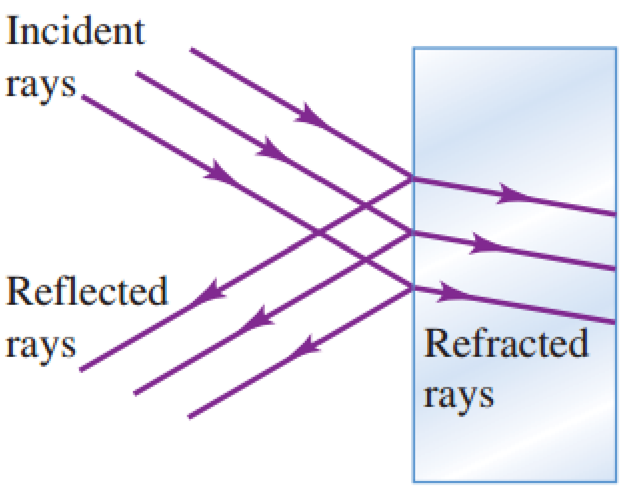
Phys 202

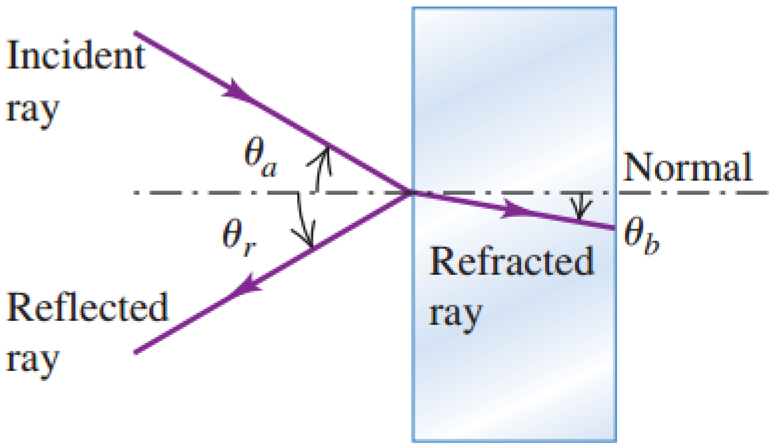
Recitation 5

Sunny Guha

http://people.physics.tamu.edu/sunnyguha/teach.html

Formulae

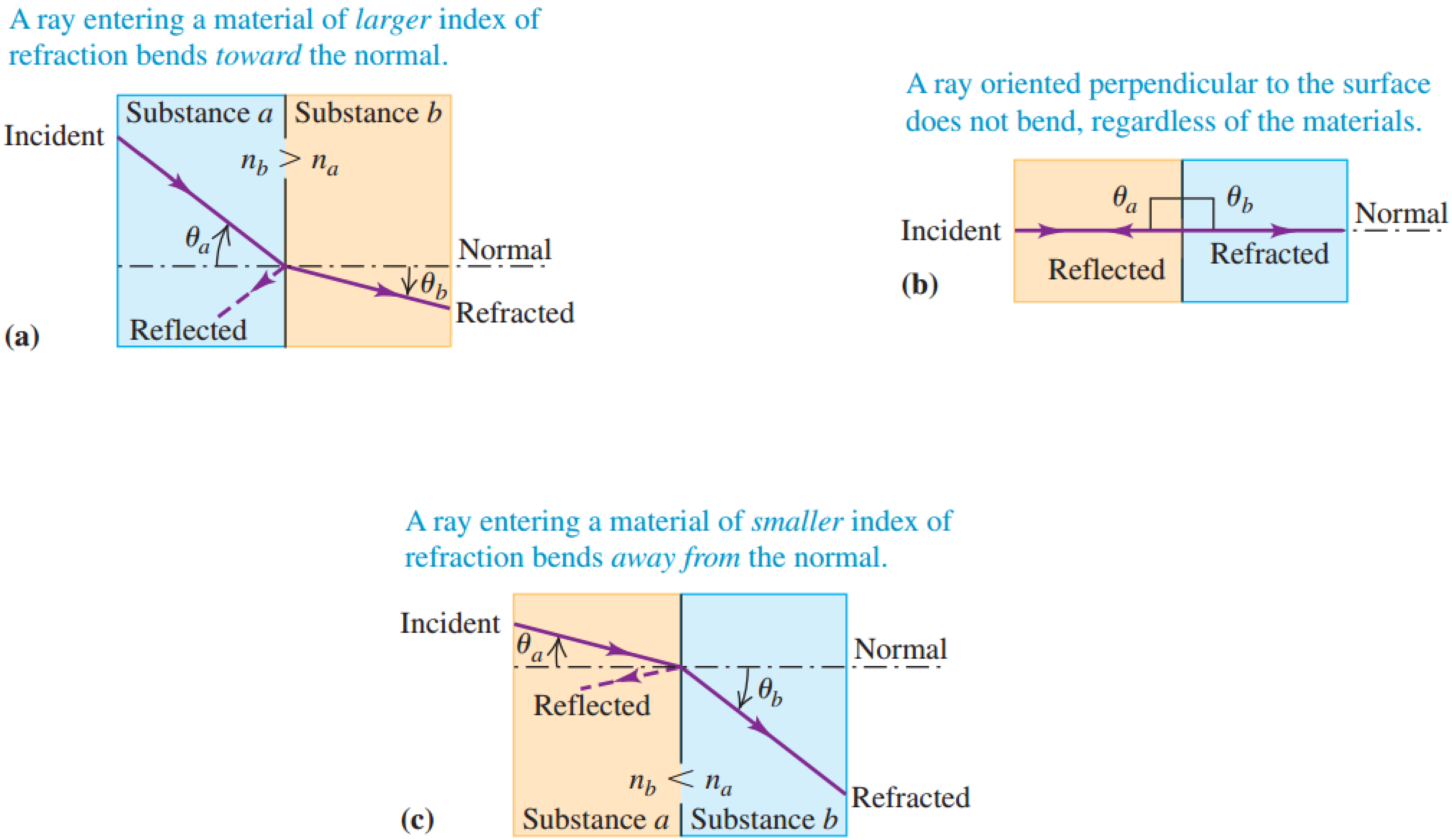


