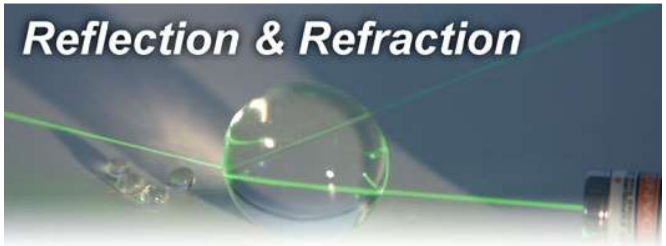


More

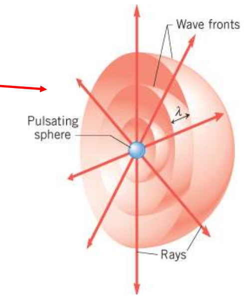
Ch 33: Electromagnetic Waves

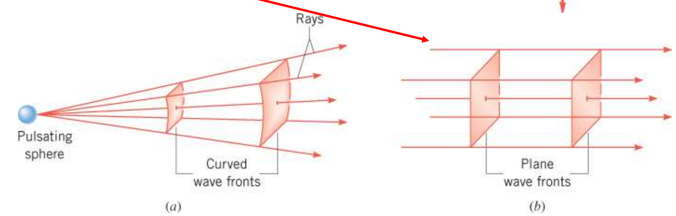
Modeling E&M Waves in Optics: Wave Fronts & Rays

A hemispherical view of a wave emitted by a pulsating sphere.

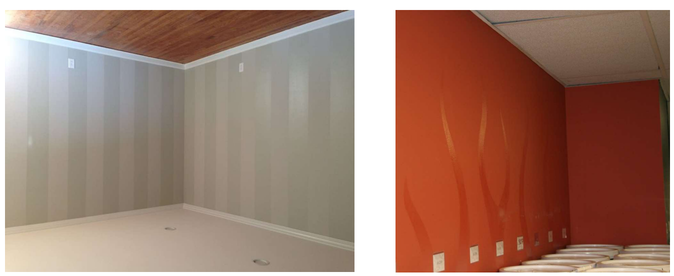
The **rays** are perpendicular to the **wave fronts**.

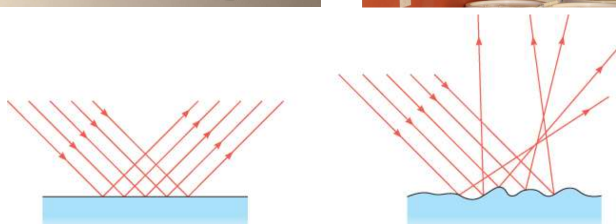
At large distances from the source, the wave fronts become less and less curved. They become **plane waves** or **plane wave fronts**.





Reflection: When Light Bounces



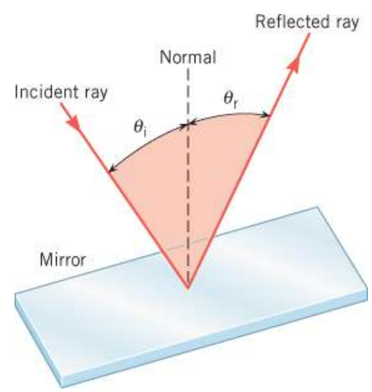


(a) Specular reflection (b) Diffuse reflection

The Reflection of Light: When Light Bounces

LAW OF REFLECTION

The incident ray, the reflected ray, and the normal to the surface all lie in the same plane, and the **angle of incidence** equals the **angle of reflection**.

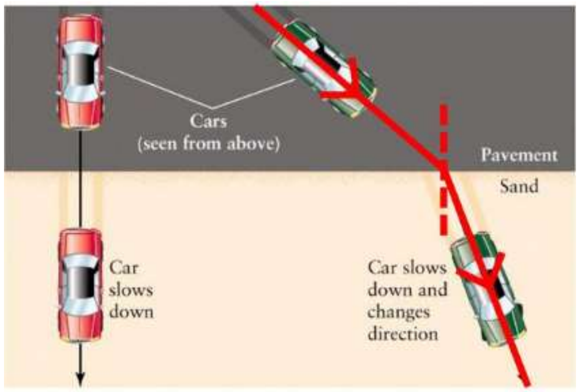


$$\theta_i = \theta_r$$

Note that the angles are always measured relative to the normal, never, ever, ***ever*** relative to the surface.

