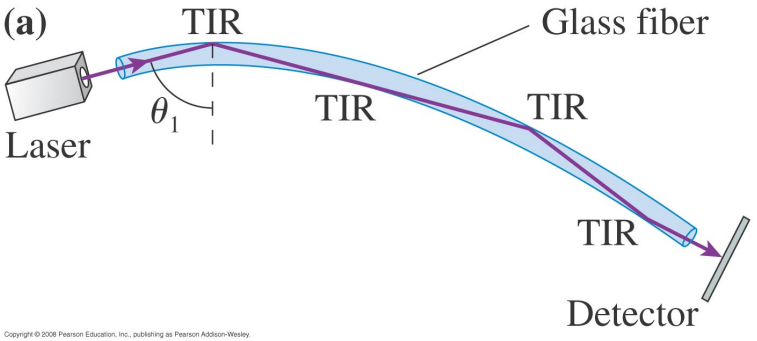
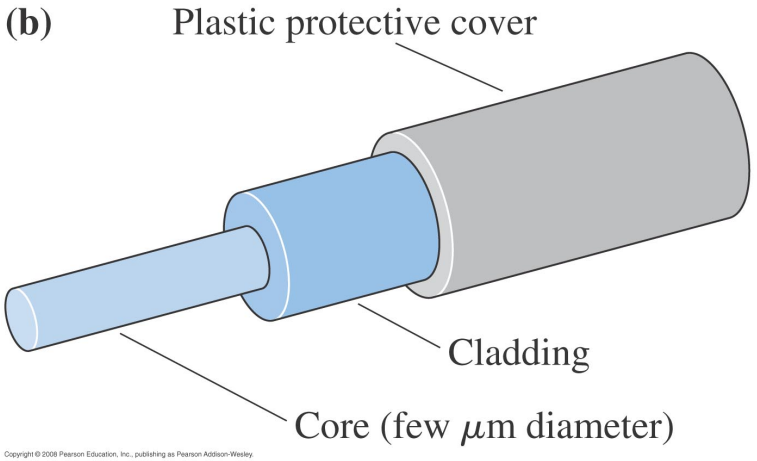
Fibre Optics





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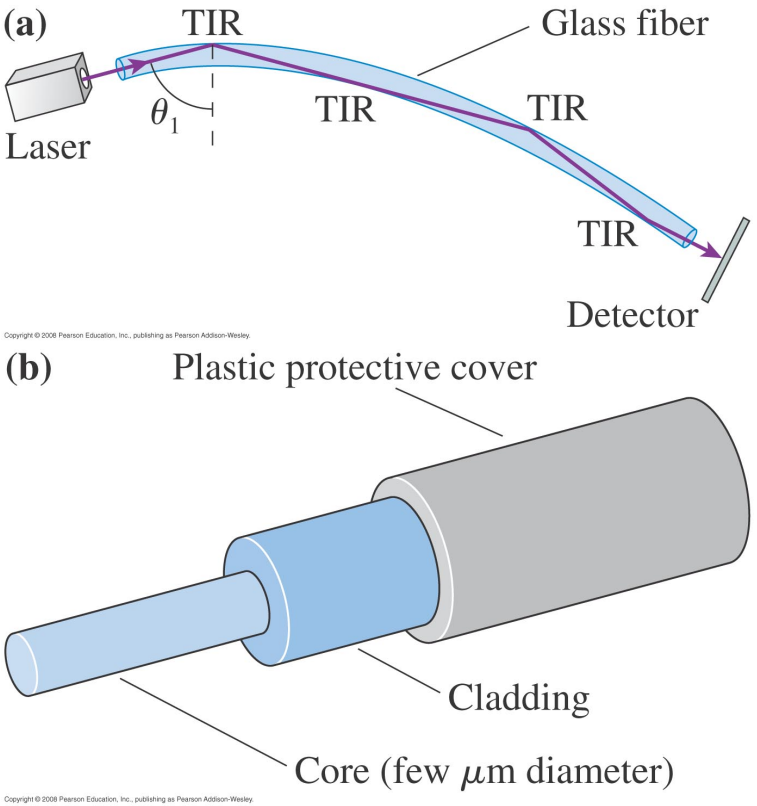
Fibre Optics



