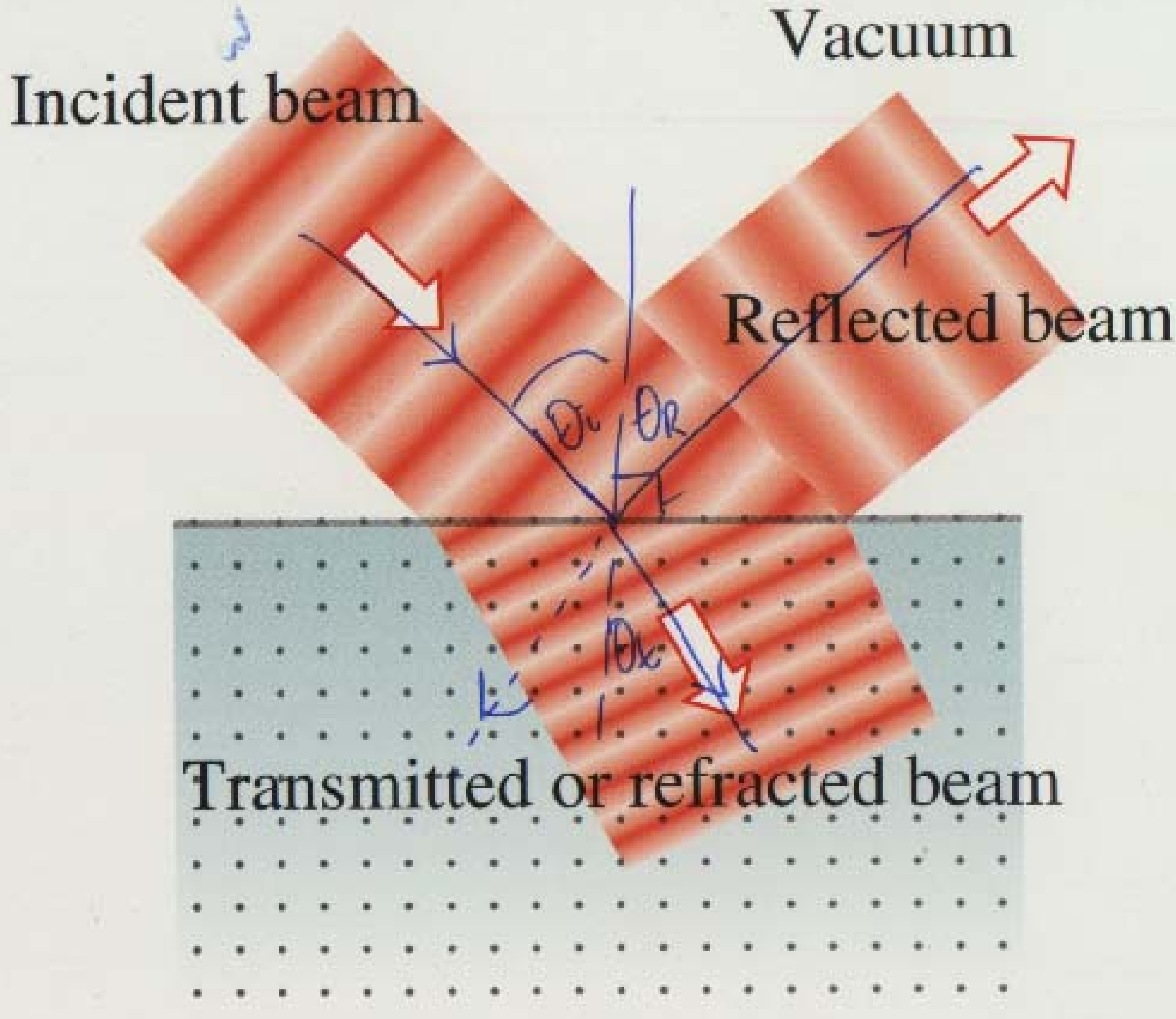
Transparency 142

Figure 23.12

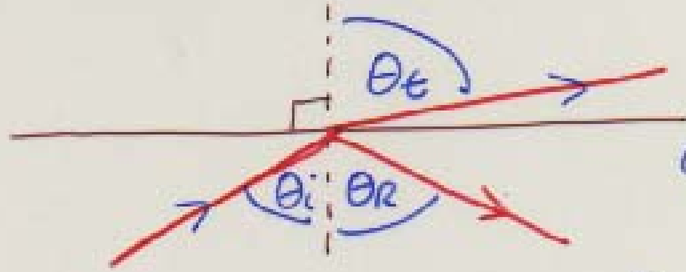
Reflected and transmitted light



Total Internal Reflection

- can occur when light beam travels from dense to less dense medium (i.e. $n_i > n_t$)

e.g glass → air, glass → water



(Fraction of beam reflected with $\theta_R = \theta_i$)

