Optics
Total Internal Reflection
Image formation from Mirrors

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Last time

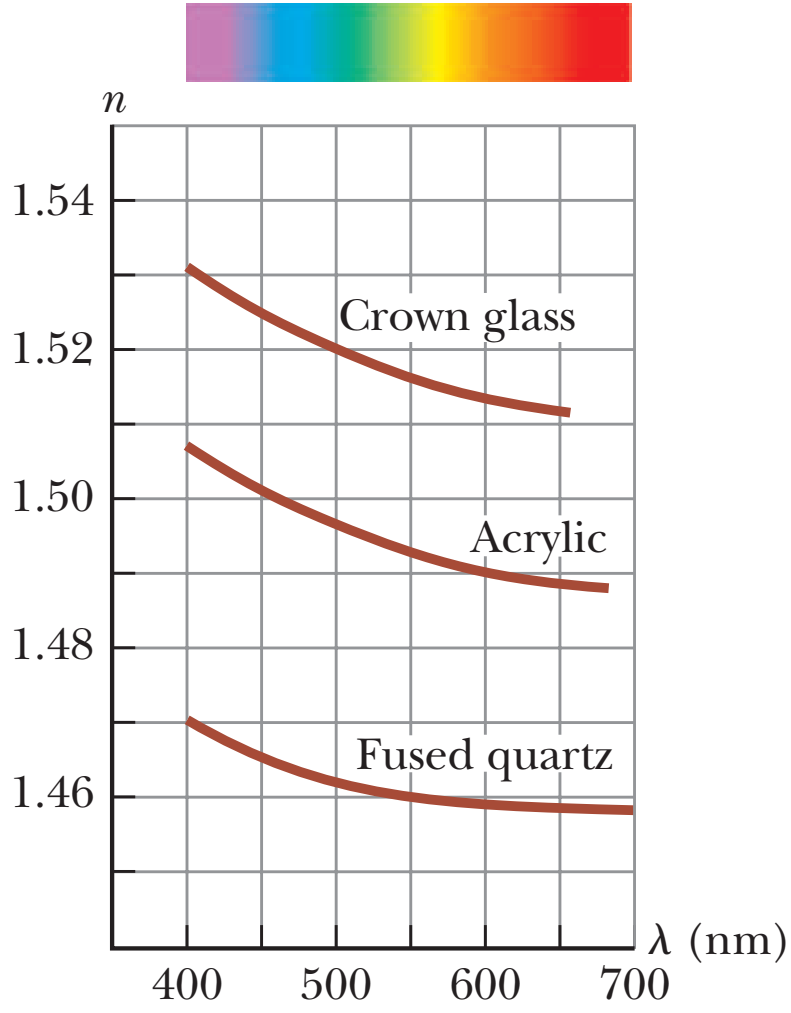
- refraction
- dispersion

Overview

- dispersion
- total internal reflection
- ray diagrams and terminology

Dispersion

A plot of refractive index vs. wavelength for some kinds of transparent solids:



Dispersion

All materials exhibit dispersion, to varying degrees, except the vacuum.

This has important effects: rainbow creation!

Dispersion can also have detrimental effects. In camera lenses, dispersion causes a blurring of the image.