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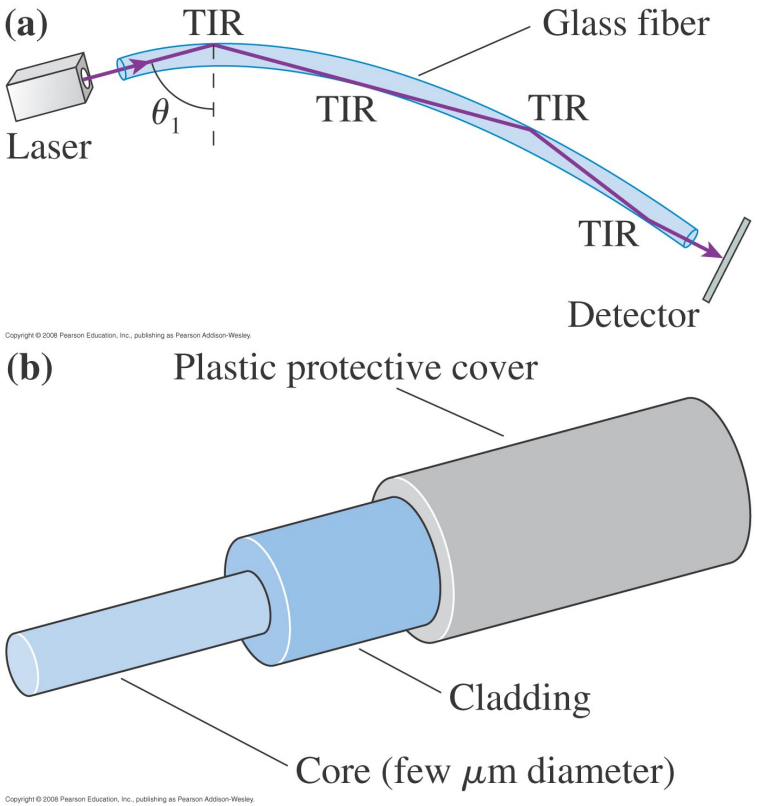

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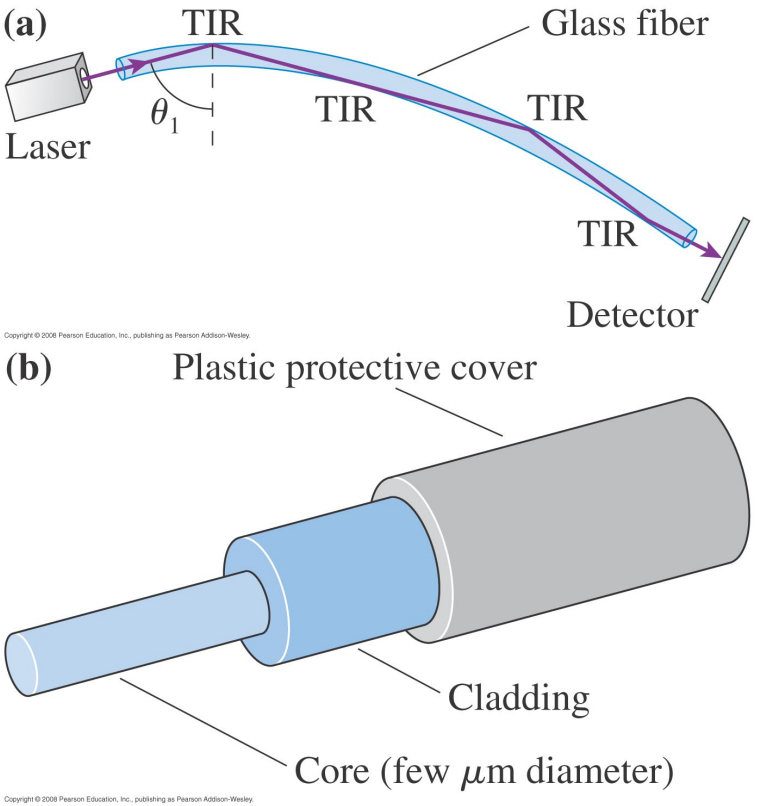

