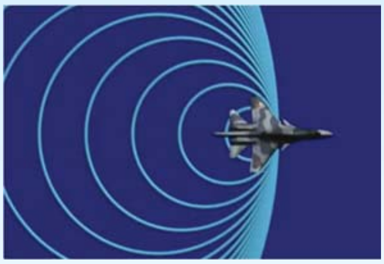
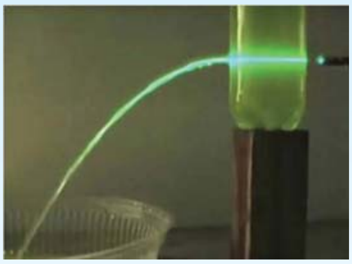
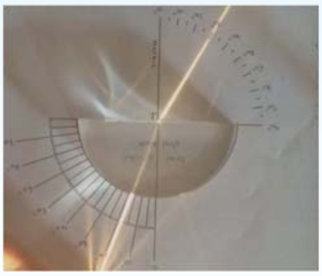
Vågrörelselära och optik



Kapitel 33 - Ljus

Vågrörelselära och optik

Kurslitteratur: University Physics by Young & Friedman

Harmonisk oscillator:	Kapitel 14.1 – 14.4
Mekaniska vågor:	Kapitel 15.1 – 15.8
Ljud och hörande:	Kapitel 16.1 – 16.9
Elektromagnetiska vågor:	Kapitel 32.1 & 32.3 & 32.4
Ljusets natur:	Kapitel 33.1 – 33.4 & 33.7
Stråloptik:	Kapitel 34.1 – 34.8
Interferens:	Kapitel 35.1 – 35.5
Diffraktion:	Kapitel 36.1 - 36.5 & 36.7

Vågrörelselära och optik

Tid	Må 02-nov	Ti 03-nov	On 04-nov	To 05-nov	Fr 06-nov
08-10	Kvantfysik (A)	Våglära/optik (A) kap 14	Kvantfysik (A)	Våglära/optik (A)	Kvantfysik (A)
10-12	Intro period 2 (A) Informationssökning (A)	Kvantfysik (A)	Våglära/optik kap 14+15 ÄFYA11 (L218)	Kvantfysik (A)	Kvantfysik (A) kap 15
13-15	Utvärdering (A) 12-13	Övningar Optik&Våg (L218-19)	SI gp6-10 (L219) ÄFYA11 (L218)	SI gp11-15 (L219)	Övningar Optik&Våg (L218-19)
15-17					

Tid	Må 09-nov	Ti 10-nov	On 11-nov	To 12-nov	Fr 13-nov
08-10	Kvantfysik (A)	Våglära/optik (A) kap 16	Våglära/optik (A) kap 16+32	Kvantfysik (A)	Kvantfysik (A)
10-12	Våglära/optik kap 15+16 ÄFYA11 (L218)	Kvantfysik (A)	Kvantfysik (A)	Våglära/optik (A) kap 32+33	Våglära/optik (A) kap 33
13-15	SI gp1-5 (L219) ÄFYA11 (L218)	Övningar Optik&Våg (L218-19)	ÄFYA11 (l218) SI gp6-10 (L219)	SI gp1-5 (L218) SI gp11-15 (L219)	Övningar Optik&Våg (L218-19)
15-17					

Tid	Må 16-nov	Ti 17-nov	On 18-nov	To 19-nov	Fr 20-nov
08-10	Kvantfysik (A)	Våglära/optik (A) kap 34	Kvantfysik (A)	Våglära/optik (A) kap 35 ÄFYA11 (L218)	Våglära/optik (A) kap 36
10-12	Våglära/optik (A) kap 34	Kvantfysik (A)	Våglära/optik (A) kap 34+35	Våglära/optik (A) kap 36	Kvantfysik (A)
13-15	SI gp6-10 (L219)	Övningar Optik&Våg (L218-19)	Seminar.gen.gång (A) 12-13 SI gp1-5 (L218) 13-15 SI gp11-15 (L219) 13-15	Labbintroduktion (A) O2-O3, K1-K3	Övningar Optik&Våg (L218-19)
15-17					

The nature of light

The nature of light

The nature of light

The nature of light

Electromagnetic radiation

Wave properties → Propagation

Particle properties (Photons) → Emission and Absorption

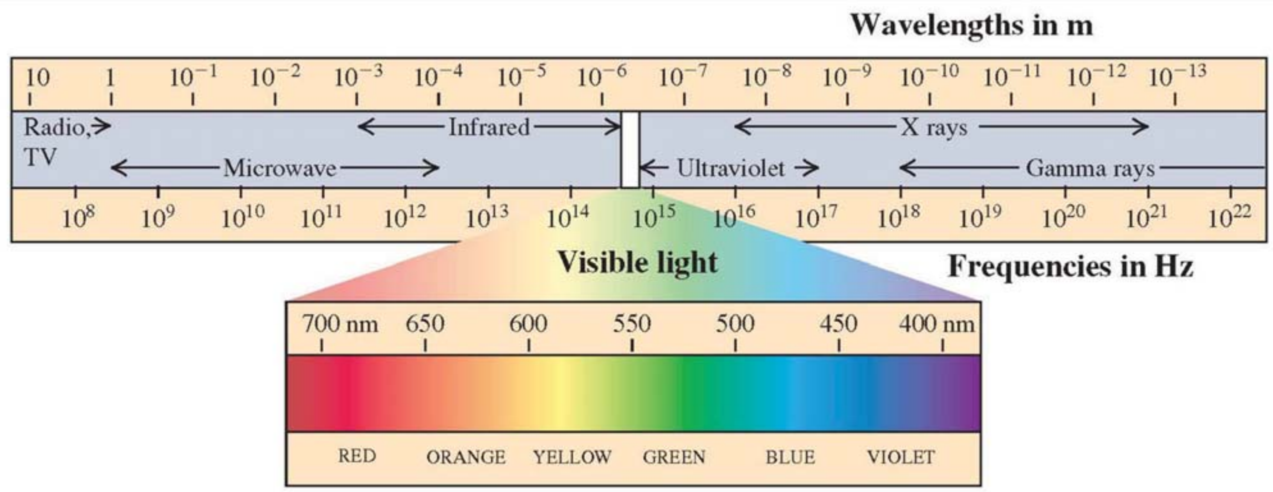
Quantum electrodynamics

Principle of complementarity: Both the wave and the particle descriptions are needed to explain light. But not at the same time for the same phenomena.

