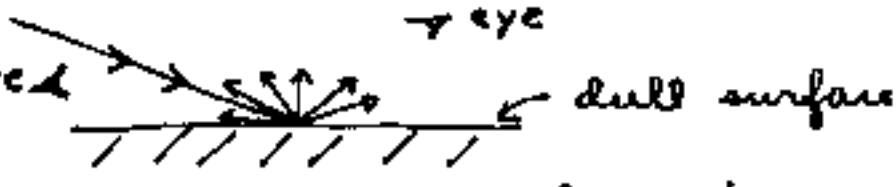
Geometrical Optics

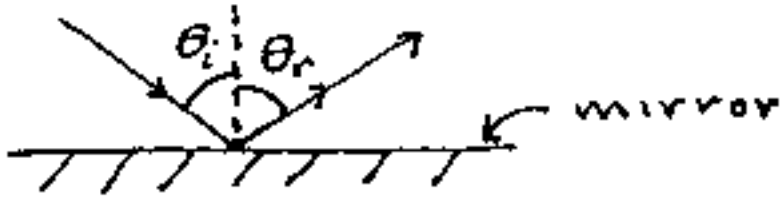
In many circumstances, can ignore wave nature of light and assume that light is a stream of particles that travel in straight lines called rays.

When light reflects off dull surface, rays scatter in all directions:



- see reflected rays in all directions.

When ray scatters off mirror, see reflected ray in one direction only.

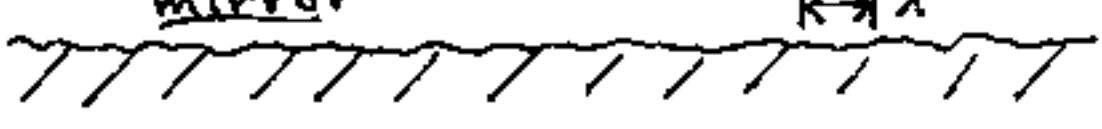


$\theta_i = \theta_r$, incident $\angle$ = reflected $\angle$

Any surface is shiny, mirror-like if smooth compared to $\lambda_{light} \approx 500$ nm

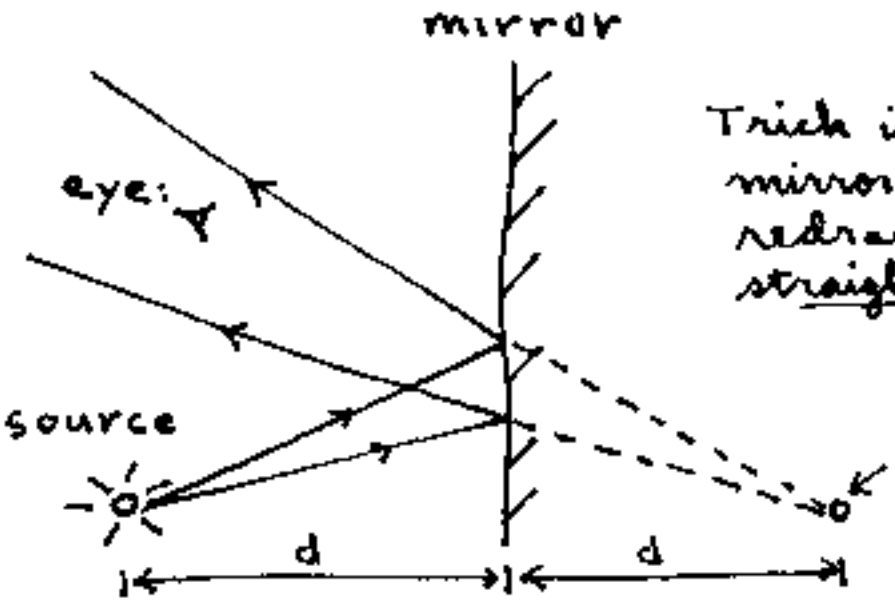
dull

mirror



Dull surface in visible can be shiny in IR!

Rays from point source reflected from mirror appear to be coming from point <u>behind</u> mirror.



Trick in analyzing mirror problems: redraw rays as <u>straight lines</u>.

"virtual image"

"virtual image" occurs when rays <u>appear</u> to be coming from point in space but are <u>not</u> really.

Refraction / Snell's Law

Any transparent medium (air, water, glass) characterized by dimensionless number

index of refraction = $n = \frac{c}{v} = \frac{\text{speed of light in vacuum}}{\text{speed of light in medium}}$

c = <u>max</u> speed, $v_{\text{light in medium}} < c$ <u>always</u>

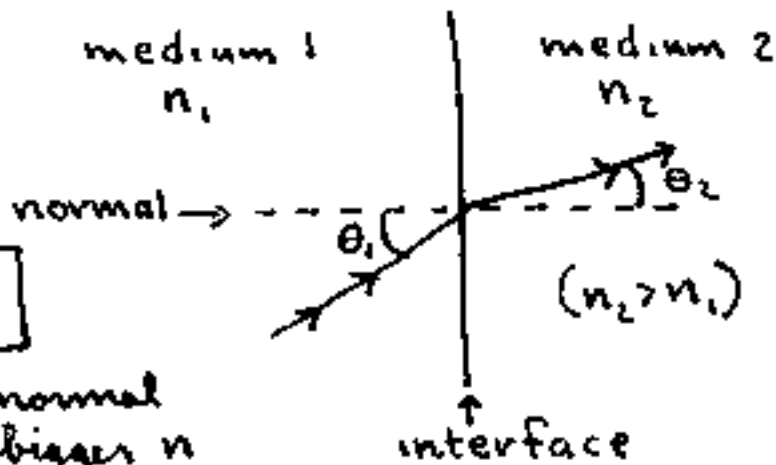
$\Rightarrow n > 1$ always

material	n
vacuum	1
air	1.0003 ≃ 1
water	1.33
Lucite	1.51
glass	1.45 - 1.7 (depends on type)
diamond	2.42

