Lecture 36: Ray optics

- Reflection and refraction
- Snell's Law
- Total internal reflection

Ray model of light

- Light travels in a straight line
- Light rays can cross
- Light travels forever unless it interacts with matter
- Objects are sources of light rays: if we see it, light is coming from it
- Light rays originate fro every point of an object and travel outwards in all directions
- In Ray diagrams, we show a few selected rays leaving top and bottom of an object

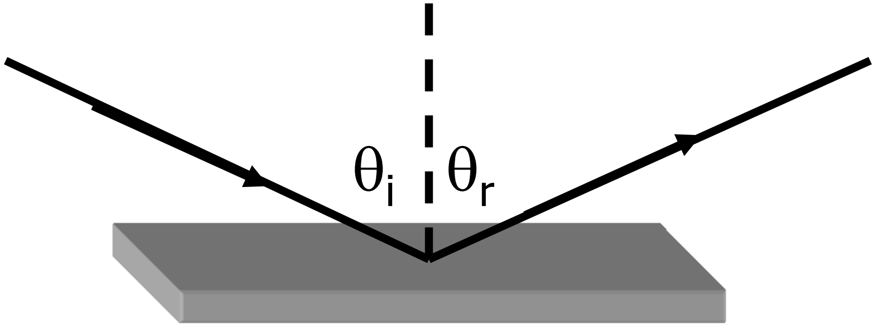
Refraction and reflection

- $n = \frac{c}{v}$ **Refractive index,** $n \geq 1$
- Light travels slower in materials than in vacuum
- Incident, reflected, refracted rays and surface normal are all in the same plane

Reflection

Reflected light leaves surface at the same angle it was incident on surface:

$$\theta_i = \theta_r$$

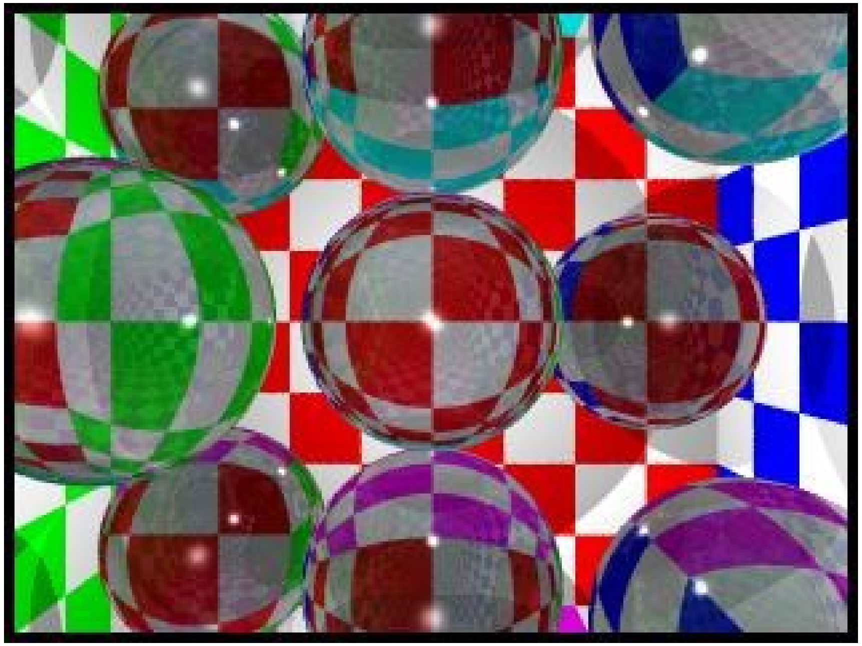


Important: the angles are measured **relative to the surface normal**.