The Refraction of Light: When Light Bends

When the medium through which the wave travels changes, the speed with which the wave travels changes



The Index of Refraction

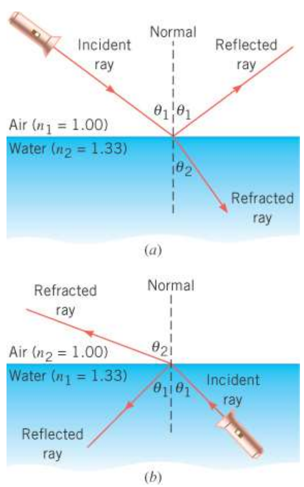
Substance	Index of Refraction, n
Solids at 20 °C	
Diamond	2.419
Glass, crown	1.523
Ice (0 °C)	1.309
Sodium chloride	1.544
Quartz	
Crystalline	1.544
Fused	1.458
Liquids at 20 °C	
Benzene	1.501
Carbon disulfide	1.632
Carbon tetrachloride	1.461
Ethyl alcohol	1.362
Water	1.333
Gases at 0 °C, 1 atm	
Air	1.000 293
Carbon dioxide	1.000 45
Oxygen, O_2	1.000 271
Hydrogen, H_2	1.000 139

[a] Measured with light whose wavelength in a vacuum is 589 nm.

The **index of refraction** of a material is the ratio of the speed of light in a vacuum to the speed of light in the material:

$$n = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in the material}} = \frac{c}{v}$$

The Refraction of Light: When Light Bends



SNELL'S LAW OF REFRACTION

When light travels from a material with one index of refraction to a material with a different index of refraction, the angle of incidence is related to the angle of refraction by

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

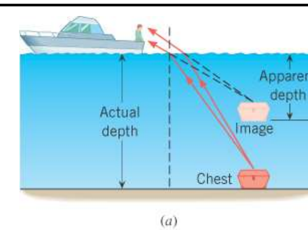
How does the light bend if:

1) $V_2 < V_1 \rightarrow n_2 > n_1$?

2) $V_2 > V_1 \rightarrow n_2 < n_1$?

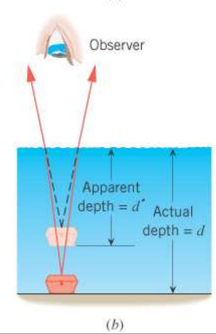
Apparent Depth

If $n_1 > n_2$, the apparent depth (d') is less than actual depth (d).



Apparent depth, observer directly above object

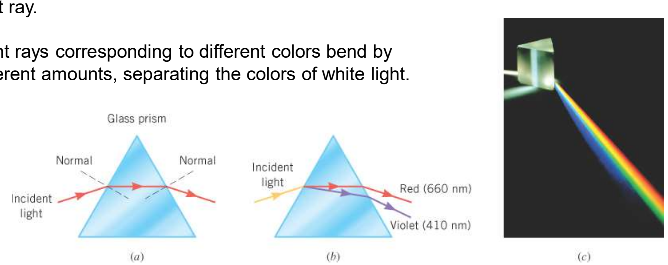
$$d' = d\left(\frac{n_2}{n_1}\right)$$



The Dispersion of Light: Prisms and Rainbows

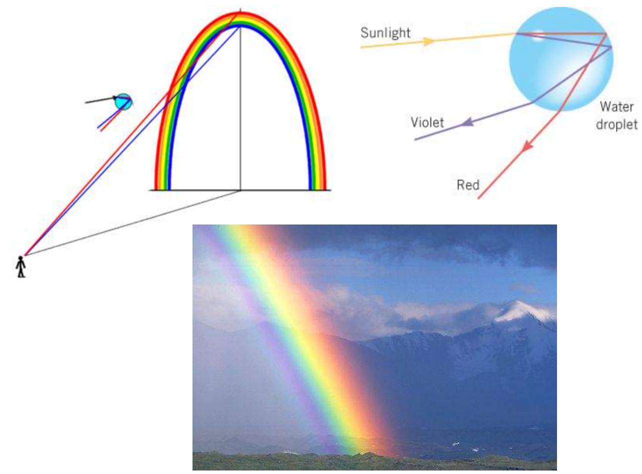
The net effect of a prism is to change the direction of a light ray.

Light rays corresponding to different colors bend by different amounts, separating the colors of white light.



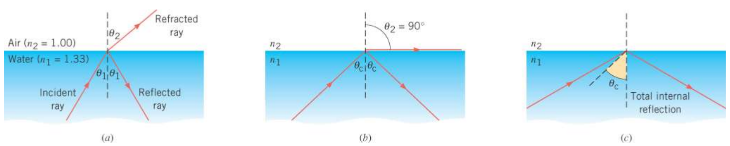
Approximate Color	Wavelength in Vacuum (nm)	Index of Refraction, n
Red	660	1.520
Orange	610	1.522
Yellow	580	1.523
Green	550	1.526
Blue	470	1.531
Violet	410	1.538

The Dispersion of Light: Prisms and Rainbows



Total Internal Reflection: When $\Theta_2 = 90^o$

When light passes from a medium of larger refractive index into one of smaller refractive index, the refracted ray bends away from the normal.