The nature of light

The electromagnetic spectrum

$$\lambda = c / f$$



The nature of light

Source of electromagnetic radiation is electric charges in accelerated motion

Thermal radiation:

Thermal motions of molecules create electromagnetic radiation.

Lamp:

A current heats the filament which then sends out thermal radiation with many wavelengths.

Laser:

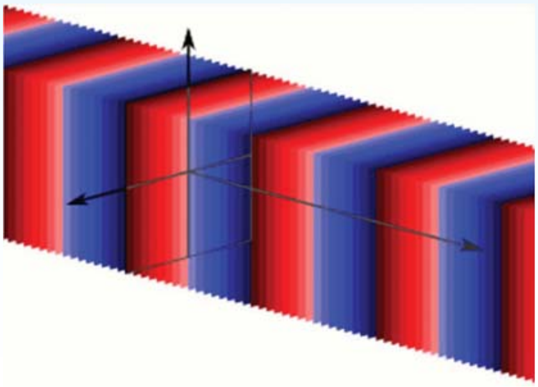
Atoms emits light coherently giving (almost) monocromatic radiation.

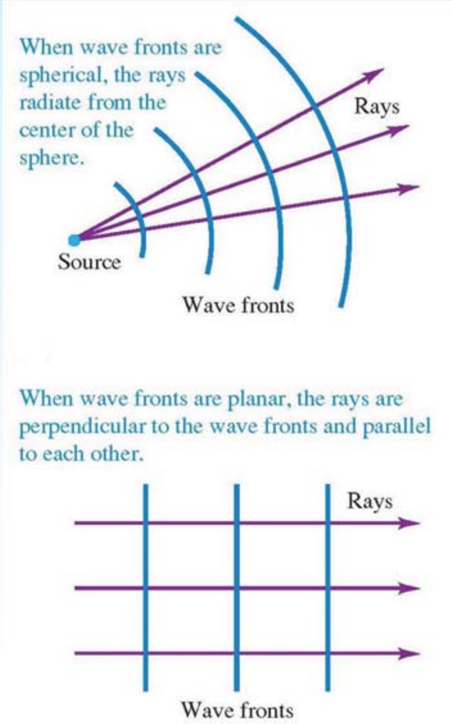
The nature of light

Wave front: surface with constant phase.

Plane wave: is a wave whose wave fronts are infinite parallel planes.

Ray: an imaginary line along the direction of the wave's propagation.