Refraction

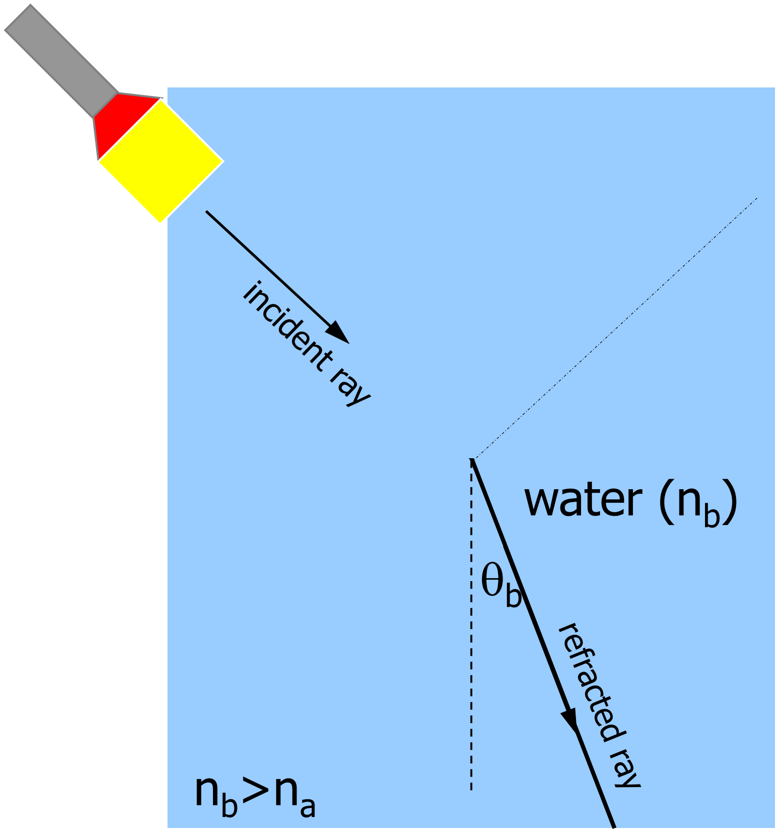
- light rays **change direction** (are "refracted") when they move from one medium to another

- refraction takes place because light travels with different speeds in different media



Snell's Law

θ_a: angle of incidence, θ_b: angle of refraction

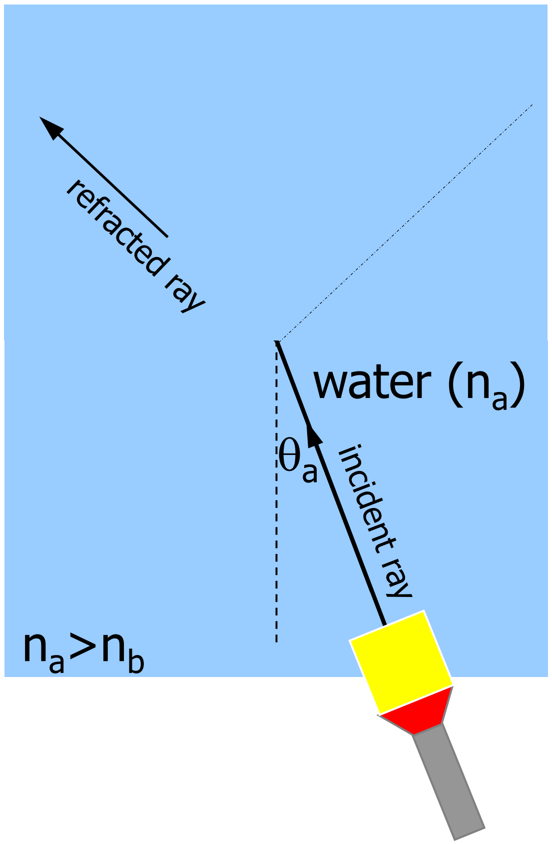


$$n_a \sin(\theta_a) = n_b \sin(\theta_b)$$

Caution: angles are measured **From the surface normal**.

