PHY 1120 - Dr. Rowley

Chapter 25 - Light: Geometrical Optics

Summer 2020

What do you see?

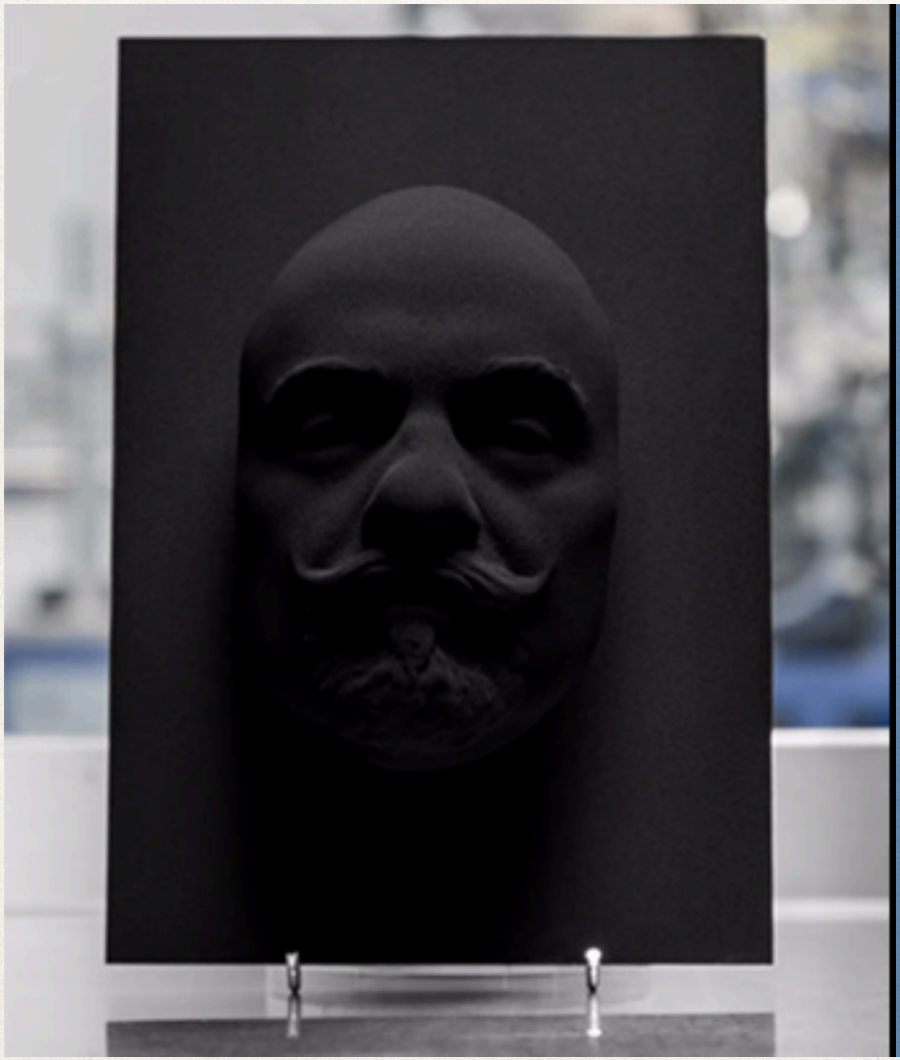
- You stand in a windowless room that has no lights of any kind. The room has a chair in the middle of the room and framed pictures on one wall. The door has insulation all the way around so all the cracks are sealed.

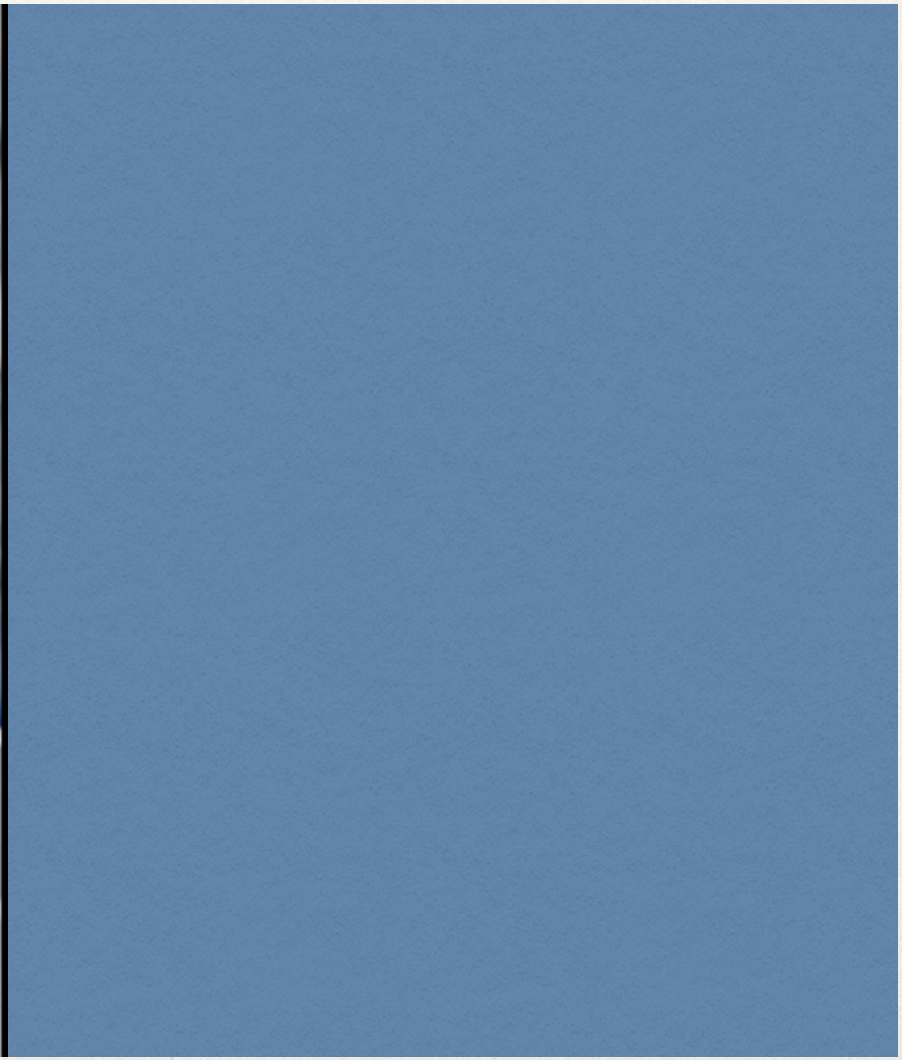
- What do you see?

