



Ray Tracing in Entertainment Industry

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Week 6

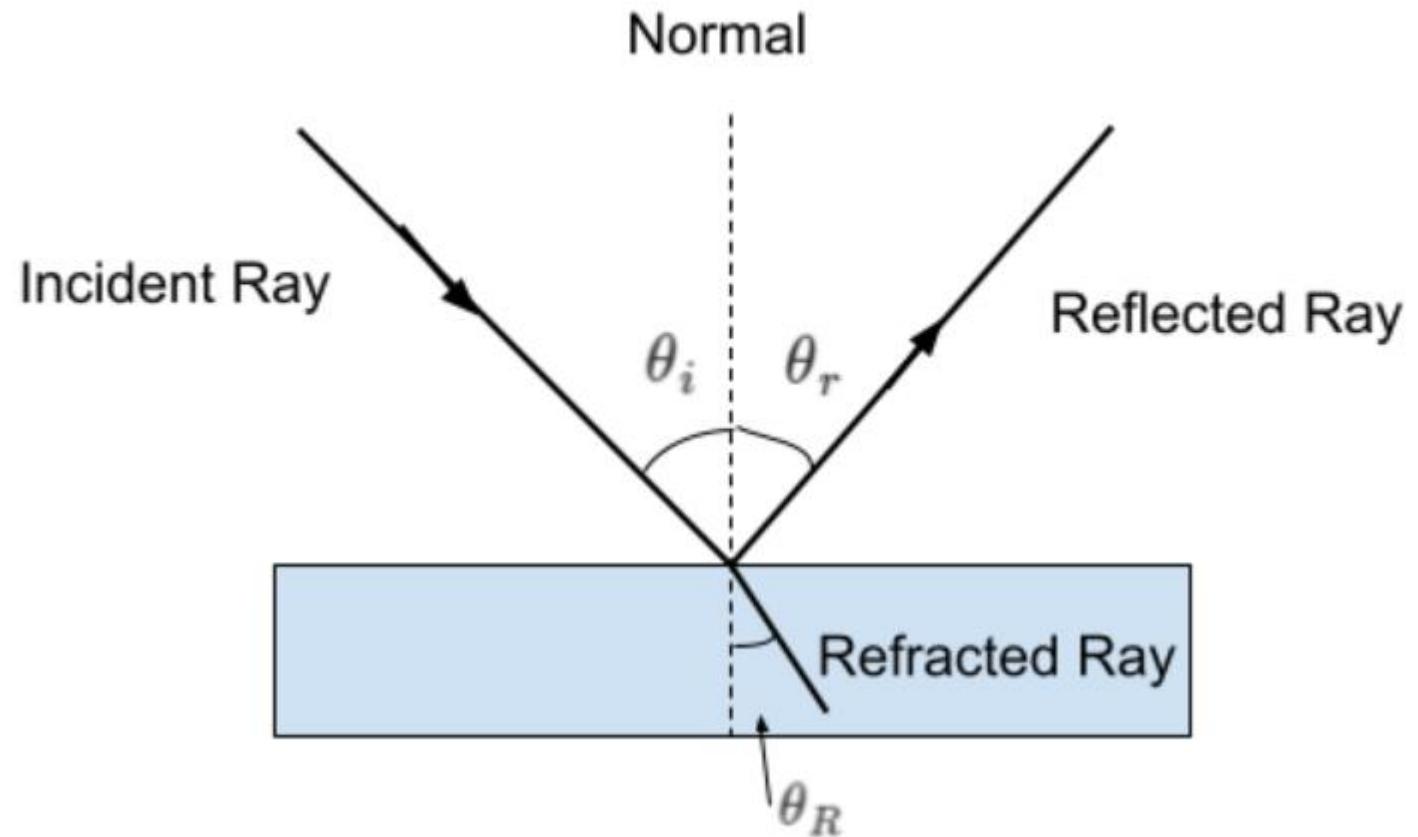
Geometric optics

Geometric optics

- Definition
 - A model of optics describing how light propagates in terms of rays.
- We can utilize this model to create several material appearances.
- Physical properties
 - Reflection
 - Refraction



Revisit



What is reflection ?

A change in light direction when it hits the surface (medium) then the light ray bounces off the surface in another direction.