Snell's Law

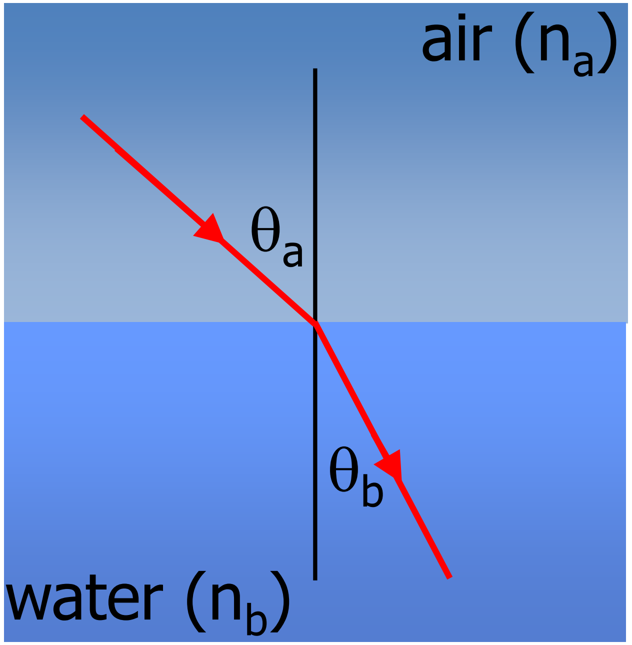
θ_a: angle of incidence, θ_b: angle of refraction

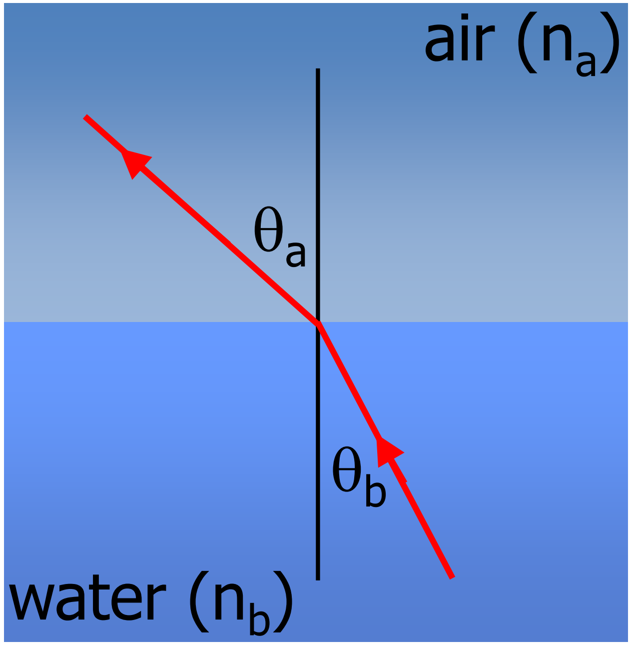


$$n_a \sin(\theta_a) = n_b \sin(\theta_b)$$

Snell's law:

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





Example

Total internal reflection

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

$$\sin(\theta_1) = \frac{n_2}{n_1} \sin(\theta_2)$$

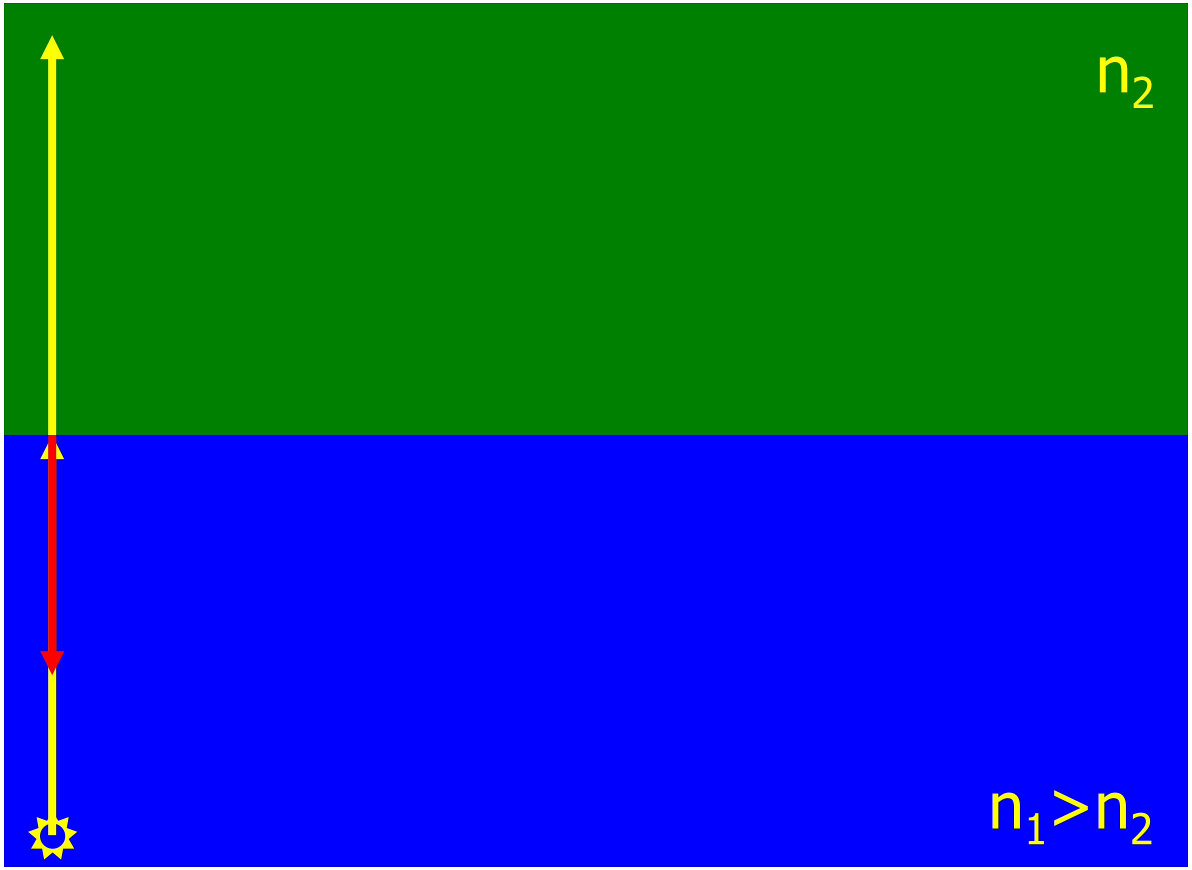
If $n_2 < n_1$:

- largest possible value of $\sin(\theta_2)$ is 1 (when $\theta_2 = 90$)
- therefore, largest possible value of $\sin(\theta_1)$ is

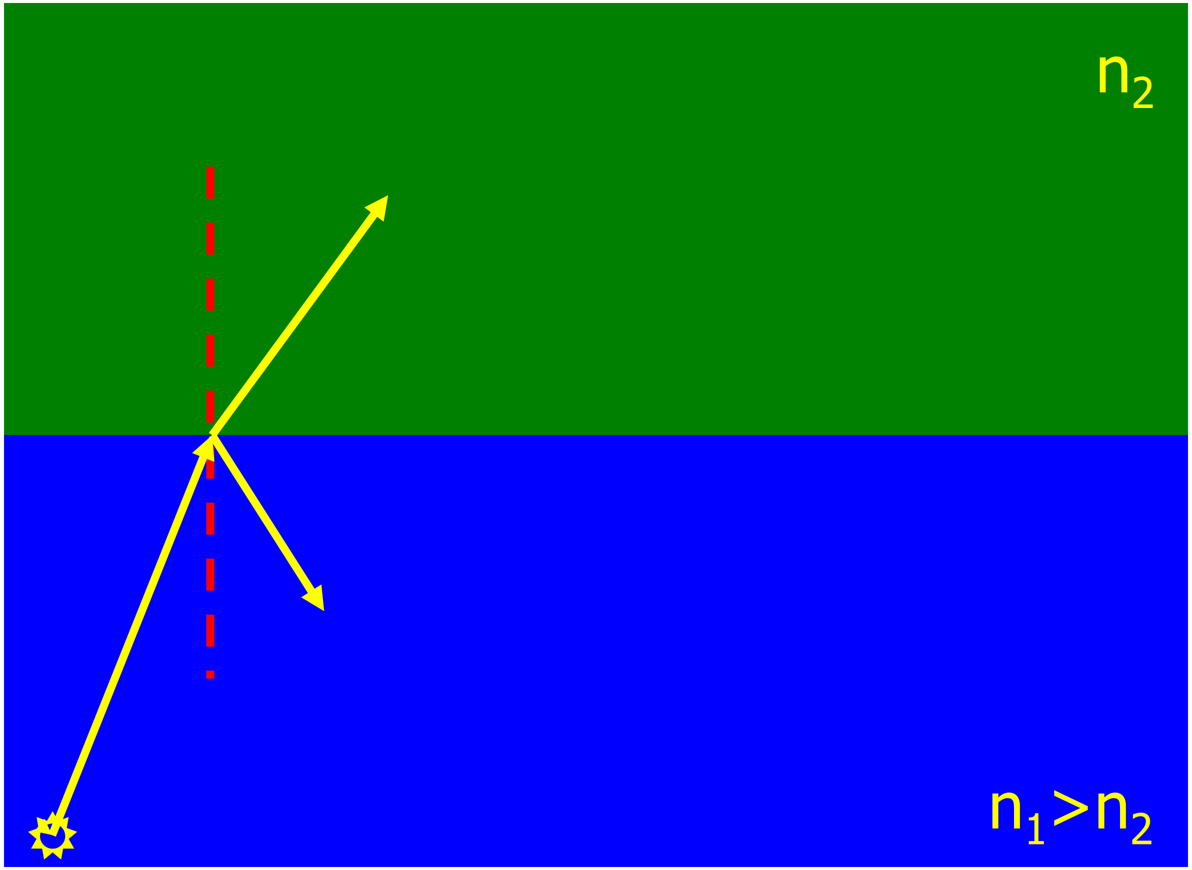
$$\sin(\theta_{1,max}) = \sin(\theta_c) = \frac{n_2}{n_1}.$$