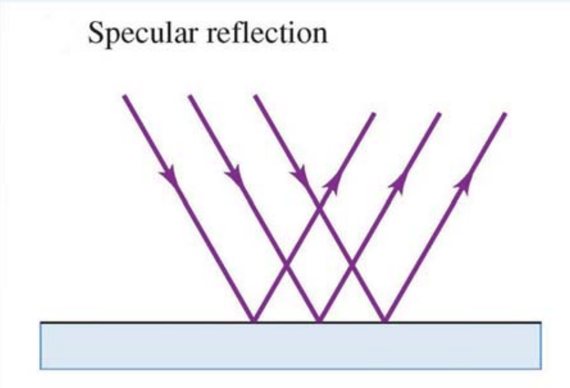


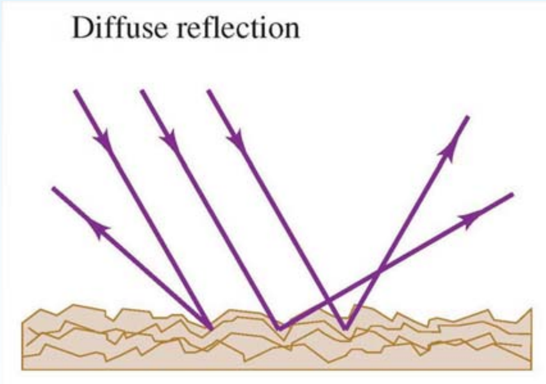
The nature of light

Reflection and refraction

The nature of light

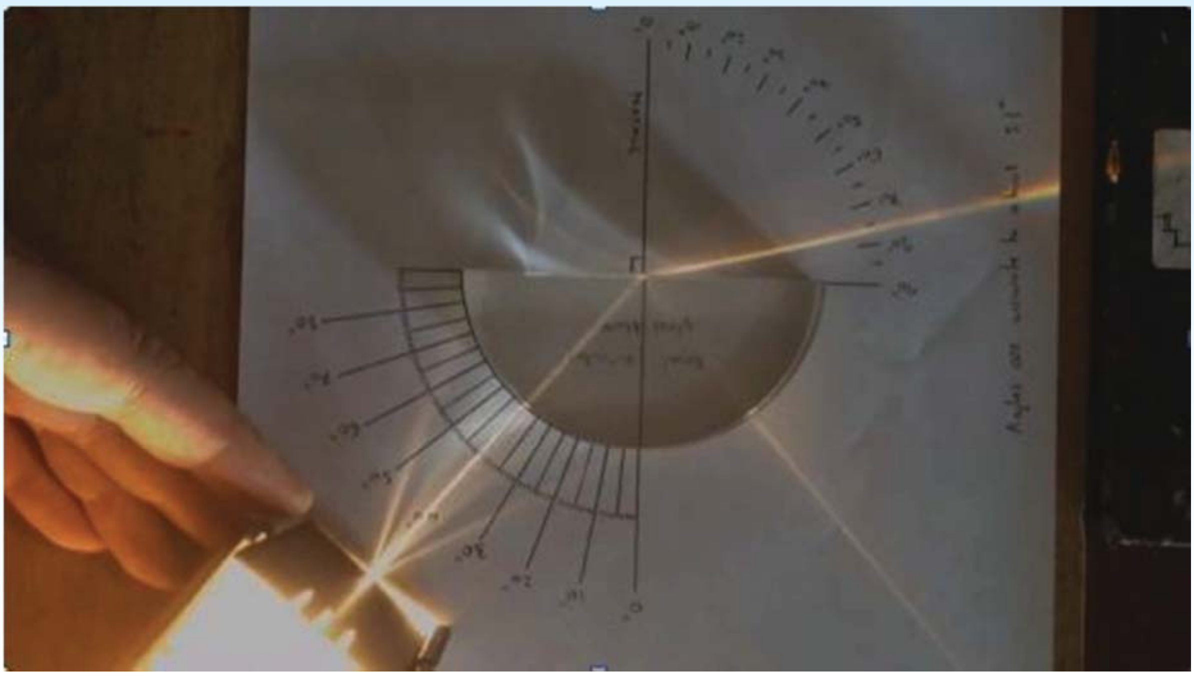
Types of reflection





The nature of light

Reflection & Refraction



The nature of light

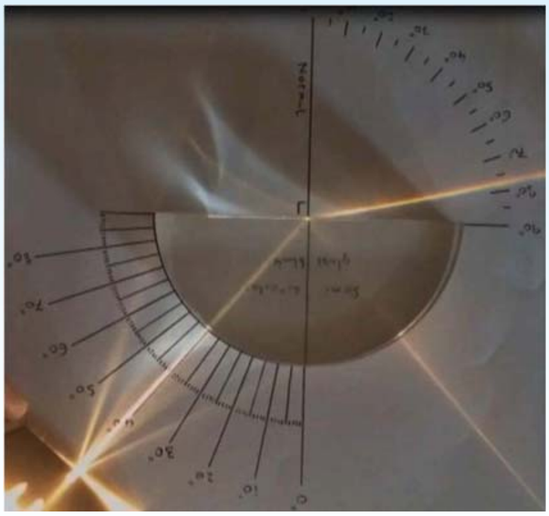
Conclusions:

At the surface between air and glass the angle is always 90 degrees and then the reflected and refracted light is also at 90 degrees.

At the surface between glass and air some of the light is reflected and some is refracted.

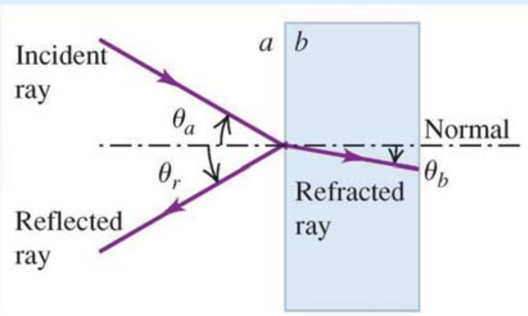
The angle of reflection is the same as the incident angle.

The angle of refraction is larger than the incident angle.



The nature of light

n_a n_b



$n = \frac{c}{v}$ (index of refraction)

n = 1 in vacuum
n > 1 in a material

The plane of incident:
The plane of the incident ray and the normal to the surface.

The reflected and refracted rays are in the plane of incident.

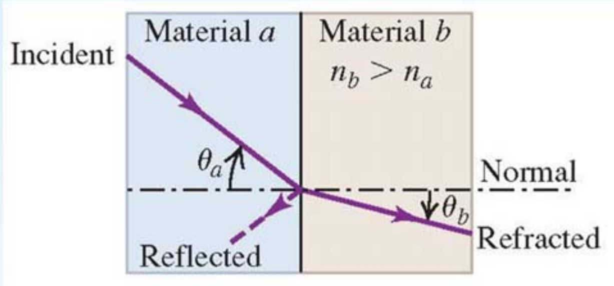
$\theta_r = \theta_a$ (law of reflection)

Snell's law:

$n_a \sin\theta_a = n_b \sin\theta_b$ (law of refraction)

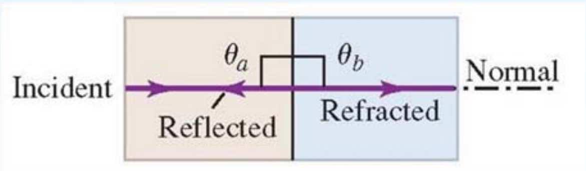
The nature of light

n_a < n_b

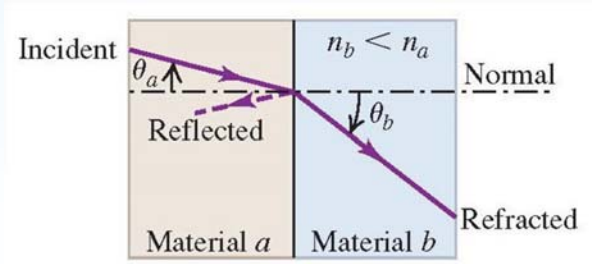


Snell's law:

$$n_a \sin\theta_a = n_b \sin\theta_b \qquad \text{(law of refraction)}$$



n_a > n_b



Rule:

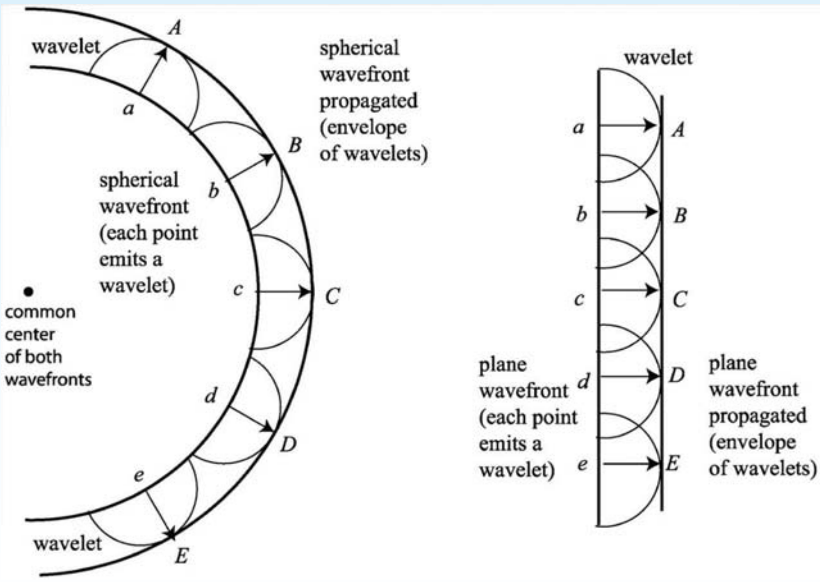
Large n ➡ Small angle

The nature of light

Huygen's principle

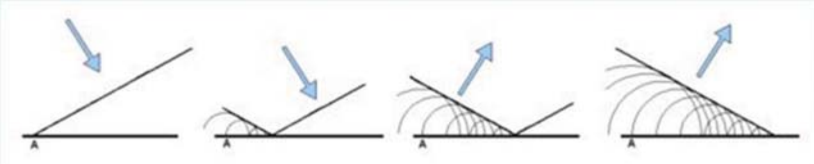
Each point in a wavefront is regarded as a new source of secondary wavelets.

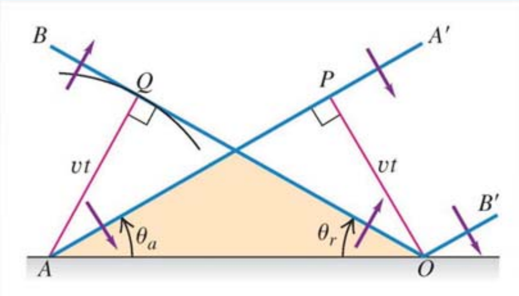
All the combined circles (wavelets) from all the points add up to create the new wavefronts.



The nature of light

Huygen's principle & the law of reflection





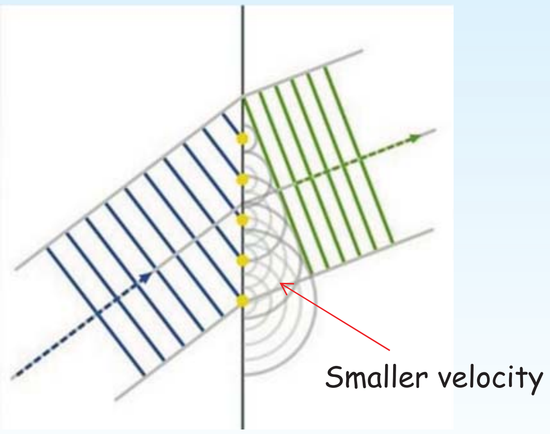
$\sin(\theta_a) = vt / AO$
$\sin(\theta_r) = vt / AO$

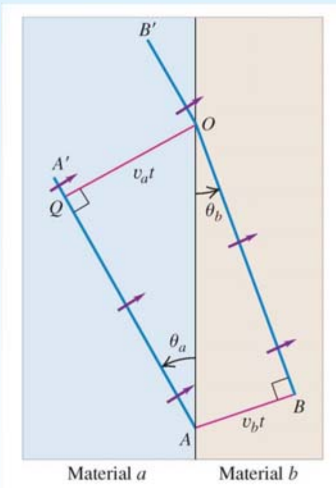
$\theta_a = \theta_r$

Since the wave speed is the same before and after reflection the angle of reflection has to be the same as the incident angle.