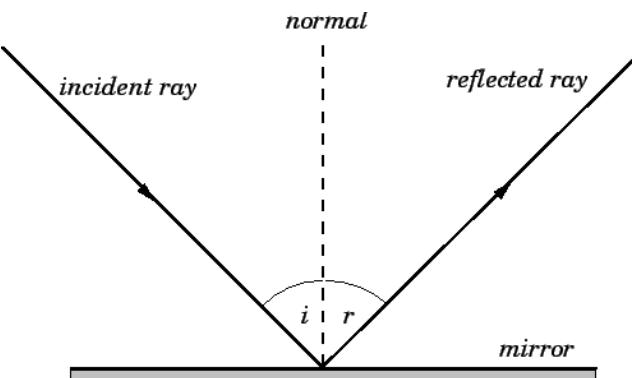
The law of reflection governs the very smooth surfaces.

Laws of reflection

The incident ray, the reflected ray and the normal to the reflection surface at the point of the incidence lie in the same plane.

The angle which the incident ray makes with the normal is equal to the angle which the reflected ray makes to the same normal.

The reflected ray and the incident ray are on the opposite sides of the normal.



Reflections of light

Perfect
reflection

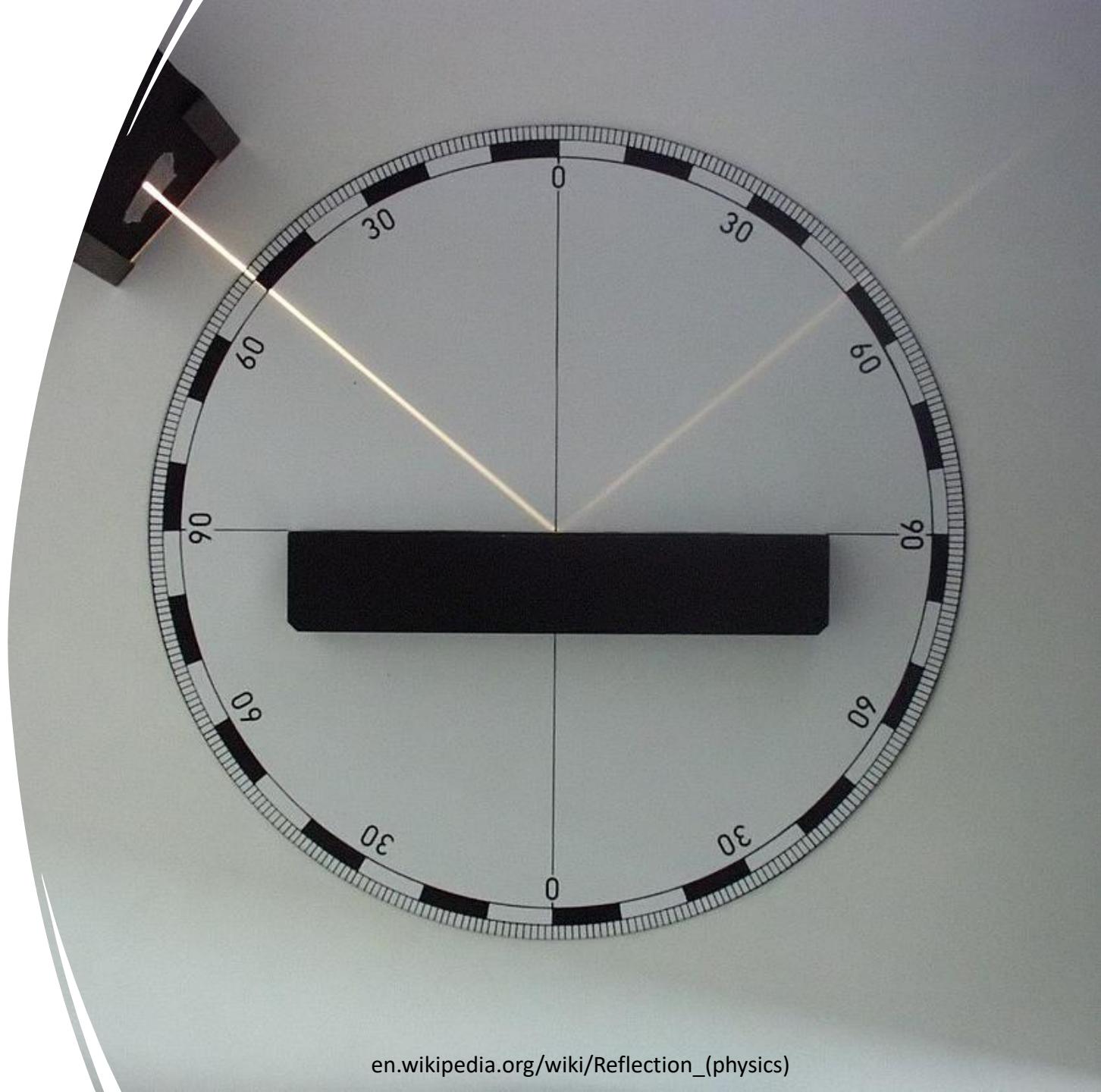
Diffuse
reflection

Specular
reflection

Retro
reflection

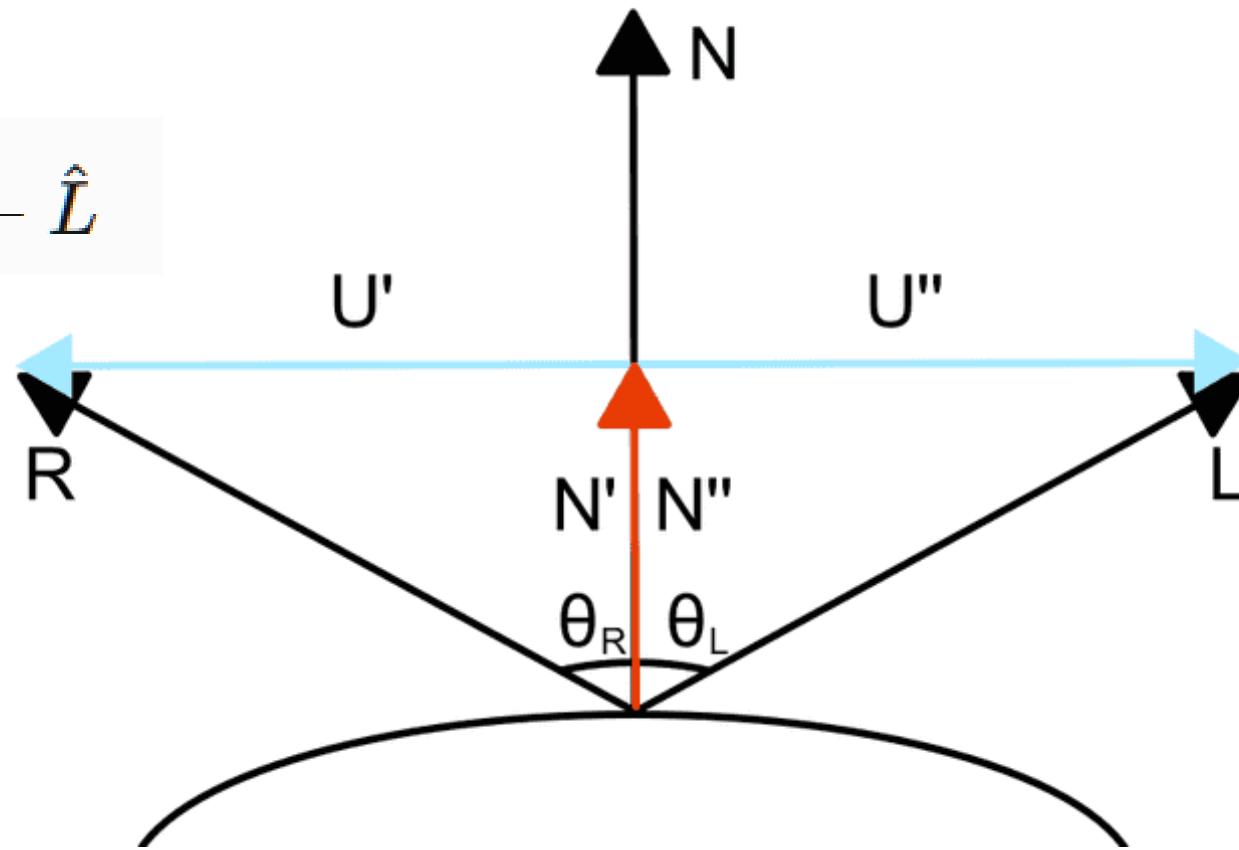
Perfect reflection

- Examples ?