[1]Image from http://imaging.nikon.com

Dispersion Question

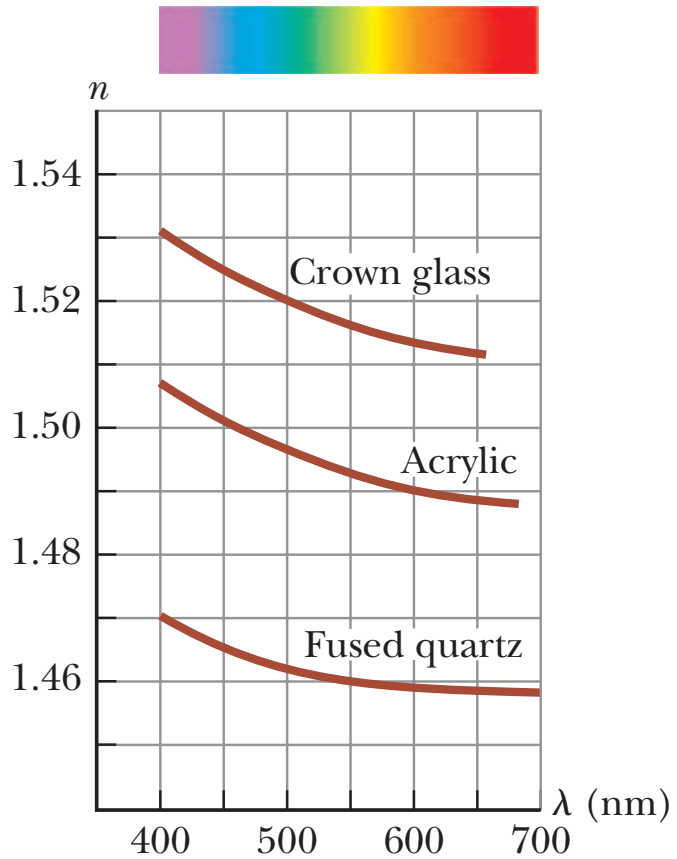
Quick Quiz 35.4[1] In photography, lenses in a camera use refraction to form an image on a light-sensitive surface. Ideally, you want all the colors in the light from the object being photographed to be refracted by the same amount. Of the materials shown, which would you choose for a single-element camera lens?

(A) crown glass

(B) acrylic

(C) fused quartz

(D) impossible to determine



[1] Serway & Jewett, page1074.

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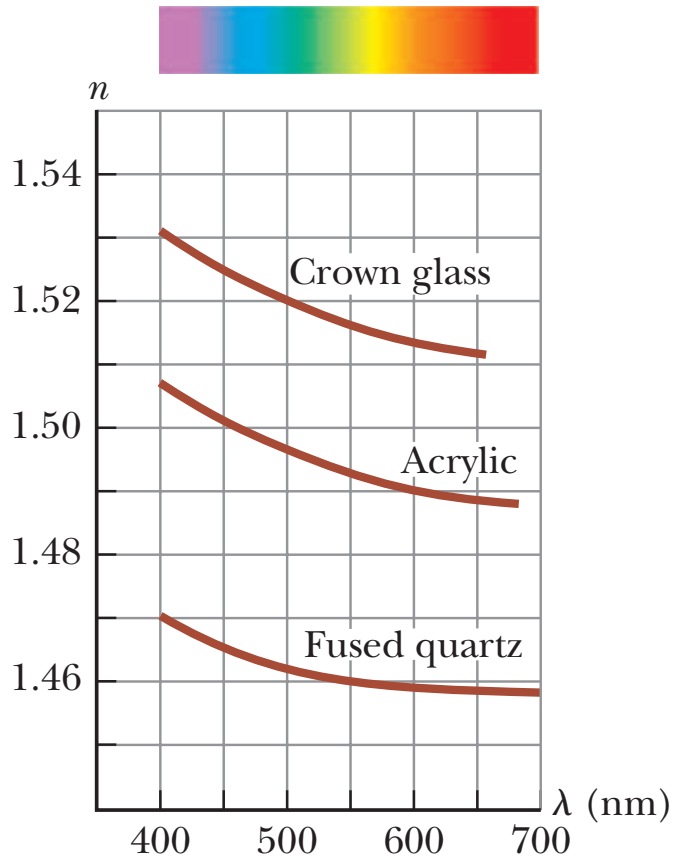