The nature of light

Huygen's principle & the law of refraction





$$\sin\theta_a = \frac{v_a t}{AO}$$

$$\sin\theta_b = \frac{v_b t}{AO}$$

$$\frac{\sin\theta_a}{\sin\theta_b} = \frac{v_a}{v_b}$$

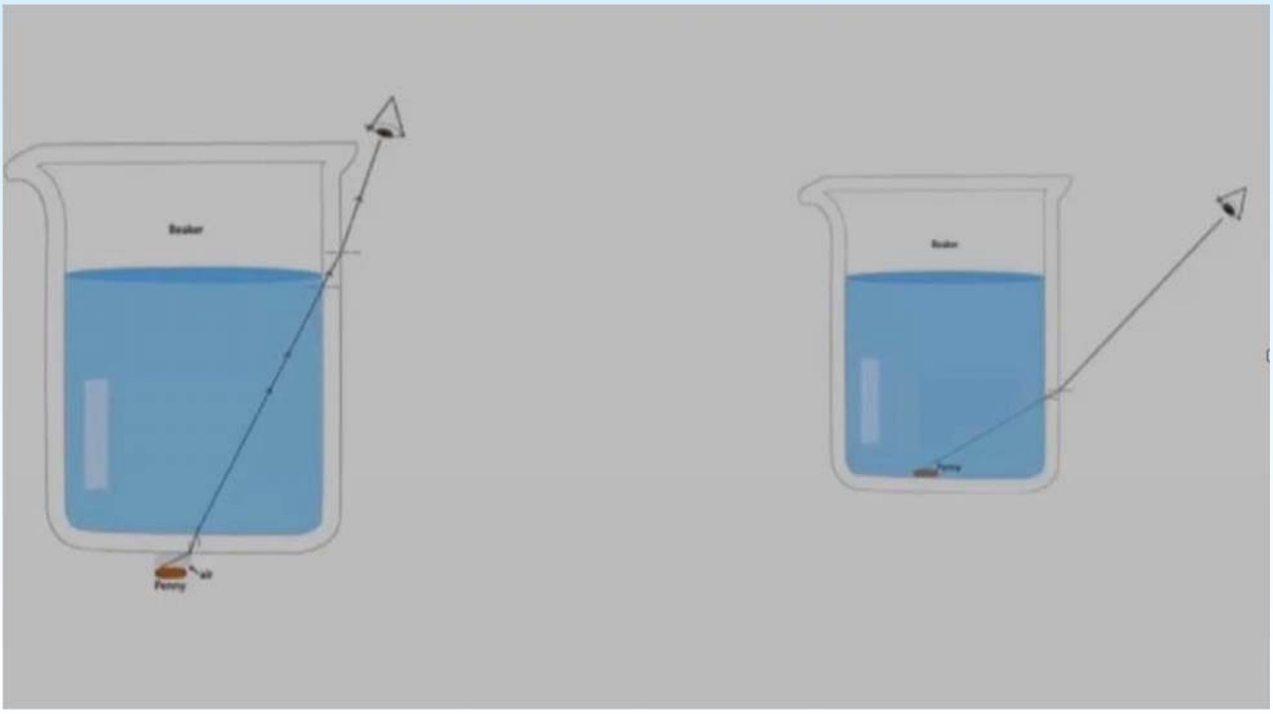
The difference of wave speed in the two materials changes the angle.

$$\frac{n_b}{n_a} = \frac{c/v_b}{c/v_a} = \frac{v_a}{v_b}$$

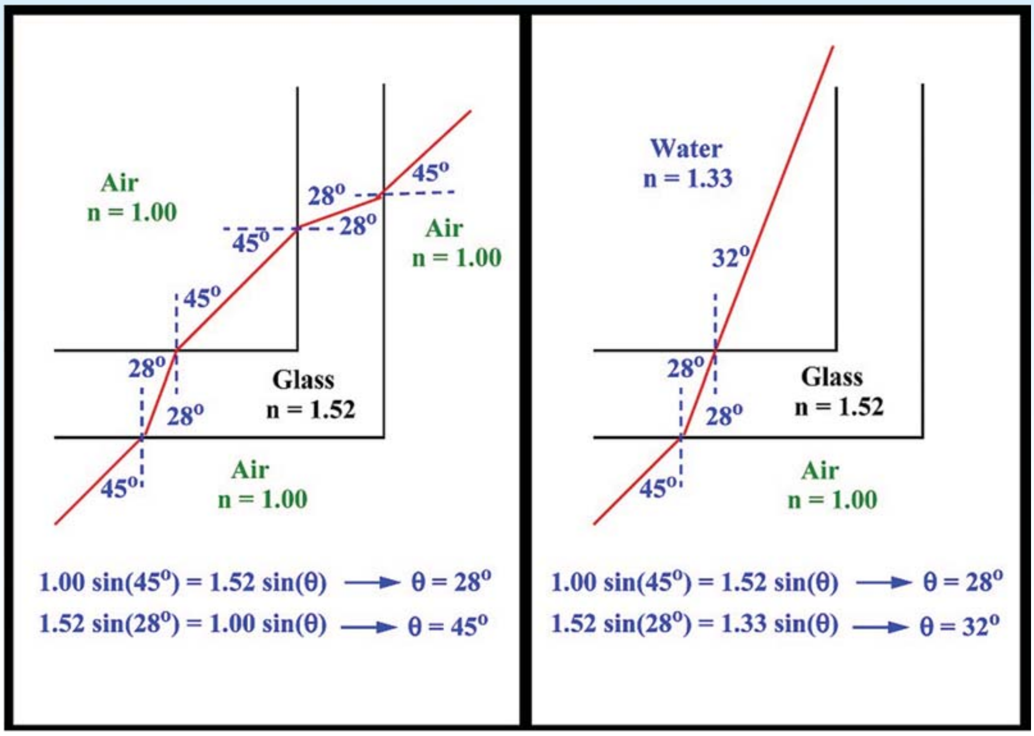
$$\frac{\sin\theta_a}{\sin\theta_b} = \frac{n_b}{n_a}$$

$$n_a \sin\theta_a = n_b \sin\theta_b$$

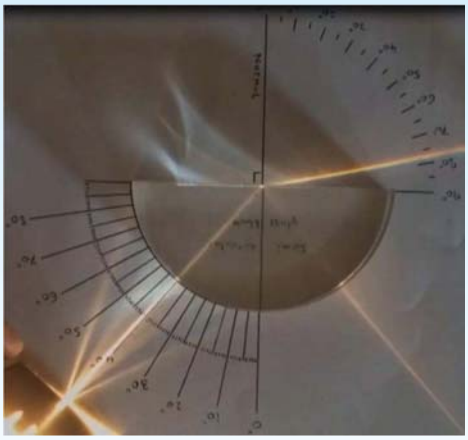
The nature of light



The nature of light



Problem solving



What is n for the glass ?