Perfect reflection direction

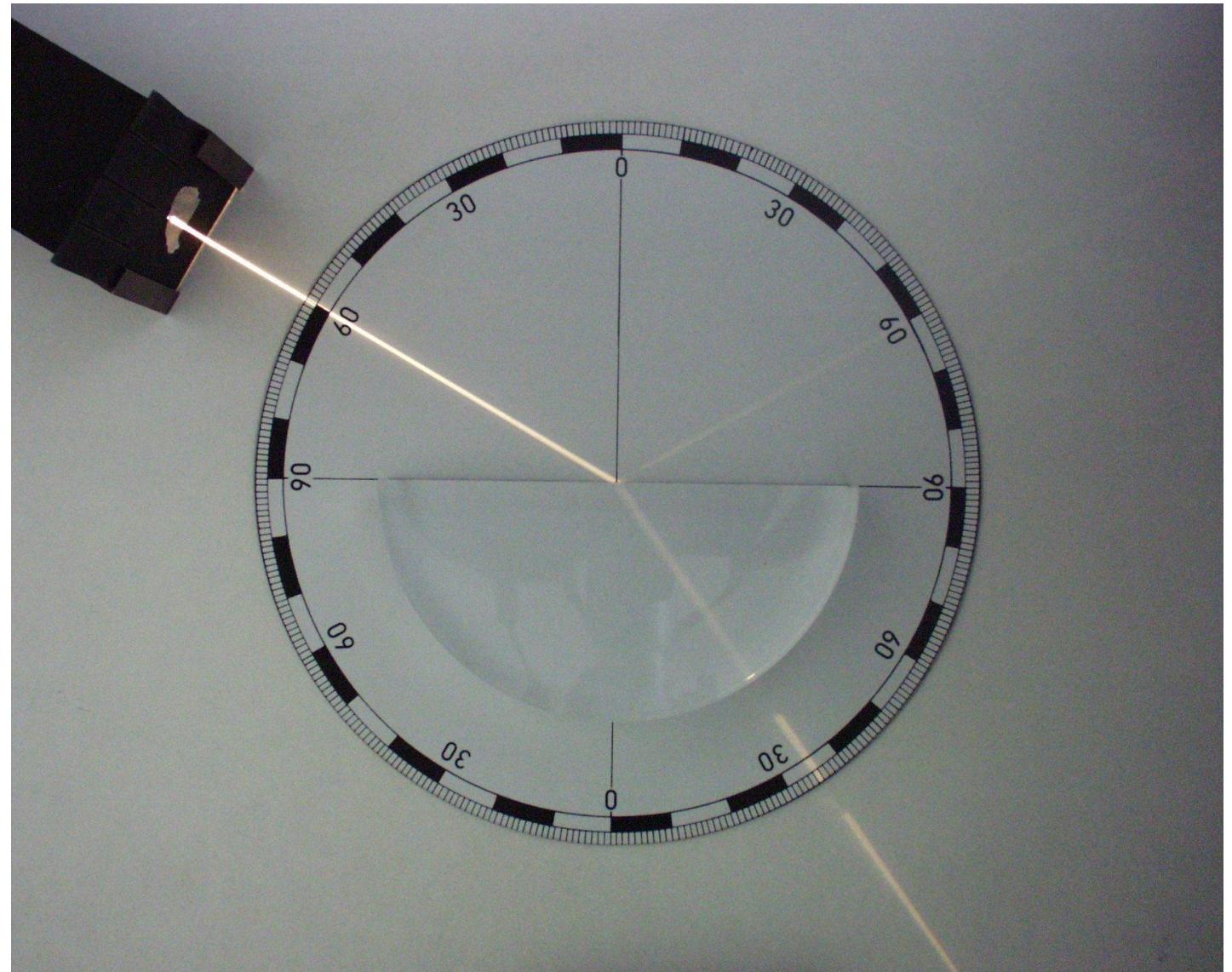
$$R = 2(\hat{N} \cdot \hat{L})\hat{N} - \hat{L}$$





Which one is perfect reflection ?