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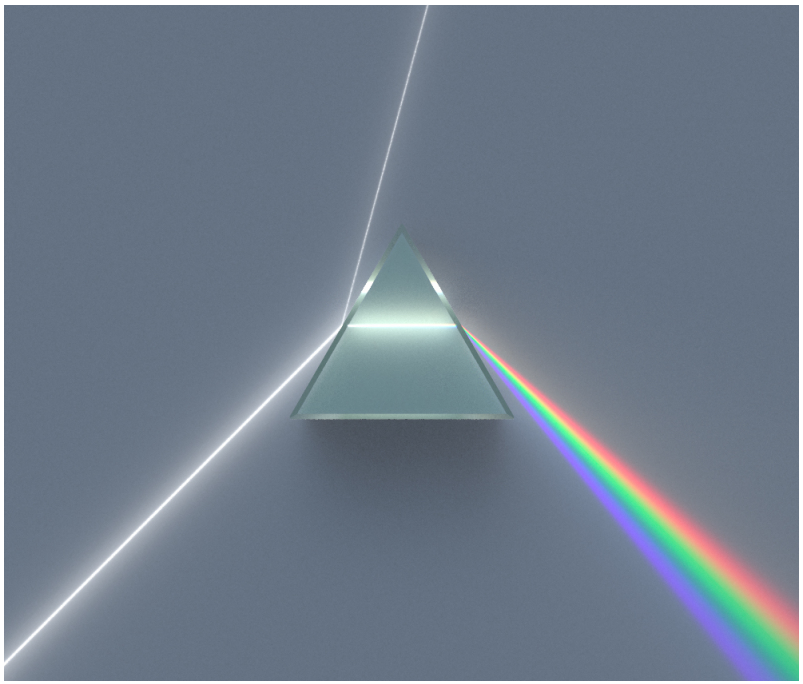
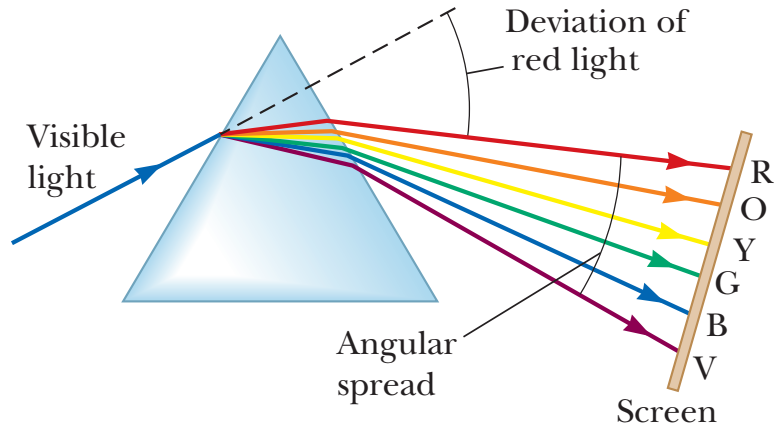
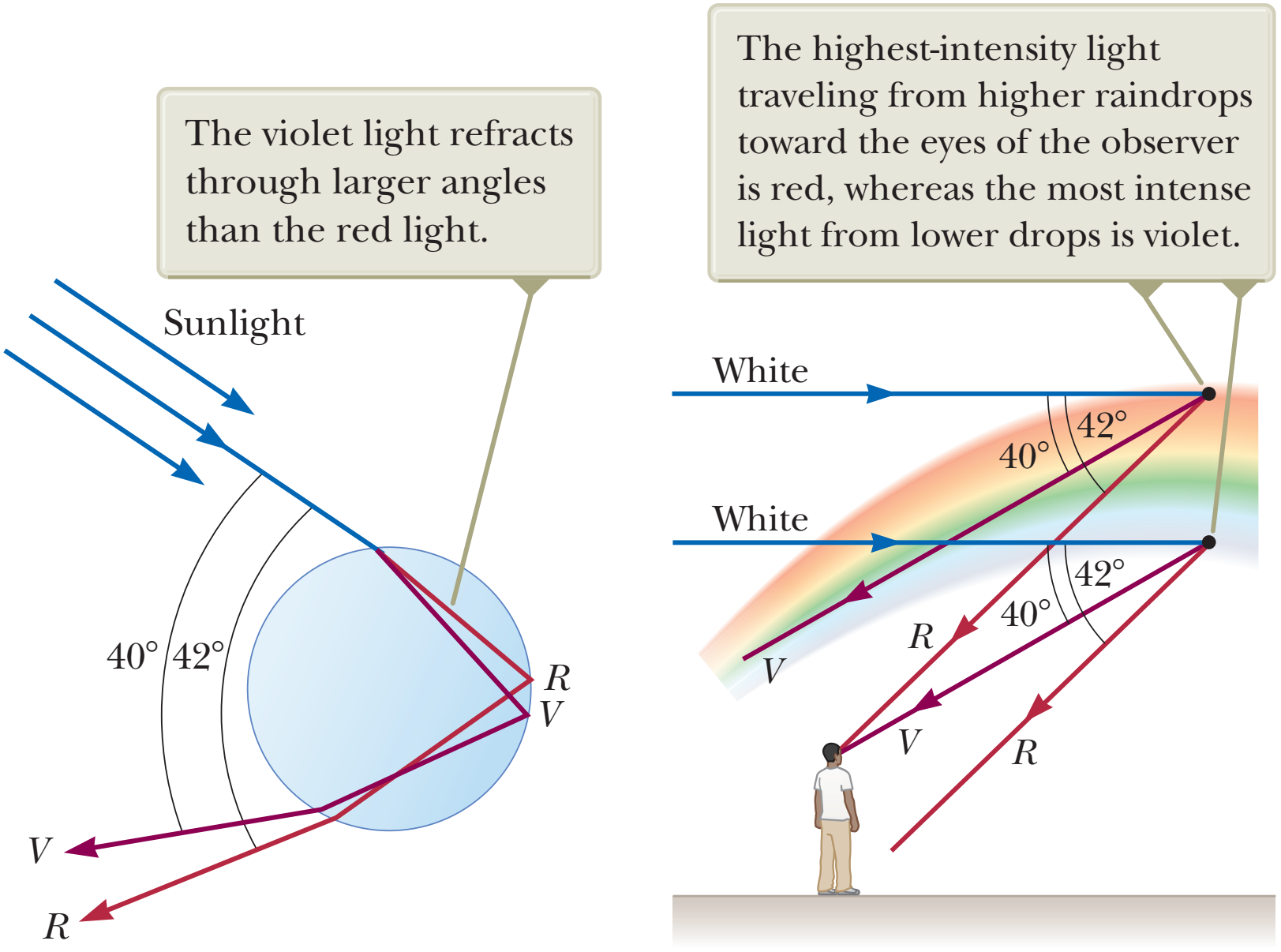
Prism Dispersion