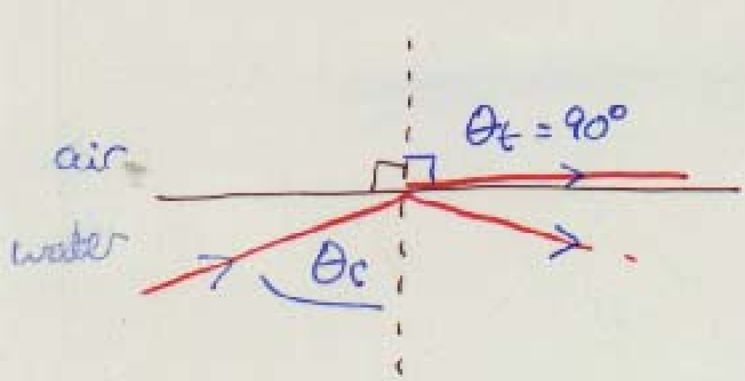
From Snell's laws, refracted beam has $\theta_t > \theta_i$
i.e. bends away from surface normal

As θ_i increases:

- reflected fraction increases
- refracted light has $\sin\theta_t = \overbrace{\left(\frac{n_i}{n_t}\right)}^{>1} \sin\theta_i$

When θ_i is such that $\sin\theta_i = \left(\frac{n_t}{n_i}\right)$, $\Rightarrow \sin\theta_t = 1$

i.e. $\theta_t = 90°$, refracted ray skims along surface



This is the critical angle θ_c of incidence

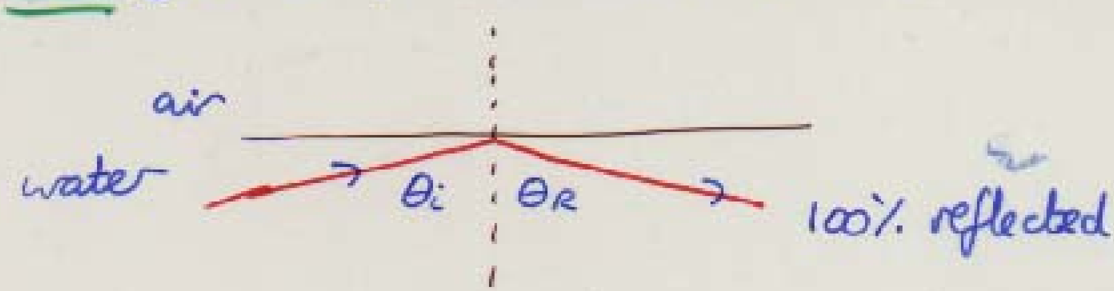
$$\sin\theta_c = \left(\frac{n_t}{n_i}\right) \quad (<1)$$

T. I. R. cont/d

For $\theta_i > \theta_c$, $\sin\theta_t = \frac{n_i}{n_t}\sin\theta_i > 1$

i.e. no refraction possible!

So **all** light is reflected inside surface, cannot escape.

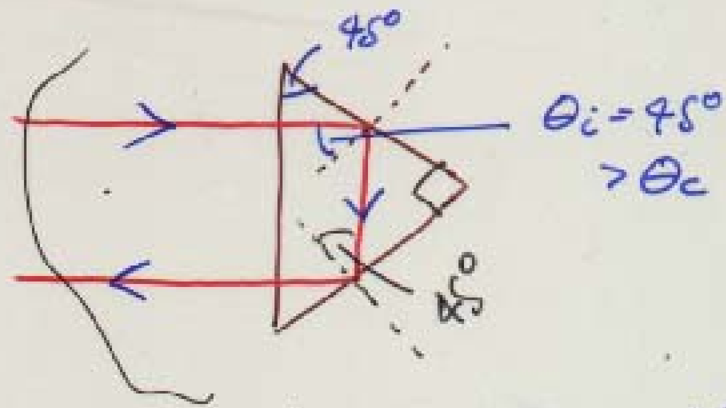


e.g. binoculars use prisms as mirrors: ≈ 100% efficient!