A dielectric
material



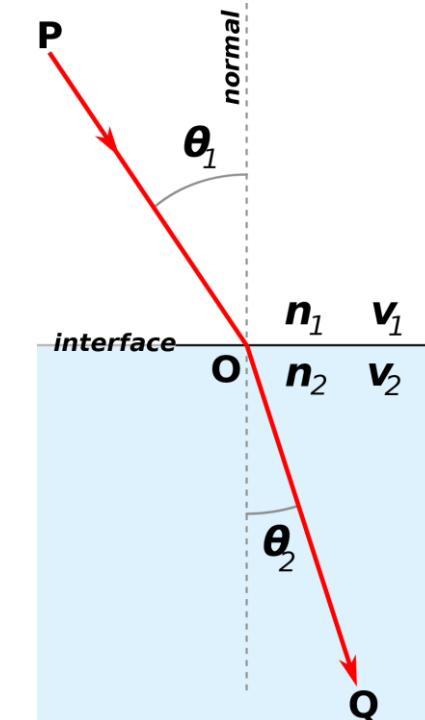
Examples of dielectric materials

- Refractive index = $\frac{\text{speed of light in vacuum}}{\text{speed of light in the medium}}$
- - It determines how much light is bent when travels through the medium.
- - Snell's law of refraction can be used to describe this light propagation.

Material	Refractive index
Vacuum	1
Air	1.000293
Water	1.333
Ice	1.31
Window glass	1.52
Diamond	2.42