[1]Left, Wikipedia by Spigget; right, Serway & Jewett, page 1083.

Dispersion in Rainbows



Question

A water resistant flashlight is switched on under water in a pool. The ray from the flashlight strikes the top surface of the water, and makes an angle of 30° with the water's surface. What is the angle of refraction?

The refractive index of water is $n = 1.333$.

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What's happening?

Total Internal Reflection

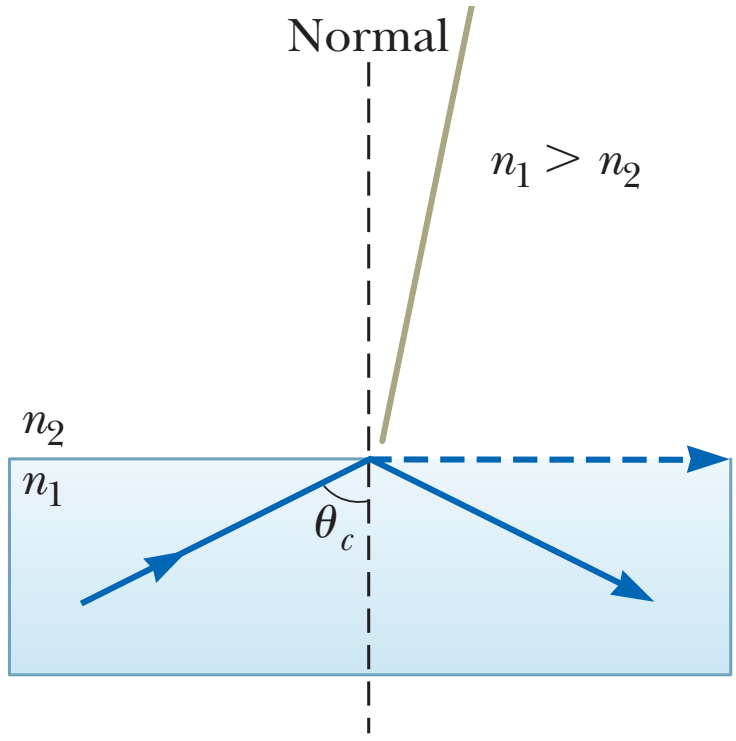
When a light ray travels from a medium with a higher refractive index to one with a lower refractive index, and it strikes the interface at a sufficiently large incident angle, there is no valid solution for the refracted ray.