Snell's Law: $n_1 \sin\theta_1 = n_2 \sin\theta_2$

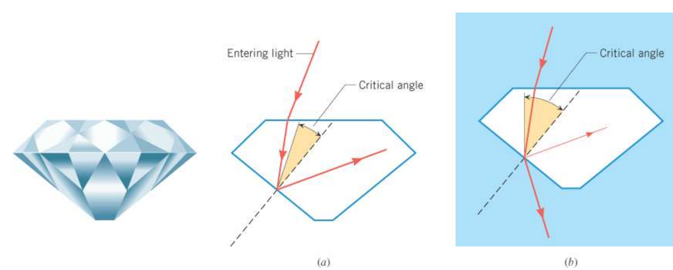
What happens if $\Theta_2 = 90^o$?

Critical Angle: $\sin\theta_c = \dfrac{n_2}{n_1} \qquad n_1 > n_2$

Total Internal Reflection – The Sparkle of a Diamond

Why does a diamond sparkle?

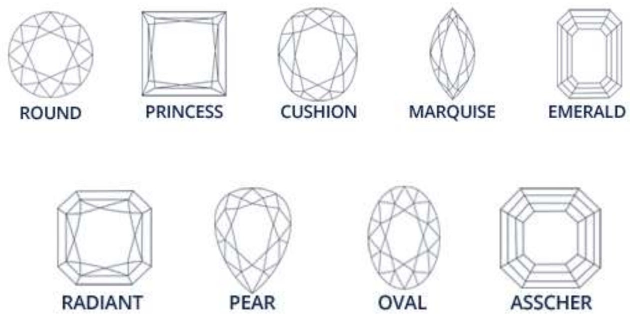
Why does it sparkle less under water?



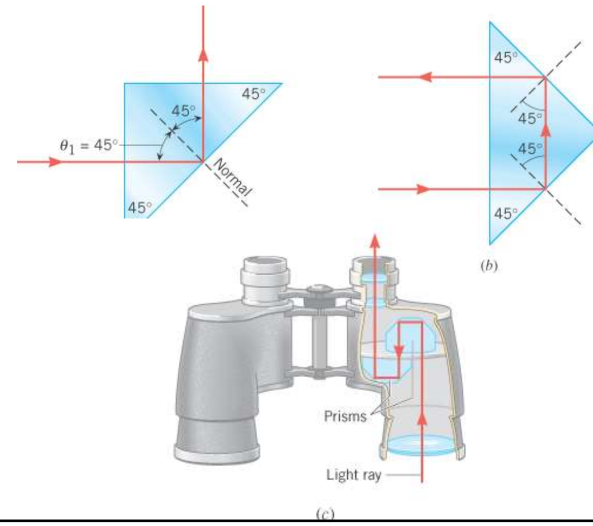
Find Θ_c for both cases.

$n_{air} = 1.00$ $n_{diamond} = 2.42$ $n_{water} = 1.33$

Total Internal Reflection – The Sparkle of a Diamond



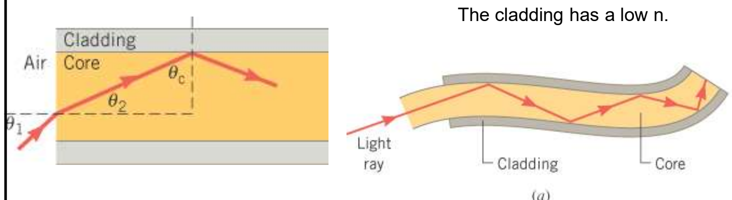
Total Internal Reflection – Usefulness Other than Pretty Diamonds



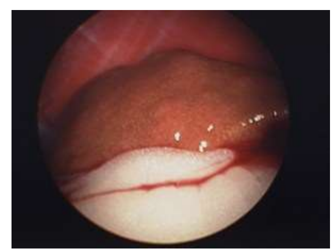
Total Internal Reflection – Fiber Optics

The core has a high n.

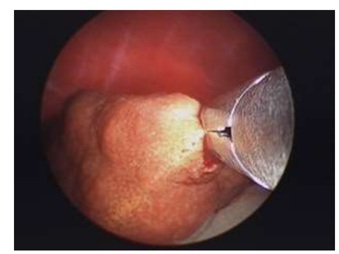
The cladding has a low n.



Laparoscopy – A Small Fiber Optic Telescope



View of liver (center) through Laparoscope



Liver biopsy collected through Laparoscope