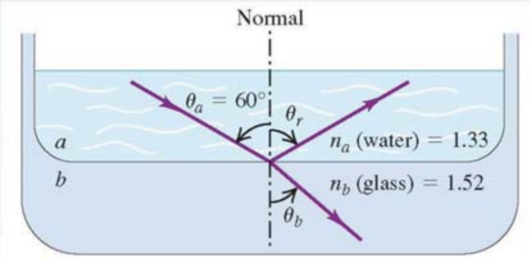
$$n_a \sin\theta_a = n_b \sin\theta_b \qquad \text{(law of refraction)}$$

θ_a = 40 deg. θ_b = 77 deg. n_b = 1

$n_a = \sin(77^\circ) / \sin(40^\circ) = 1.52$

The nature of light

material a is water and material b is glass with index of refraction 1.52. The incident ray makes an angle of 60.0° with the normal; find the directions of the reflected and refracted rays.



$$\theta_r = \theta_a = 60.0°$$

$$n_a \sin\theta_a = n_b \sin\theta_b$$

$$\sin\theta_b = \frac{n_a}{n_b}\sin\theta_a = \frac{1.33}{1.52}\sin 60.0° = 0.758$$

$$\theta_b = \arcsin(0.758) = 49.3°$$

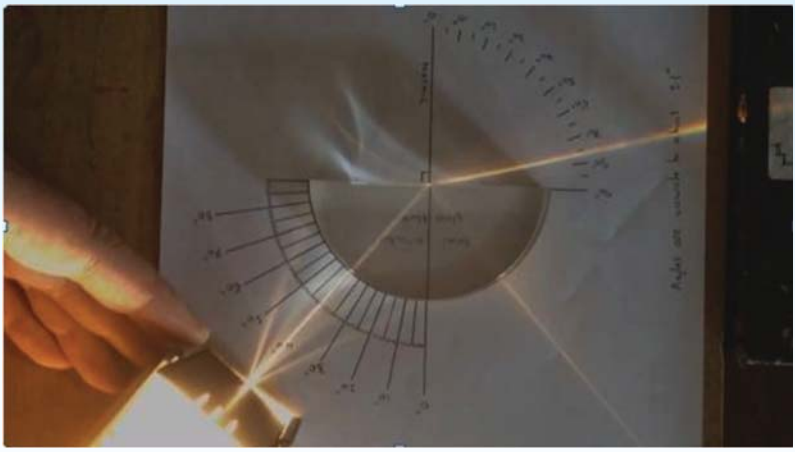
The nature of light

Light intensity

The nature of light

Intensity

The intensity of the reflected light increases from almost 0% at $\theta = 0^o$ to 100% at $\theta = 90^o$.



The intensity of the reflected light also depends on n and on polarization of the incoming light.

The sum of the intensity of the reflected and refracted light is equal to the intensity of the incoming light.

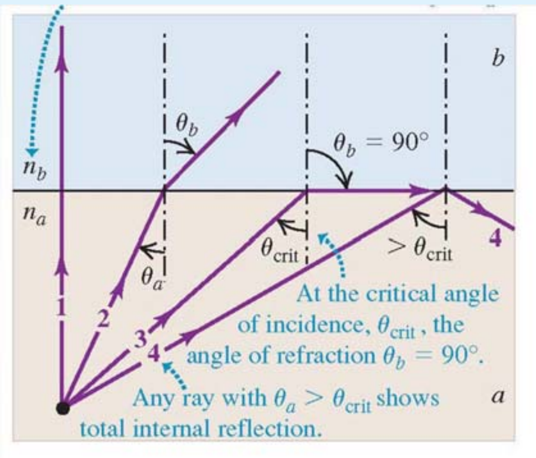
The nature of light

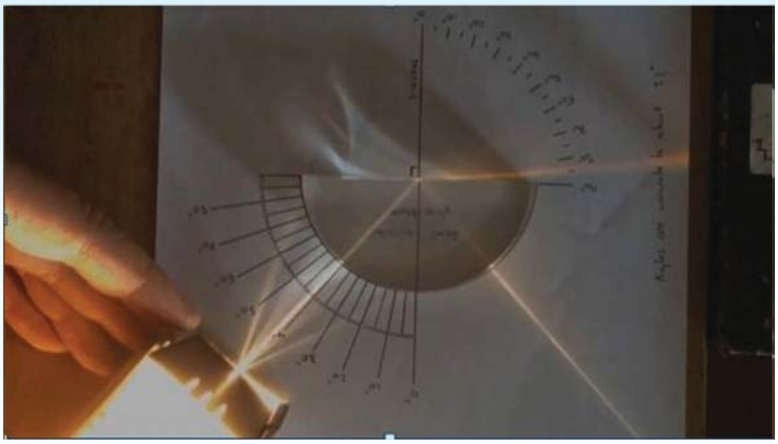
Total internal reflection

The nature of light

Total Internal Reflection

when light goes to a medium with smaller n





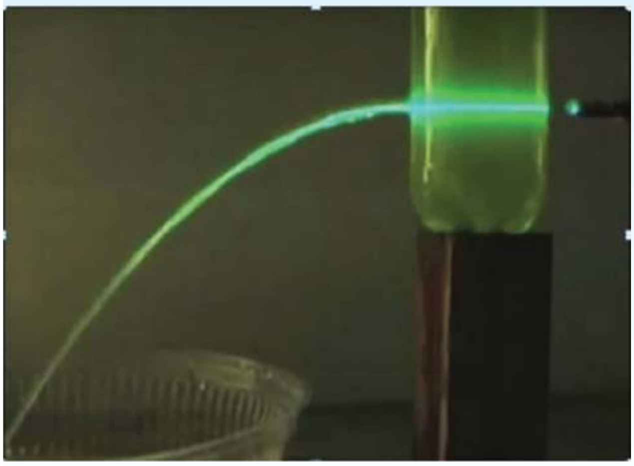
90°

$$n_a \sin\theta_a = n_b \sin\theta_b$$

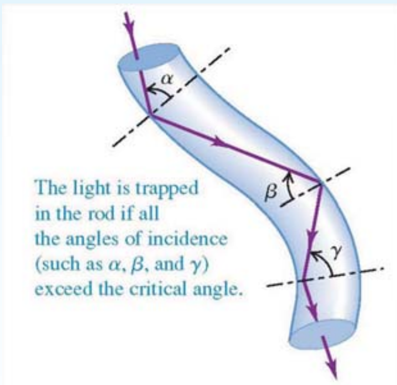
$$\sin\theta_{crit} = \frac{n_b}{n_a} \quad \text{(critical angle for total internal reflection)}$$