For θ_1 larger than θ_c, Snell's Law cannot be satisfied!

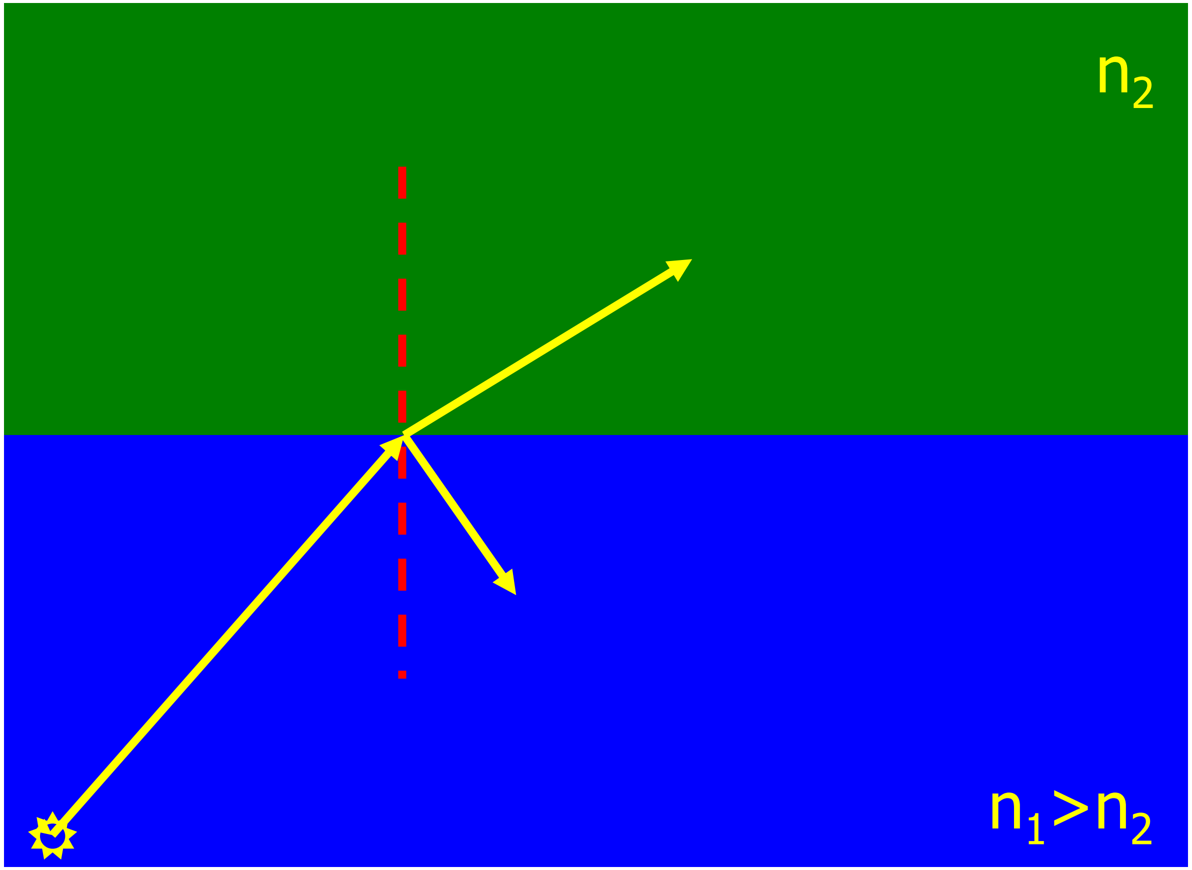
- for $\theta_1 > \theta_C$: no refracted ray, light is **totally reflected**
- θ_C is called the **critical angle** of total internal reflection