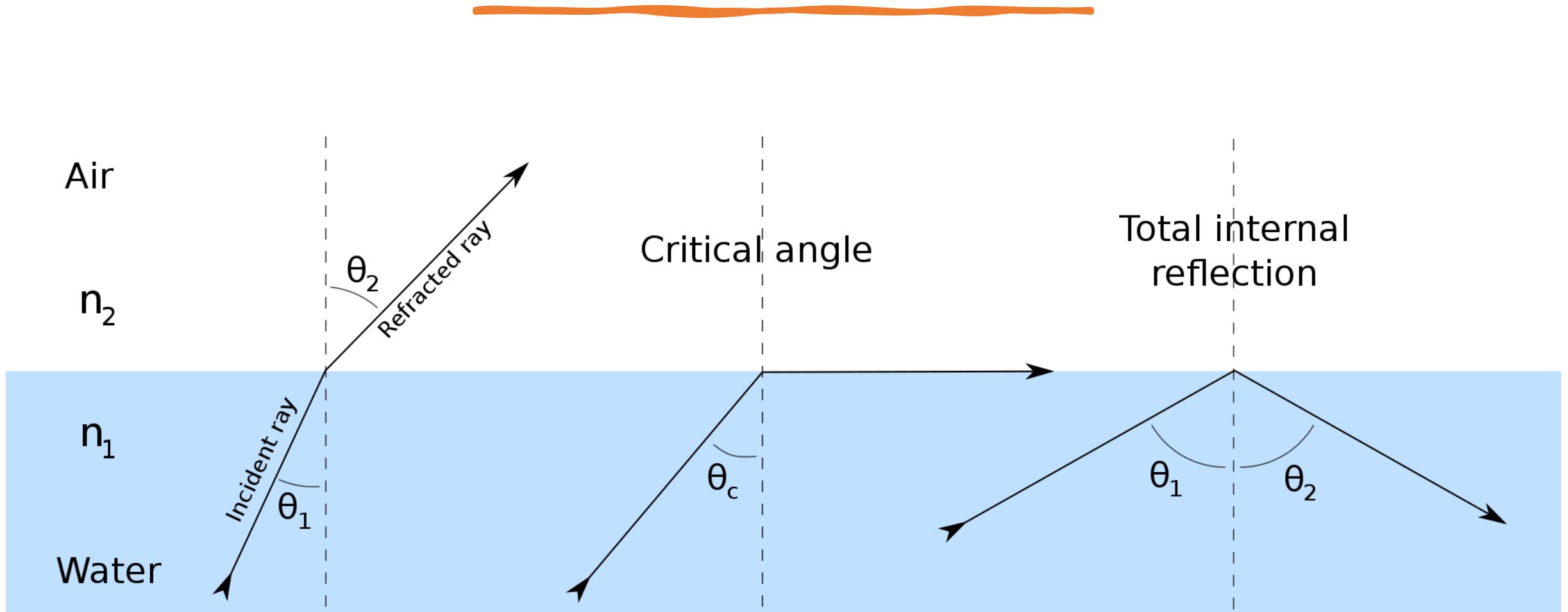
Snell's law of refraction

- Snell's law describes the relationship between the **angles and velocities** of waves.
- It states that the **ratio of the angle of incidence to the angle of refraction** of a wave as it travels through a boundary **between two media** is a constant termed the refractive index.



$$\frac{\sin \theta_1}{\sin \theta_2} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$$

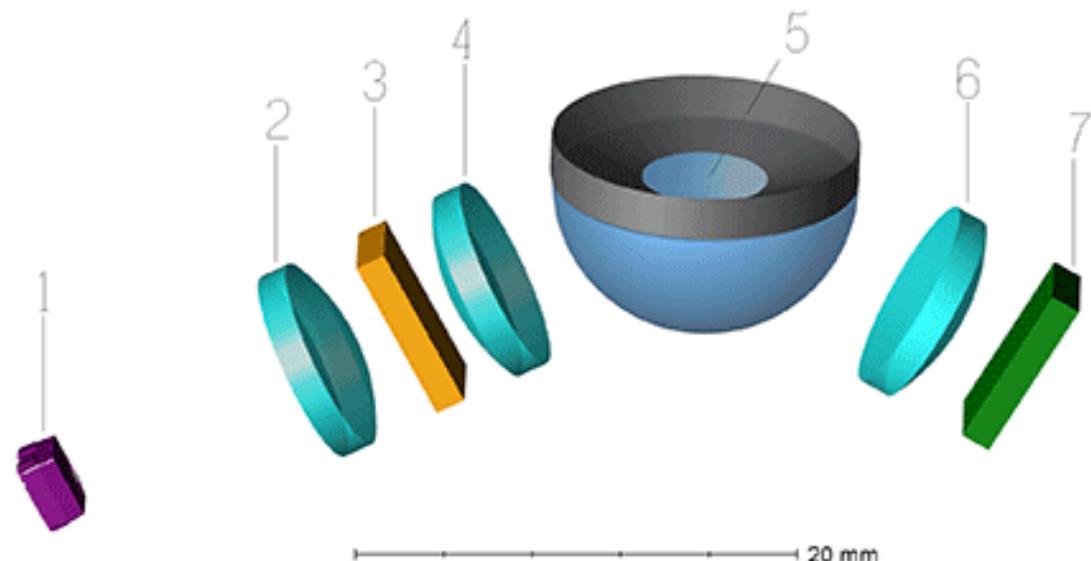
Refraction of light at the interface between two media



Refractometer

When measuring refractive index:

1. A light-emitting diode or LED serves as the light source and emits a light beam. The LED beam that is emitted then passes through:
2. The polarization filter,
3. The interference filter, and
4. The focal lens. After filtering, the LED beam then reaches:
5. The sample held by the sapphire prism.
6. Light is reflected and deflected via a lens in the sapphire prism to
7. The optical CCD sensor, which measures the critical angle.



Additionally, a modern digital refractometer controls the temperature at the prism/sample boundary automatically, further enhancing measurement accuracy.

Refraction direction

```
def refract(vRay, vNormal, fRefractRatio):
    cos_theta = min(rtu.Vec3.dot_product(-vRay, vNormal), 1.0)
    sin_theta = math.sqrt(1.0 - cos_theta*cos_theta)
    cannot_refract = fRefractRatio*sin_theta > 1.0

    if cannot_refract or schlick(cos_theta, fRefractRatio) > rtu.random_double():
        return reflect(vRay, vNormal)
    else:
        perpendicular_dir = (vRay + vNormal*cos_theta)*fRefractRatio
        parallel_dir = vNormal*(-math.sqrt(math.fabs(1.0 - perpendicular_dir.len_squared())))
        return perpendicular_dir + parallel_dir
```