In fact, in this case we don't see one! All of the light is reflected at the boundary.

This is called **total internal reflection**.

Total Internal Reflection

The **critical angle**, θ_c, is the maximum angle of incidence such that there could be a refracted ray. The ray would just skim along the surface between the media.



In this case, the angle of refraction $\theta_2 = 90°$.

Total Internal Reflection (TIR) Question

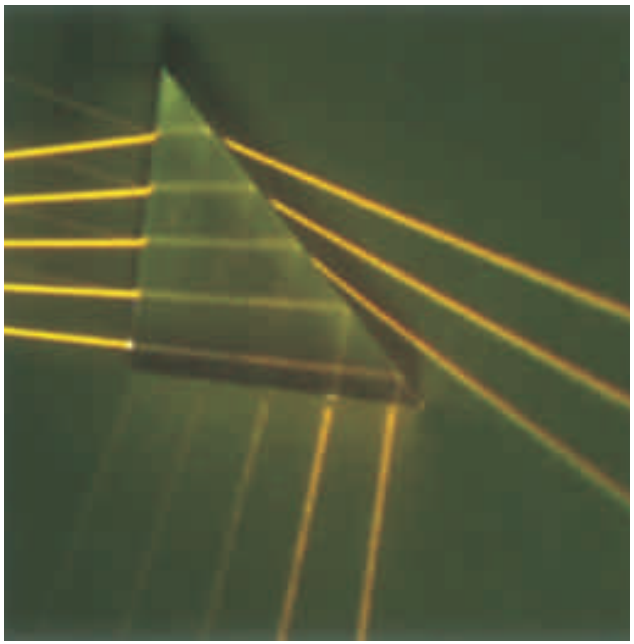
Quick Quiz 35.5[2] In the picture, five light rays enter a glass prism from the left. (i) How many of these rays undergo total internal reflection at the slanted surface of the prism?

(A) one

(B) two

(C) three

(D) four



Courtesy of Henry Leap and Jim Lehman

[2] Serway & Jewett, page1075.

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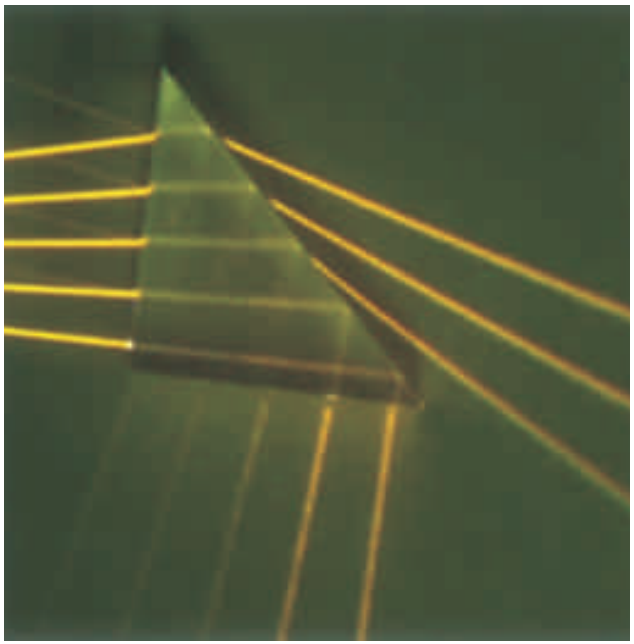

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Total Internal Reflection (TIR) Question

Quick Quiz 35.5[3] In the picture, five light rays enter a glass prism from the left. (ii) Suppose the prism can be rotated in the plane of the paper. For all five rays to experience total internal reflection from the slanted surface, the prism should be rotated