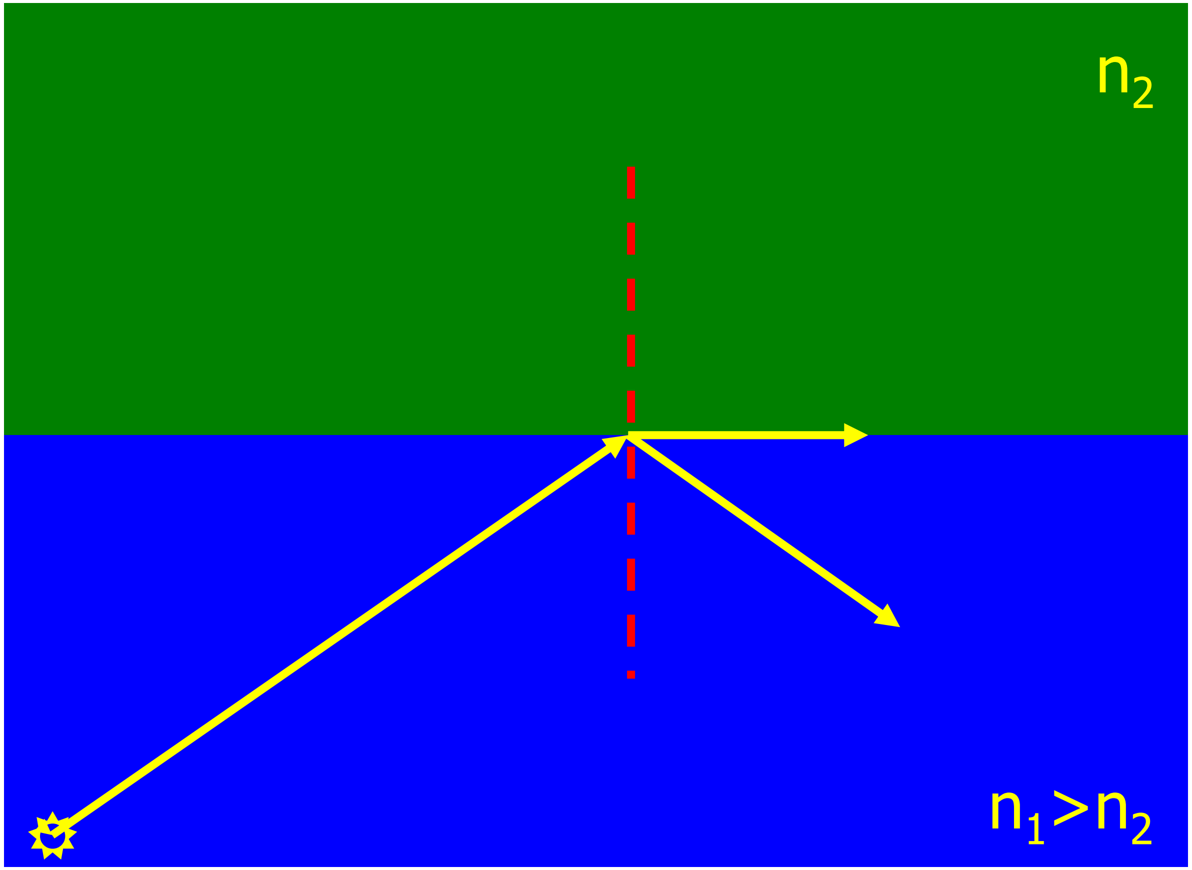
Ray incident normal to surface is not “bent.” Some is reflected,