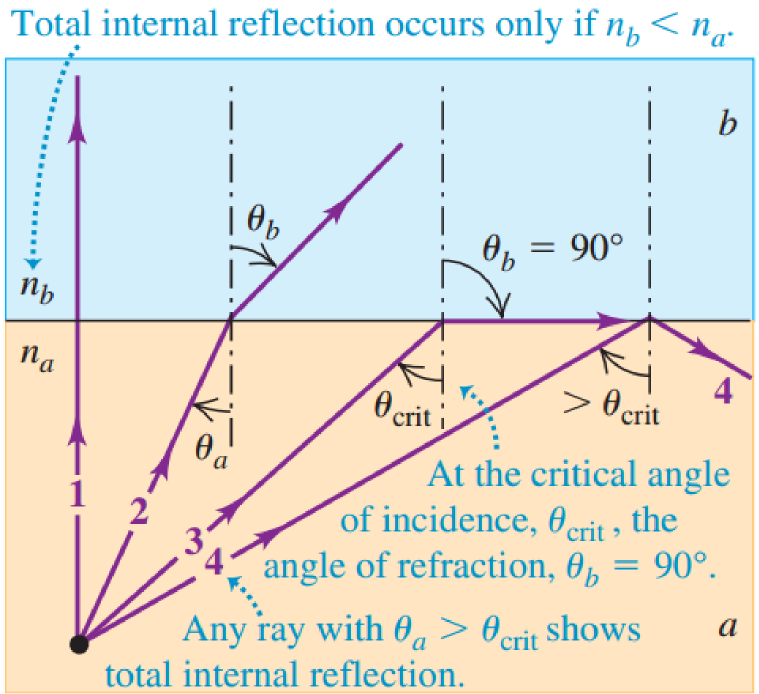


Definition of index of refraction
The index of refraction of an optical material, denoted as n, is the ratio of the speed of light in vacuum (c) to the speed of light in the material (v):