When ray passes from 1 medium to another, ray is bent or refracted, according to

Snell's Law

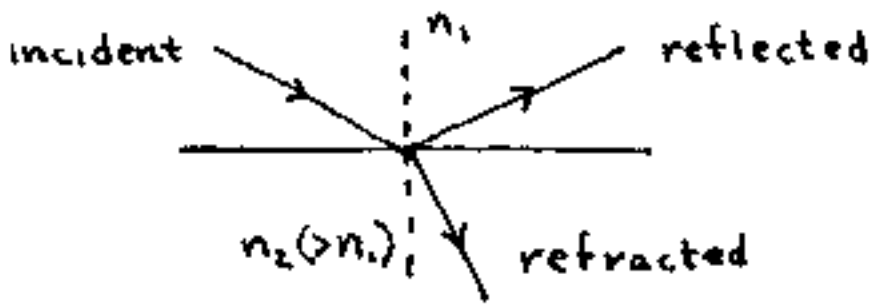
$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$



Ray is closer to normal in medium w/ bigger n

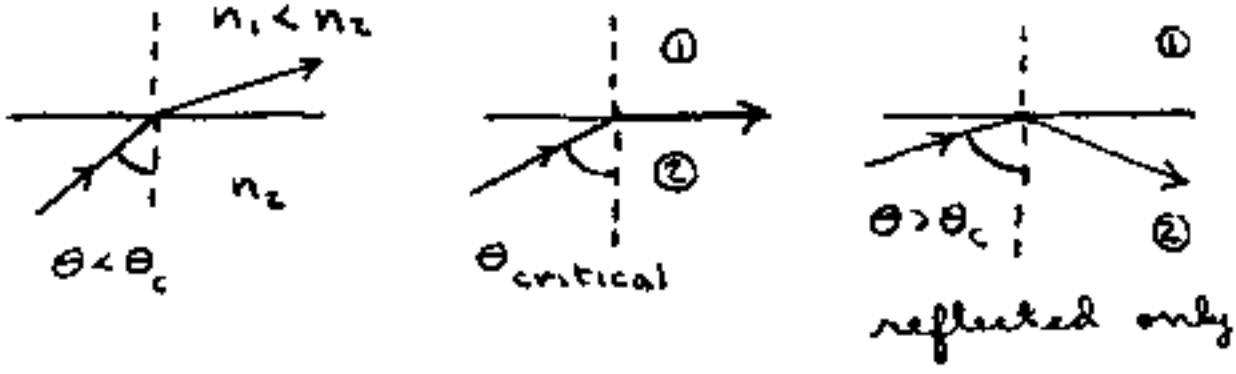
Bigger change in n ⇒ ray bent more

incident ray usually partially reflected, partially refracted:



If ray passes from higher n ⇒ lower n ⇒ ray bent away from normal, can have total internal reflection

⇒ No refracted ray



θ_c for water ($n = 1.33$) $\longrightarrow$ air ($n \approx 1$)

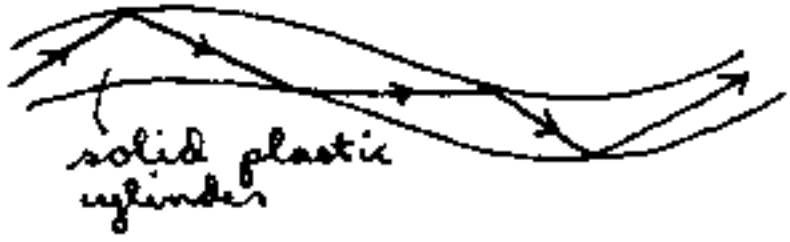
$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$n_w \sin\theta_c = (1)\underbrace{\sin 90^\circ}_{1} = 1$$

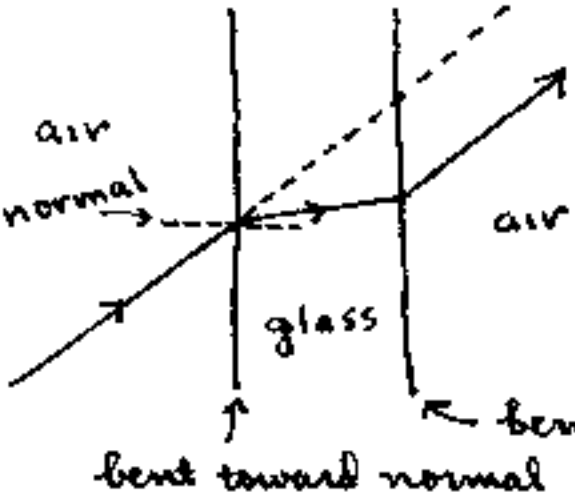
$$\sin\theta_c = 1/n_w \Rightarrow \theta_c = \sin^{-1}\left(\frac{1}{n_w}\right) = \sin^{-1}\left(\frac{1}{1.33}\right) = 48.8^\circ$$

Light pipes

$n_{pipe} > n_{air}$



Two flat, parallel surfaces (glass plate)



2 interfaces ⇒ 2 refractions
ray emerges parallel to original ray,
but displaced