For glass → air

$n_g = 1.5$, $n_a = 1.00028$

$\Rightarrow \sin\theta_c = \frac{1}{1.5} \Rightarrow \theta_c = 41.8°$



(Note, would not work underwater! Then $\sin\theta_c = \frac{1.33}{1.5}$ $\frac{n_t}{n_i}$

$\Rightarrow \theta_c = 62°$)

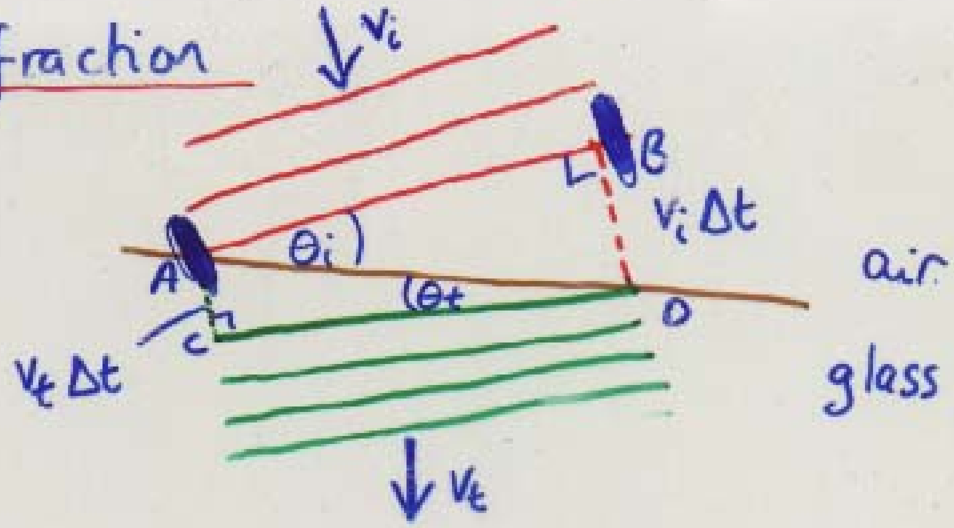
c.f. diamond/air with $n_d = 2.42 \Rightarrow \theta_c = 24.4°$

(cut facets designed to trap light inside: sparkle)

Note: If $n_t < n_i$ or $n_t = n_i$, no T.I.R. can occur

(some light always transmitted)

Refraction



Across interface:

1. $n_i \sin\theta_i = n_t \sin\theta_t$: Snell's Law
2. Speed changes $v = \frac{c}{n}$
3. Wavelengths $\lambda = \frac{v}{f} \Rightarrow \lambda_i n_i = \lambda_t n_t$

Note: "color" measures f, not λ, so unchanged
λ_0 = max (vacuum) wavelength

4. Area of beam changes:

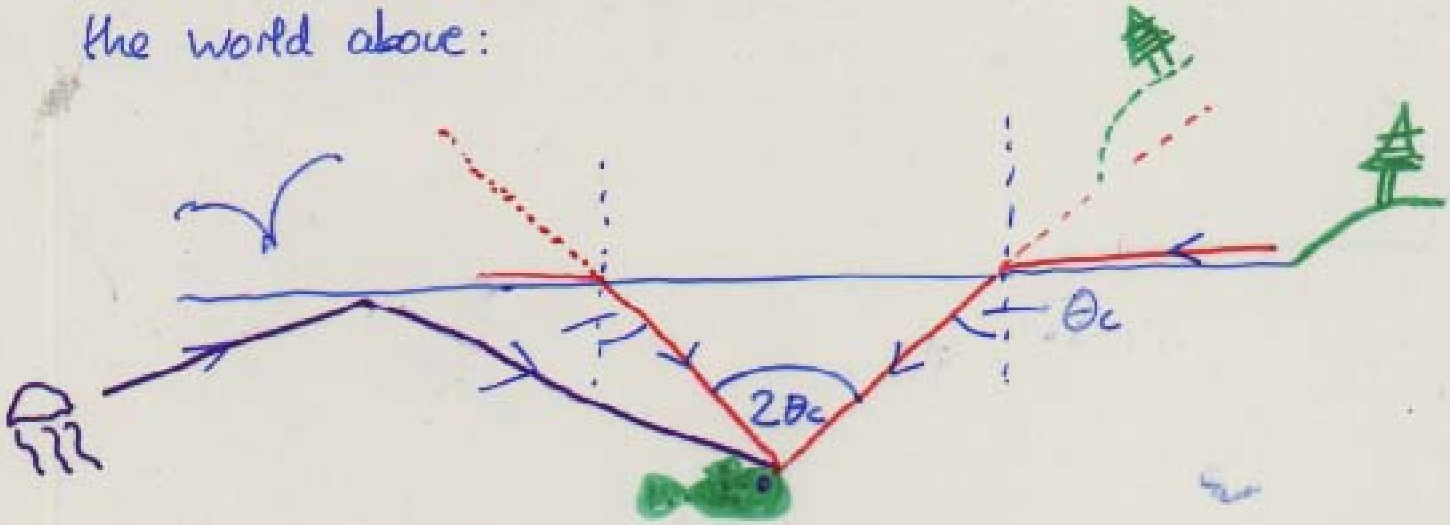
In glass, cross-section $CD = AD \cos\theta_t$