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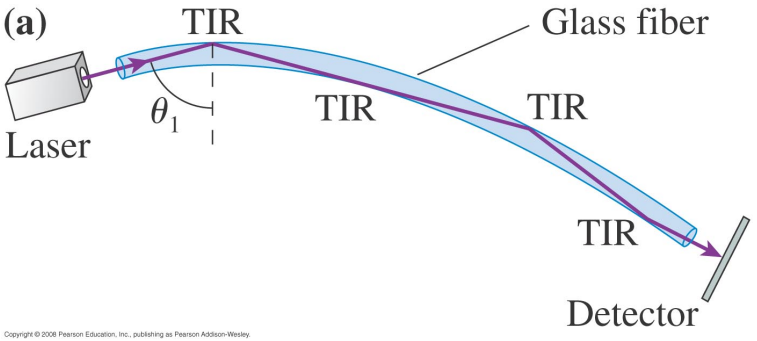
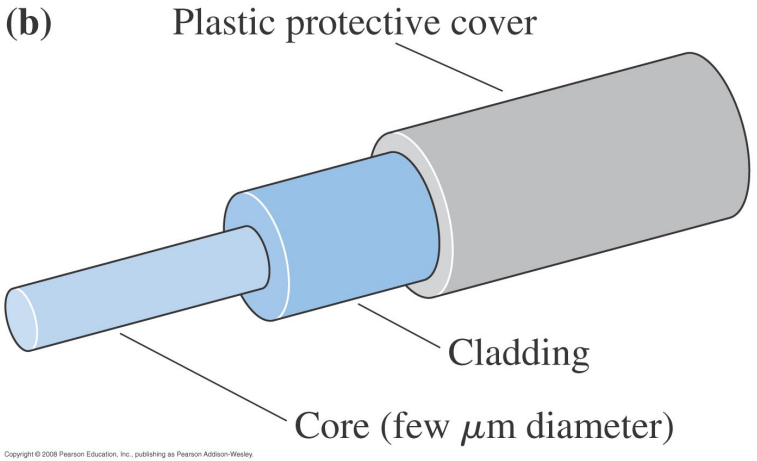
- They are covered in lower-index cladding to prevent light leakage (e.g., scratches).

Fibre Optics





- Tremendous advantages for transmitting information:

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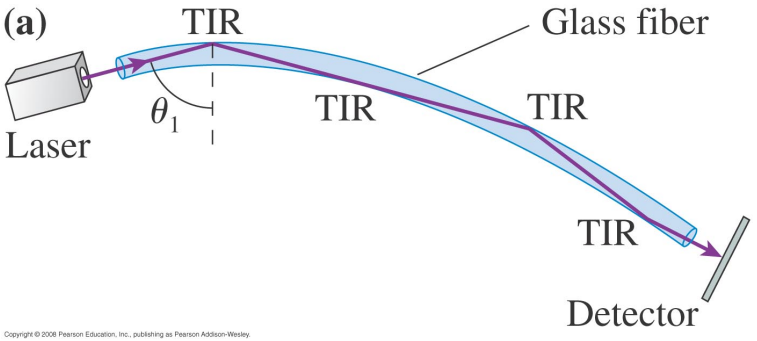

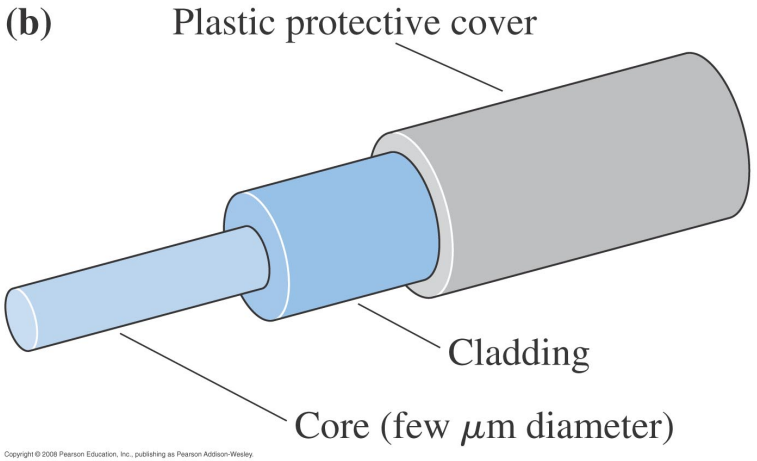

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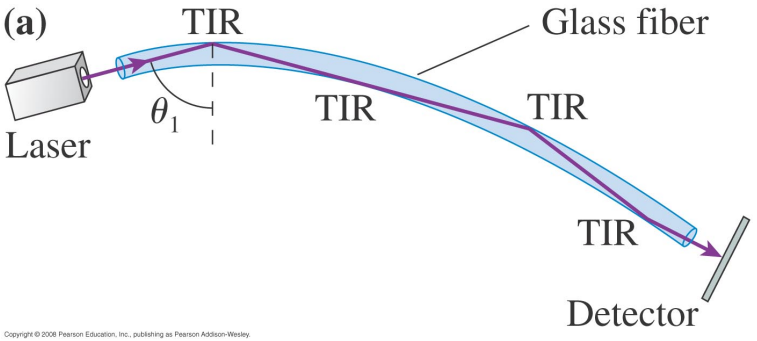