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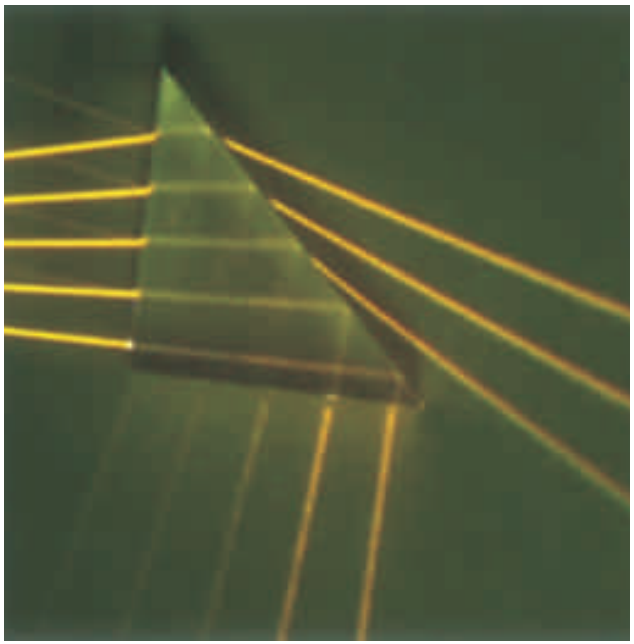
(B) counterclockwise



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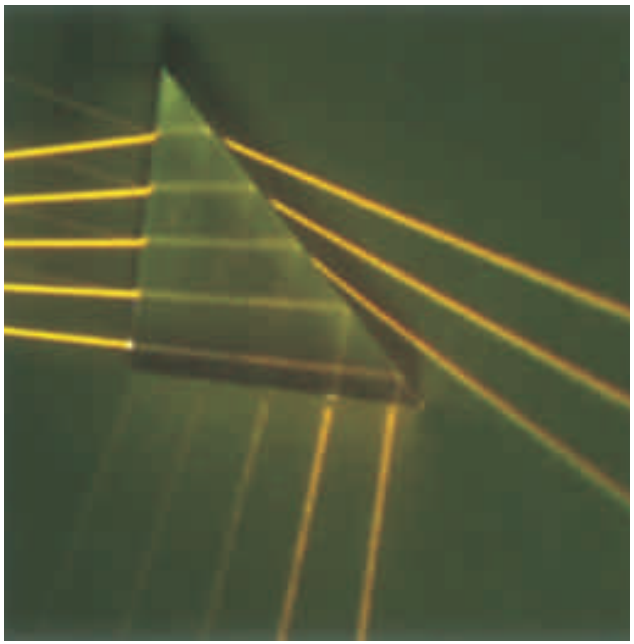