In air, $AB = AD \cos\theta_i$

From Snell's Law, $\theta_t < \theta_i$ so $CD > AB$

($\Rightarrow$ same energy spread over lager area
$\Rightarrow$ irradiance $\downarrow$)

Example (HW ch 23, problem 67) - A fish's view of the world above:



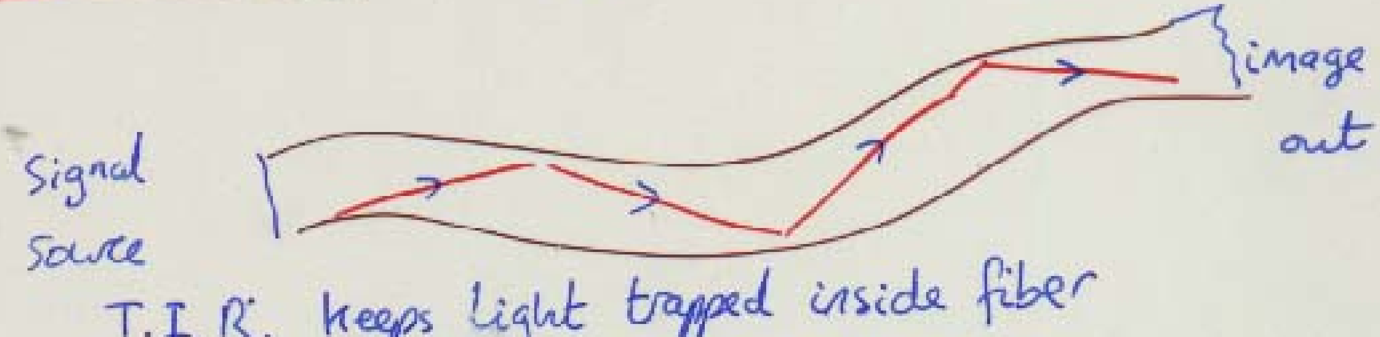
Objects on shore (or on surface far away) have $\theta_{air} = 90°$

Panorama of world above lake appears in a cone of light above fish, with cone angle $2\theta_c$

(For water/air, $\theta_c = \sin^{-1}\left(\frac{1}{1.33}\right) = 48.6°$)

Outside this cone, fish sees a reflection of bottom + objects in water

Optical Fibers (endoscopy, cable TV/internet)



T.I.R. keeps light trapped inside fiber

Color (ch. 23·7)

Additive Color: can combine light beams to produce ~ any color we can perceive

e.g. Red + Green + Blue = White
("primary" colors: Red, Green, Blue)

Note, e.g. R + G = Yellow — eye is "fooled" by mixing 2 colors → intermediate color.

Also: Red + Blue = Magenta
Blue + Green = Cyan
Red + Green = Yellow

so:
M + G = W
C + R = W
Y + B = W

(M, C, Y: "complementary" colors.)

Adding additional color → increases "white" contribution
color becomes "unsaturated"

e.g. $M + Y = (R+B) + (R+G)$

$= (R+G+B) + R$

$=$ White + Red : "Pink"

"Subtractive" Color : Absorption + Reflection

- Filters can absorb certain frequencies from white light
  e.g. Yellow filter transmits Y = R+G, absorbs Blue

  Adding more filters ⇒ more colors absorbed
  ⇒ Black when no light transmitted

- Dyes, pigments, inks absorb some frequencies, reflect others (e.g. red shirt absorbs G+B, reflects red)

e.g. Color printing done with Cyan, Magenta, Yellow ink
(+ blacK ⇒ "CMYK" printing) - can produce ~ any color in reflected light.

- Reflected / filtered light only subtracts color, cannot "create" it, e.g. through blue-tinted glasses, all colors → shades from black to bright blue

- Transparent small particles (cloud droplets, salt or sugar crystals)
  ⇒ diffuse reflection of all colors
  ⇒ reflect "white" light (or color of light source)