$$n = \frac{c}{v}.$$

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


A ray entering a material of *larger* index of refraction bends *toward* the normal.
Substance a
Substance b
Incident
$n_b > n_a$
θ_a
Normal
θ_b
Refracted
Reflected
(a)
A ray oriented perpendicular to the surface does not bend, regardless of the materials.
θ_a
θ_b
Incident
Normal
Refracted
Reflected
(b)
A ray entering a material of *smaller* index of refraction bends *away from* the normal.
Incident
θ_a
Normal
Reflected
θ_b
$n_b < n_a$
Refracted
(c)
Substance a
Substance b



Total internal reflection

When a ray traveling in a material *a* with index of refraction n_a reaches an interface with a material *b* having index n_b, where $n_b < n_a$, it is totally reflected back into material *a* if the angle incidence is greater than the critical angle given by

$$\sin\theta_{crit} = \frac{n_b}{n_a}.$$

Light transmitted by polarizing filter

When linearly polarized light strikes a polarizing filter with its axis at an angle ϕ to the direction of polarization, the intensity of the transmitted light is

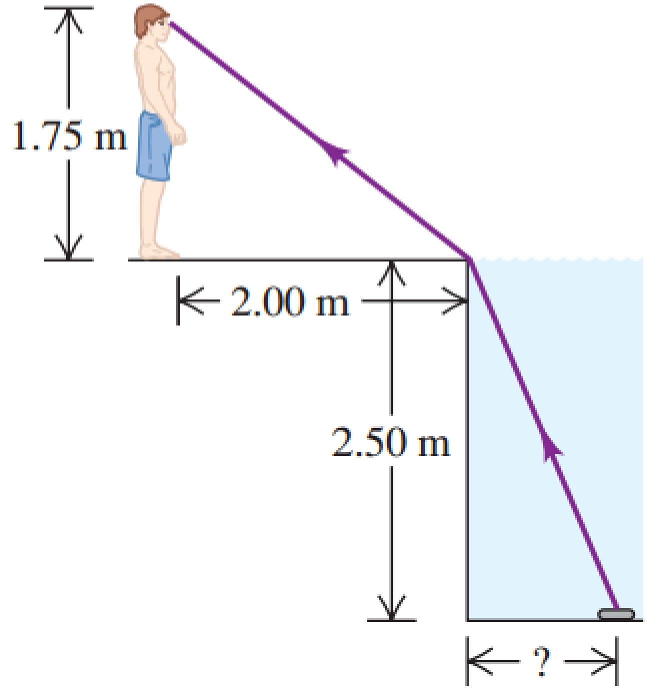
$$I = I_{max} \cos^2 \phi, \tag{23.19}$$

where I_{max} is the maximum intensity of light transmitted (at $\phi = 0$) and I is the amount transmitted at angle ϕ. This relationship, discovered experimentally by Etienne Louis Malus in 1809, is called **Malus's law.**

(6 pts) 1. A layer of water (($n = 1.33$) is floating on the surface of oil ($n = 1.60$) in a tank. A ray of light is traveling upward in the oil. What is the largest angle the ray can make with the normal to the lower surface of the water and still be partially refracted into the water?