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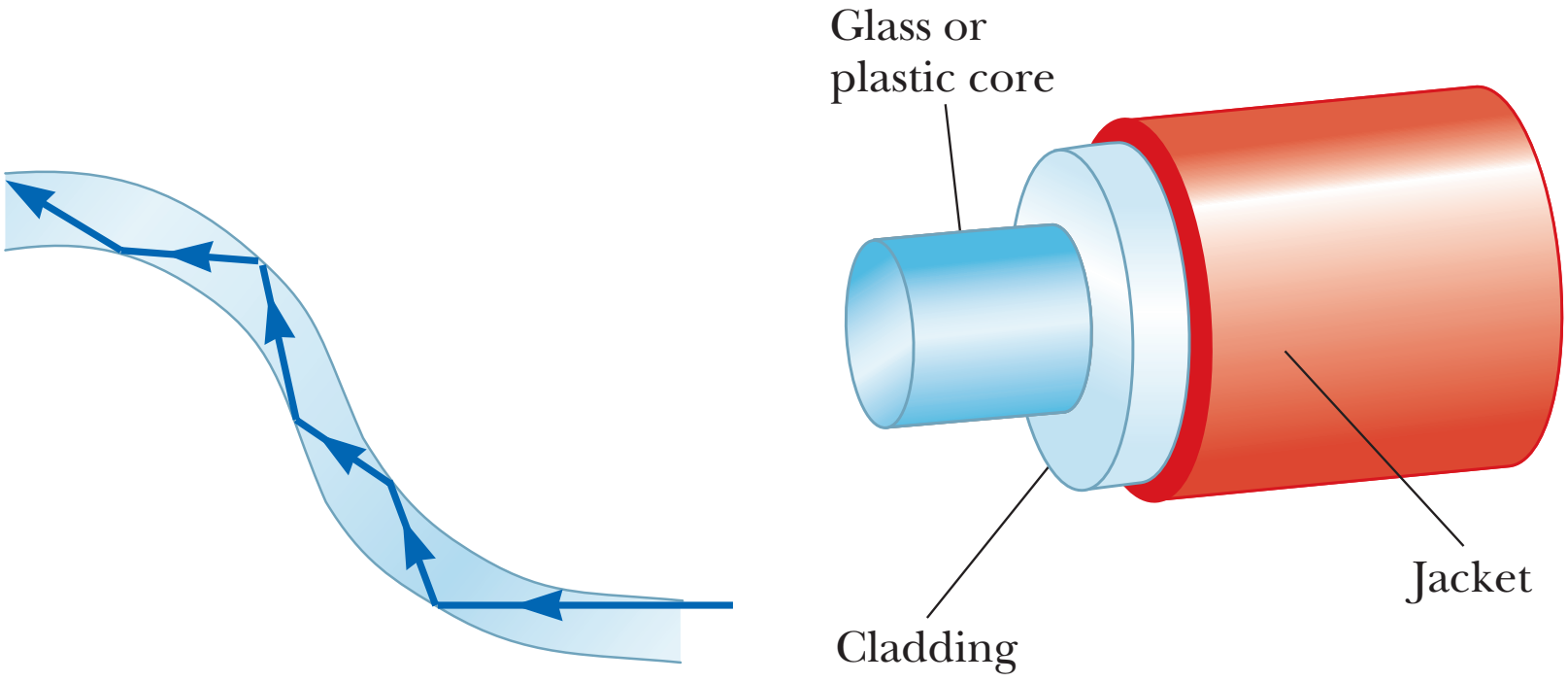
Application of TIR: Optical Fibers



Optical fibers are mainly used for telecommunications: much more information can be carried by an optical fiber than an electrical one in a given amount of time.

Optical fibers are also used in medicine.

Ray Optics and Image Formation

Simple geometric ray optics can be used to understand how images are formed by simple optical devices: mirrors and lenses.

[1]Wikipedia user Heptagon.

Images Formed by Flat Mirrors

When we see an object "in the mirror", we are not actually seeing something that is behind the mirror.

We are seeing an **image** of an **object** that is placed in front of the mirror.

The image seems to be the same distance behind the mirror as the object is in front of it.

The image seems to be the same size as the object.

This is not true for all optical devices, but we can work out things about how the image will form for many different optical devices.

Image Formation Terminology

object distance, p

The perpendicular (shortest) distance from the object to the device.

image distance, q

The perpendicular (shortest) distance from where the image appears to be to the device.

(lateral) magnification, M

The factor by which the image size exceeds the object's size

$$M = \frac{\text{image height}}{\text{object height}}$$

For mirrors and lenses

$$M = -\frac{q}{p}$$

Image Formation Terminology

real image

An image that can be displayed on a screen formed when the light rays pass through and diverge from the image point.

virtual image

An image that cannot be displayed on a screen, but can be seen "in the device" because the light rays appear to diverge from the image point.

The image in a flat mirror is virtual.

Image Formation Terminology

upright image

An image that appears to be right-side-up with respect to the object.

inverted image

An image that appears to be upside-down with respect to the object.

The image in a flat mirror is upright.

focal length, f

The distance from the optical device to where a set parallel rays striking the device head on (perpendicularly) will be focused.

For a flat mirror, the f is infinite.

Summary

- dispersion
- total internal reflection
- image terminology

Homework Serway & Jewett:

- Carefully read Chapter 36. (over the next few days)
- Ch 36, onward from page 1123. OQs: 13