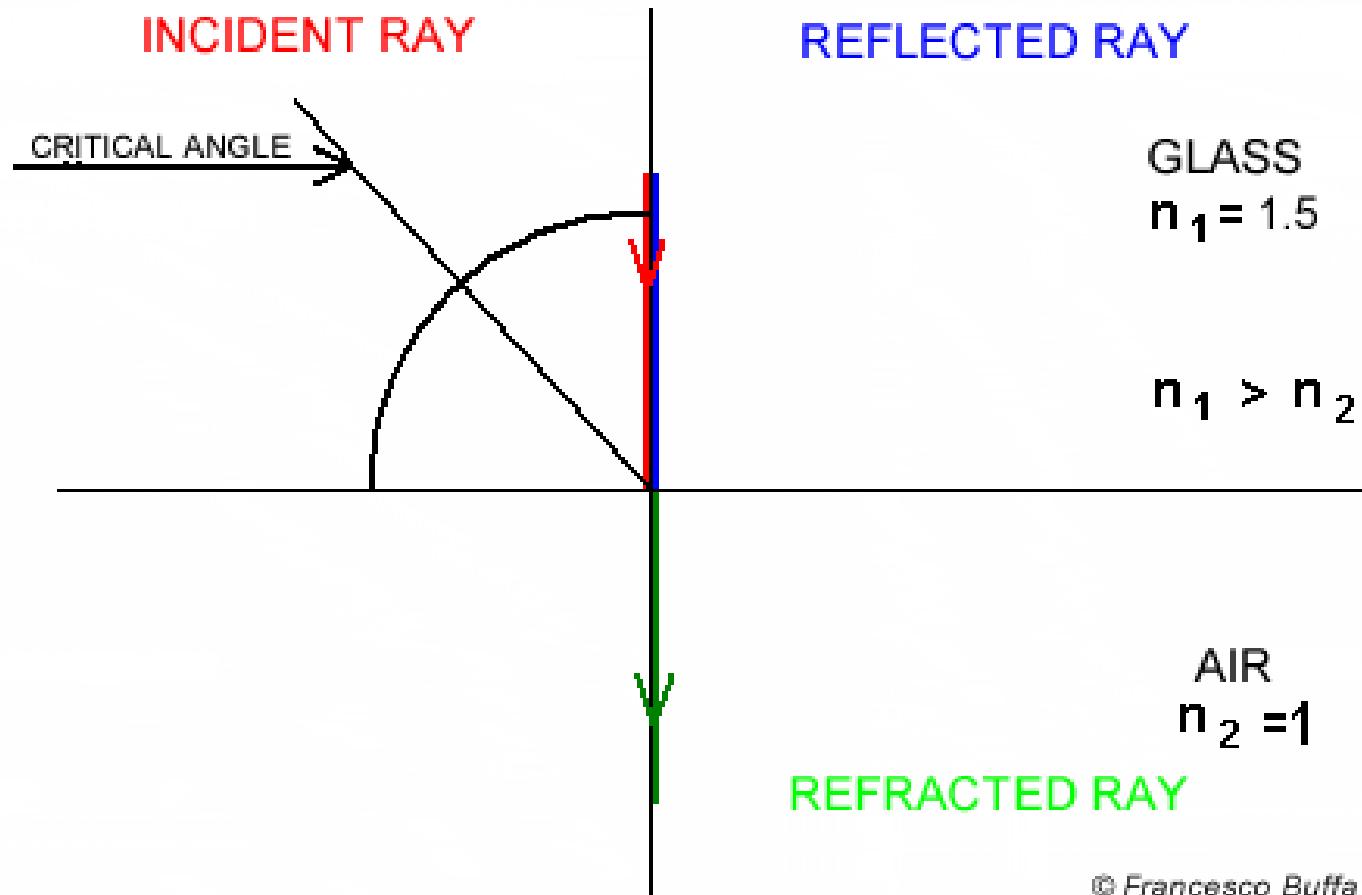
Fresnel effect

Calculate refraction

If refracted ray occurs, calculate the refracted direction.

Generate only reflected ray when it cannot refract, or the Fresnel coefficient meets a condition.

Refraction and reflection



Codes and class assignment !

- Github : RT-python-week06
 - <https://github.com/KUGA-01418283-Raytracing/RT-python-week06>