The nature of light

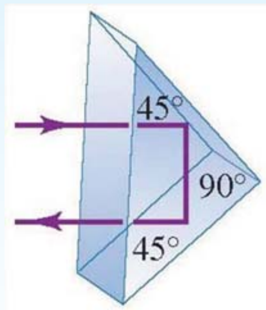
Total Internal Reflection



optical fiber



Porro prism

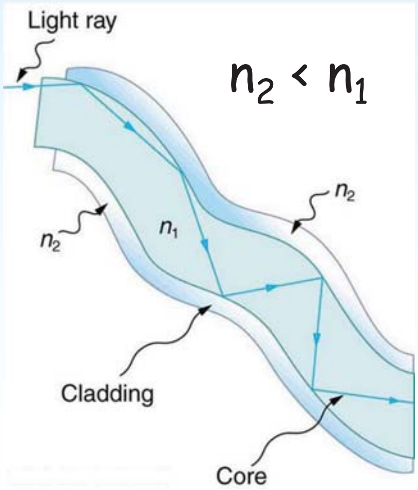


$$\theta_{crit} = 41.1°$$

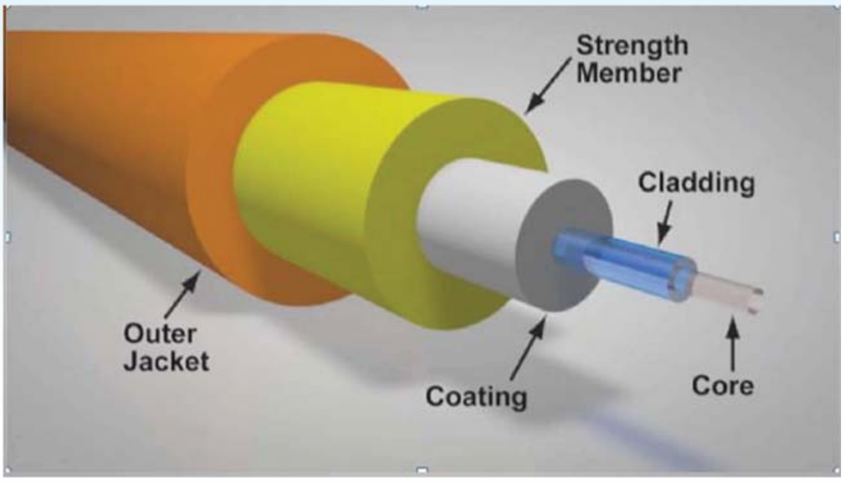
The nature of light

Optical fibers

Principle

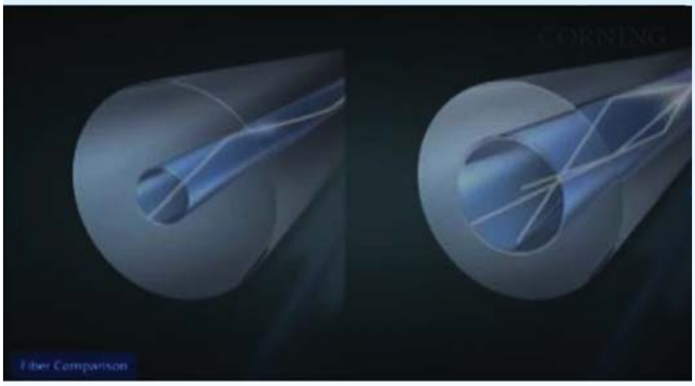


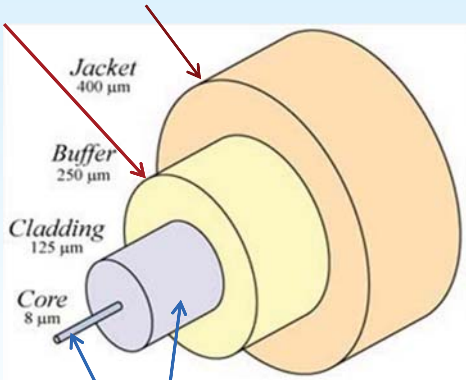
Structure



The nature of light

Protective layers
Plastics such as Teflon, polyurethane or PVC.





Single mode fiber
Small core - low attenuation

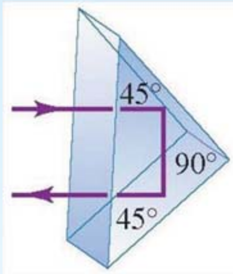
Multimode fiber
Large core – light can travel along multiple paths

Glass (SiO_2) or plastic
Dopants: Ge increase n
B or F decrease n

Problem solving

A submarine periscope uses two totally reflecting 45°–45°–90° prisms with total internal reflection on the sides adjacent to the 45° angles. Explain why the periscope will no longer work if it springs a leak and the bottom prism is covered with water.

n=1.52 for glass & n=1.33 for water



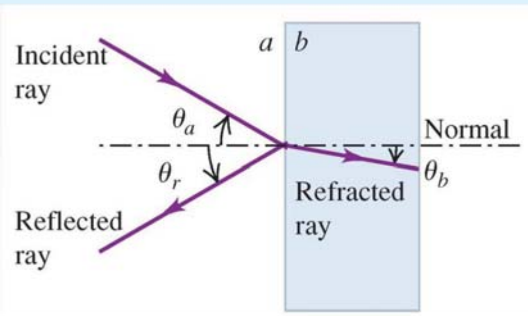
The critical angle for water ($n_b = 1.33$) on glass ($n_a = 1.52$) is

$$\theta_{crit} = \arcsin\frac{1.33}{1.52} = 61.0°$$

The incident angle has to be larger than the critical angle for total reflection. But 45° is smaller than 61° so total internal reflection will no longer take place.