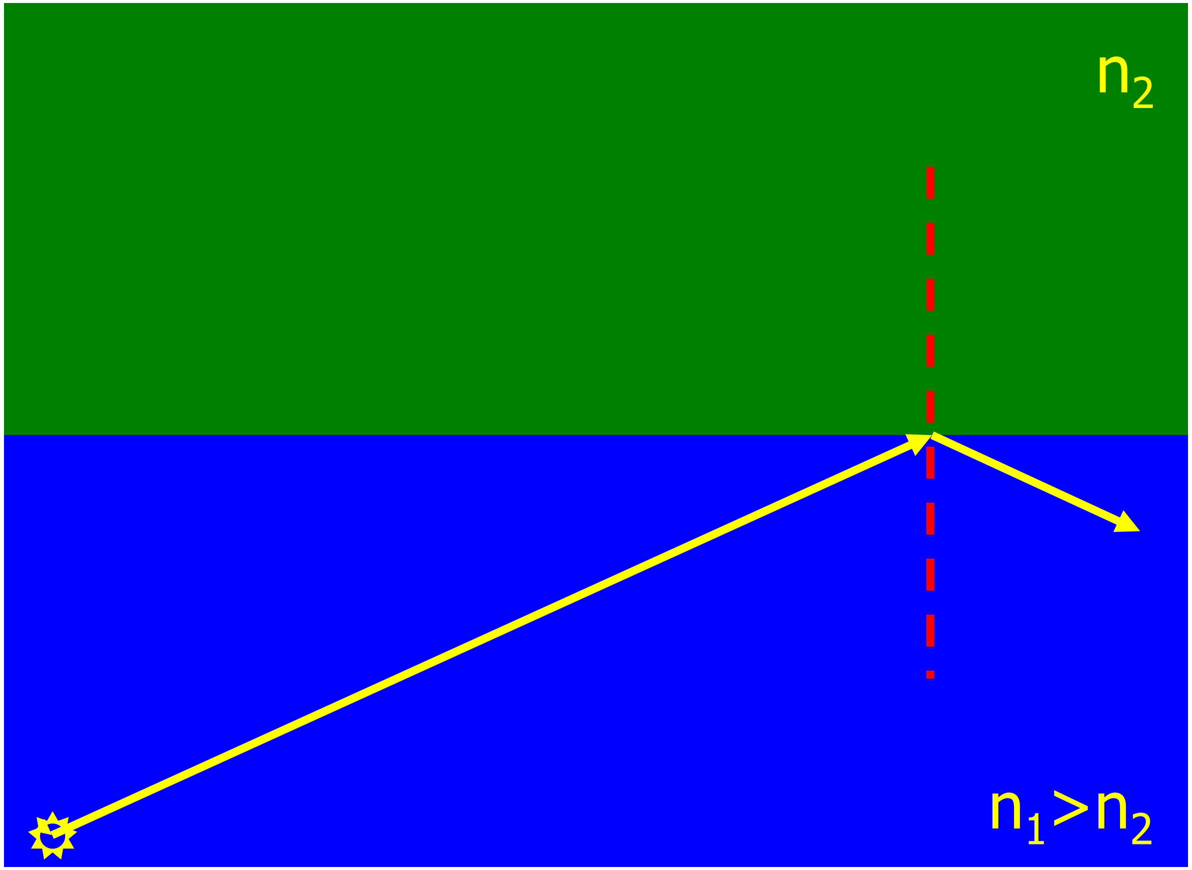
Increasing angle of incidence…



Increasing angle of incidence…more…



Increasing angle of incidence…more…critical angle reached… some of incident energy is reflected, some is “transmitted along the boundary layer.



Light incident at any angle beyond θ_C is totally internally reflected.