a (a) 56.2°
(b) 48.8°
(c) 38.7°
(d) 66.4°
(e) none of the above answers

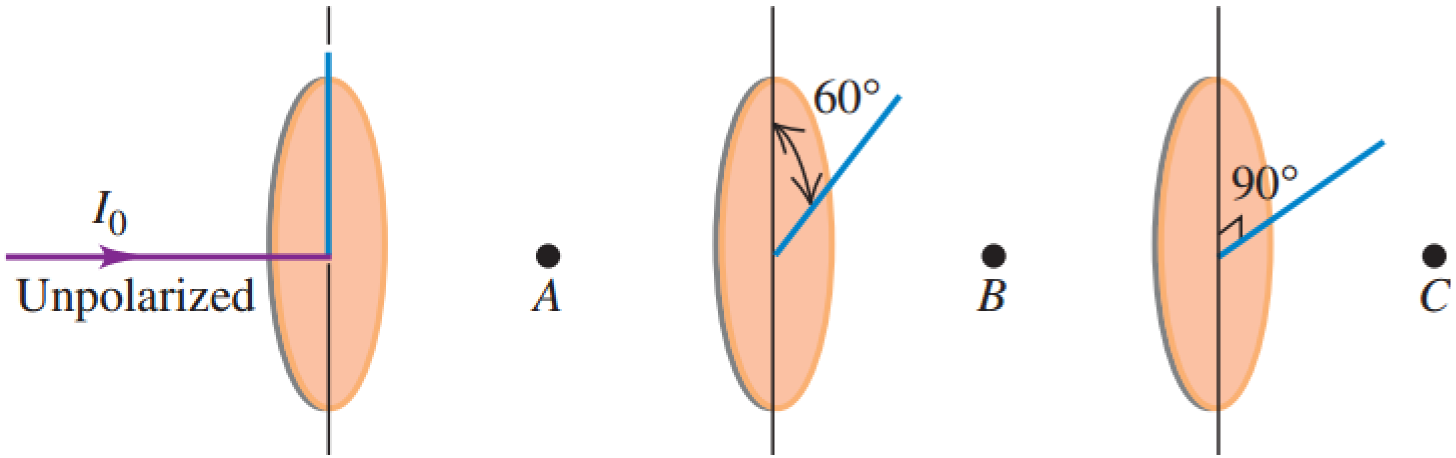
●● You (height of your eyes above the water, 1.75 m) are standing 2.00 m from the edge of a 2.50-m-deep swimming pool. You notice that you can barely see your cell phone, which went missing a few minutes before, on the bottom of the pool. How far from the side of the pool is your cell phone?



23.42. Set Up: The figure below shows a light ray from your cell phone, *P*, which grazes the corner of the pool, *C*, and reaches your eyes, *E*. We assume that the pool is full so that the light exits the water at point *C*.

Solve: From the figure we can find θ_t using geometry: $\theta_t = \tan^{-1}\left(\frac{2.00\text{ m}}{1.75\text{ m}}\right) = \underline{48.8}1^\circ$. Applying Snell's law at point *C* we obtain $(1.000)\sin \underline{48.8}1^\circ = (1.333)\sin\theta_i$, which gives $\theta_i = \underline{34.3}7^\circ$. Finally, we can find *d* from $d = (2.50\text{ m})\tan \underline{34.3}7^\circ = 1.71\text{ m}$.

59. ●● A beam of unpolarized light of intensity I_0 passes through a series of ideal polarizing filters with their polarizing directions turned to various angles as shown in Figure 23.61. (a) What is the light intensity (in terms of I_0) at points A, B, and C? (b) If we remove the middle filter, what will be the light intensity at point C?



*23.59. **Set Up:** When unpolarized light passes through a polarizer the intensity is reduced by a factor of $\frac{1}{2}$ and the transmitted light is polarized along the axis of the polarizer. When polarized light of intensity I_{max} is incident on a polarizer, the transmitted intensity is $I = I_{max}\cos^2\phi$, where ϕ is the angle between the polarization direction of the incident light and the axis of the filter.

Solve: **(a)** At point A the intensity is $I_0/2$ and the light is polarized along the vertical direction. At point B the intensity is $(I_0/2)(\cos 60°)^2 = 0.125I_0$, and the light is polarized along the axis of the second polarizer. At point C the intenisty is $(0.125I_0)(\cos 30°)^2 = 0.0938I_0$.

(b) Now for the last filter $\phi = 90°$ and $I = 0$.

Reflect: Adding the middle filter increases the transmitted intensity.

(6 pts.) 4. A small rock is at the bottom of a tank filled with water ($n = 1.33$). A person standing in the air above the tank looks straight down at the rock and the image she sees is 0.90 m below the surface of the water in the tank. What is the depth of the water in the tank?

(a) 0.68 m
(b) 1.2 m
(c) 1.8 m
(d) 2.4 m
(e) none of the above answers