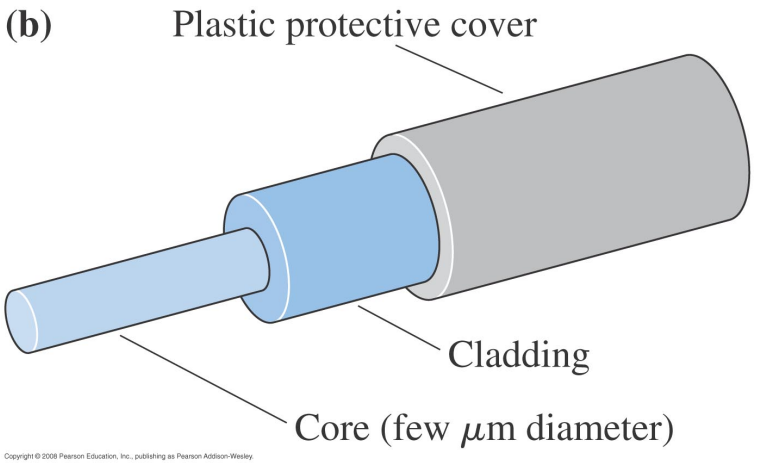

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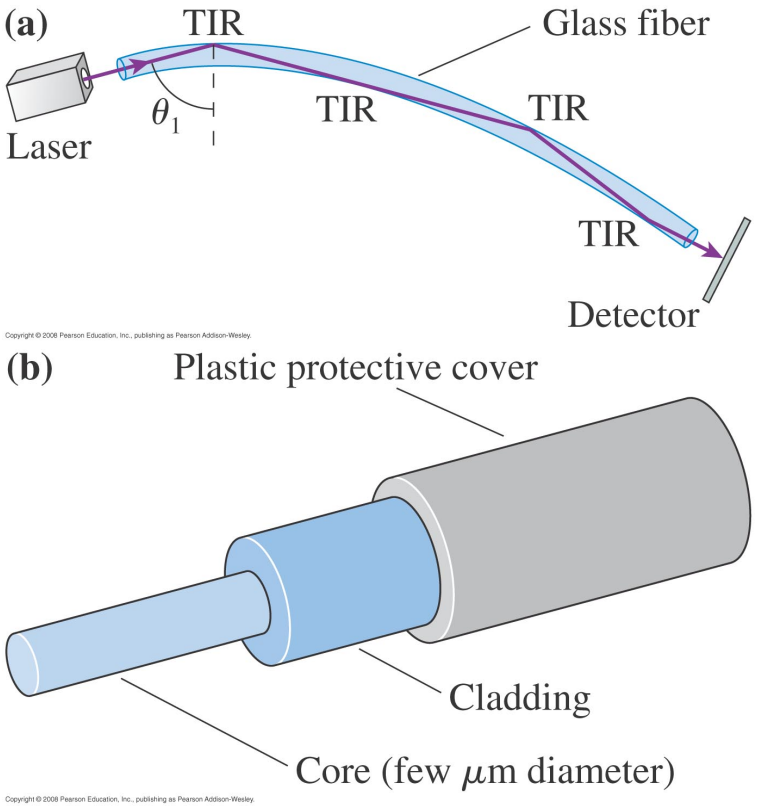

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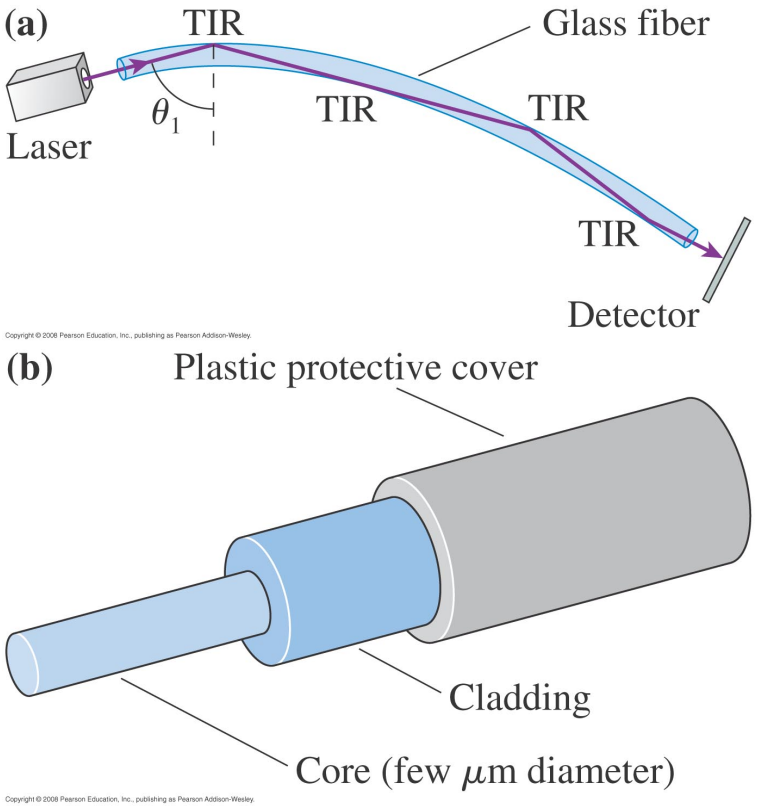