Dependency on frequency and wavelength

n_a n_b



$$n = \frac{c}{v} \quad \text{(index of refraction)}$$

n = 1 in vacuum
n > 1 in a material

Frequency and wavelength

ν: The speed is larger in a material with a small n.

f: The frequency does not depend on n.

λ: The wavelength is longer in a material with a small n.

$\lambda = v / f$ n > 1
$\lambda_0 = c / f$ n = 1

$$\lambda = \lambda_0 / n$$

Problem solving

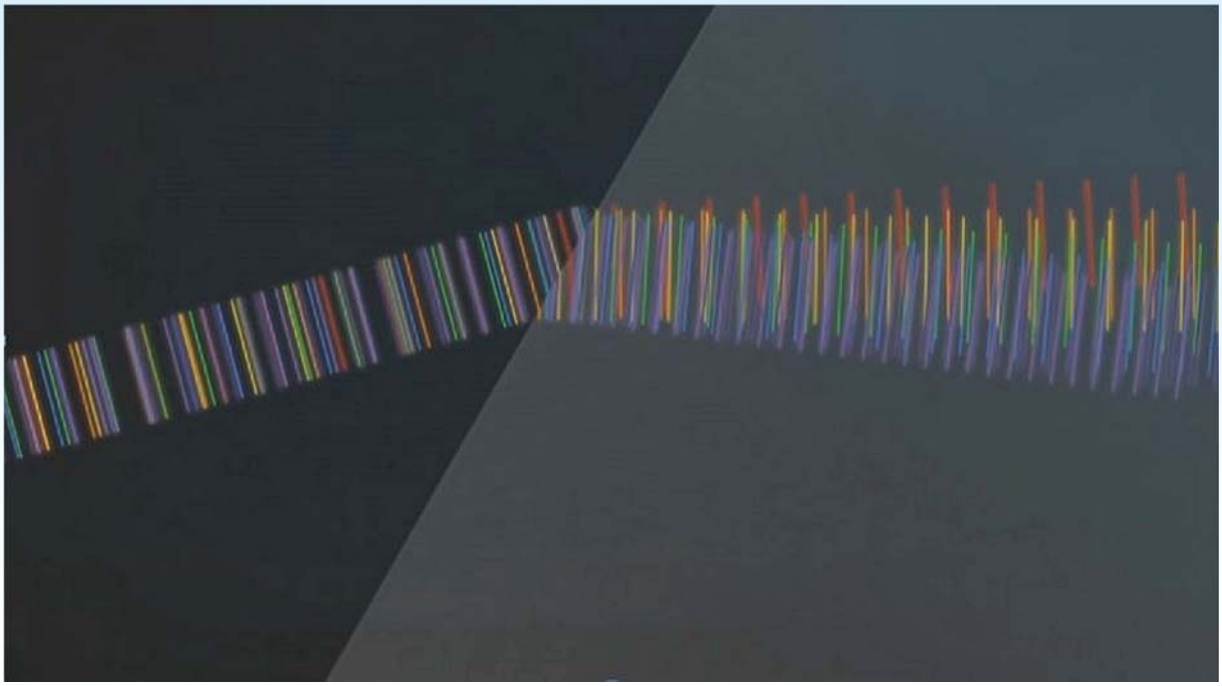
The wavelength of the red light from a helium-neon laser is 633 nm in air but 474 nm in the aqueous humor inside your eyeball. Calculate the index of refraction of the aqueous humor and the speed and frequency of the light in it.

$$\lambda = \frac{\lambda_0}{n} \qquad n = \frac{\lambda_0}{\lambda} = \frac{633\ \text{nm}}{474\ \text{nm}} = 1.34$$

$$v = \frac{c}{n} = \frac{3.00 \times 10^8\,\text{m/s}}{1.34} = 2.25 \times 10^8\,\text{m/s}$$

$$f = \frac{v}{\lambda} = \frac{2.25 \times 10^8\,\text{m/s}}{474 \times 10^{-9}\,\text{m}} = 4.74 \times 10^{14}\ \text{Hz}$$

Dispersion



Dispersion

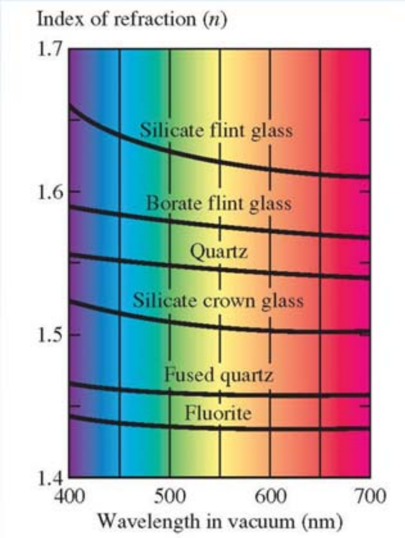
How is this possible ?

$n_a \sin\theta_a = n_b \sin\theta_b$ (law of refraction)

Answer: n must depend on λ !

n = c / v

so the speed in a material must then depend on λ



Rainbow