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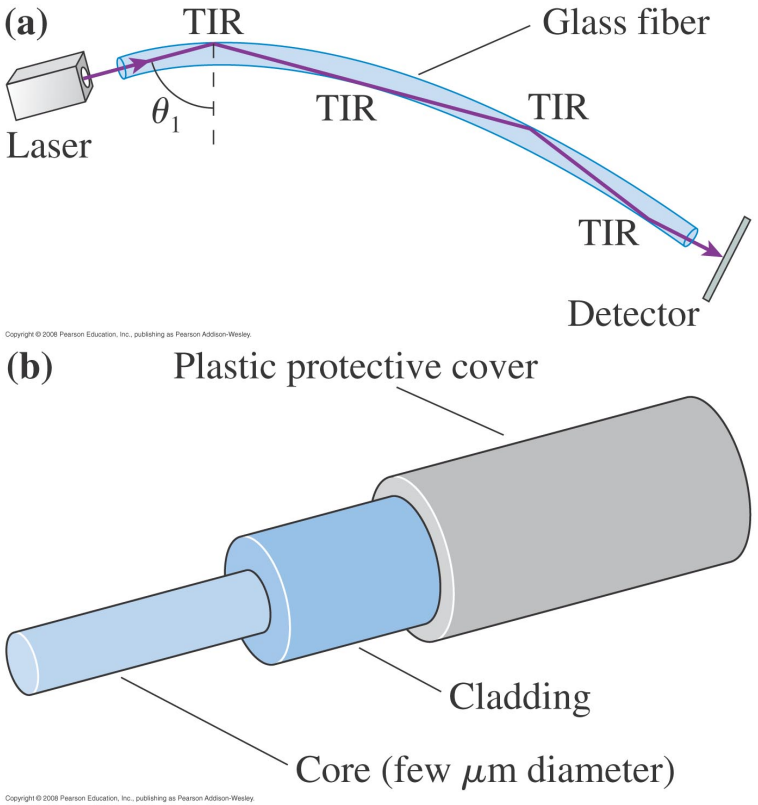

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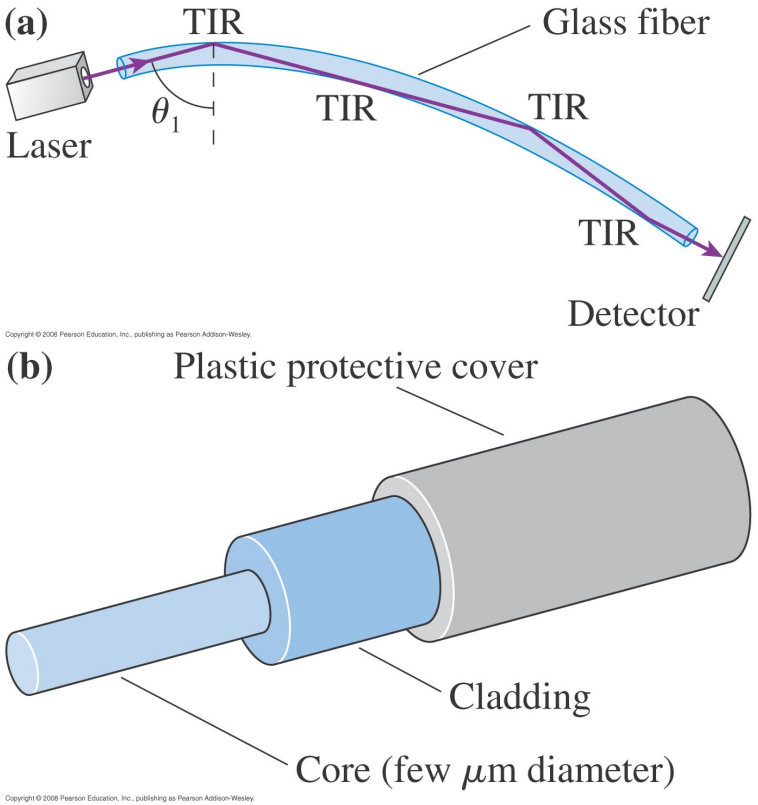

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