The Ray Model

- Light must have a source
- Light travels as rays, in straight lines, in all directions from the source.
- Light can be absorbed, reflected, or refracted
- We can only see objects that produce light or objects that reflect light.

Vanta Black: What's Happening?





Vanta Black

- Almost (99+%) all light incident on the model coated in Vanta Black is absorbed and almost (< 1%) no light is reflected. So, there is no light available to enter your eye to be detected!

Shadows

- A light is on the ground 20 m from a tall building. A 1.75 m tall person stands half-way between the light and the building. How tall is her shadow on the building?

Law of Reflection

$$\theta_i = \theta_r$$

- Always works with reflection
  - True with both specular and diffuse reflection
- Angles always measured with respect to the **normal**
  - a normal is line, perpendicular to the surface, at the point of reflection

Law of Reflection

- A light ray hits the surface of a planar mirror at an angle of 27° with respect to the surface. Find the angle of reflection and angle of incidence.

$\theta_i = \theta_r = 63°$

Reflection

- What's the speed of light after the reflection?

A. Greater than 3.00×10^8 m/s

B. Equal to 3.00×10^8 m/s

C. Less than 3.00×10^8 m/s

D. -3.00×10^8 m/s (because of the change in direction)

Reflection

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Law of Reflection

- You stand 7.0 m from a wall and hold a laser pointer at a height of 1.6 m. You point it at a mirror on the floor 2.7 m from your feet. Where does the spot appear on the wall?

Index of Refraction

- Snell's Law describes refraction of light as it passes from one medium to the next.
  - Happens @ the boundary between the surfaces.

$$c = n_1 \cdot v_1$$

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

1 = incident
2 = refracted

Index of Refraction

$n_{air} = 1.00$

$n_{water} = 1.333$

- Light passes from **air to water** and has a incident angle of 30°, what is the refracted angle?

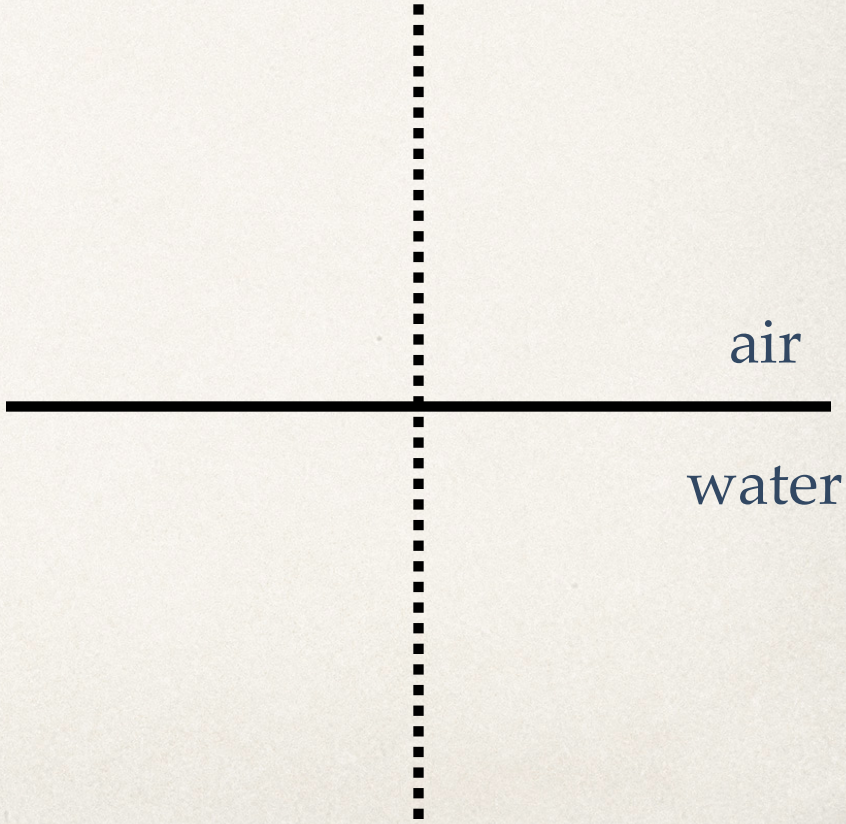
$$n_1 \cdot \sin(\theta_1) = n_2 \cdot \sin(\theta_2)$$

$$1.00 \cdot \sin(30°) = 1.333 \cdot \sin(\theta_2)$$

$$\frac{1.00 \cdot \sin(30°)}{1.333} = \sin(\theta_2)$$

$$\theta_2 = \sin^{-1}(0.3751)$$

$$\boxed{\theta_2 = 22.0°}$$



Index of Refraction

$n_{air} = 1.00$

$n_{water} = 1.333$

- Light passes from **water to air** and has a incident angle of 30°, what is the refracted angle?

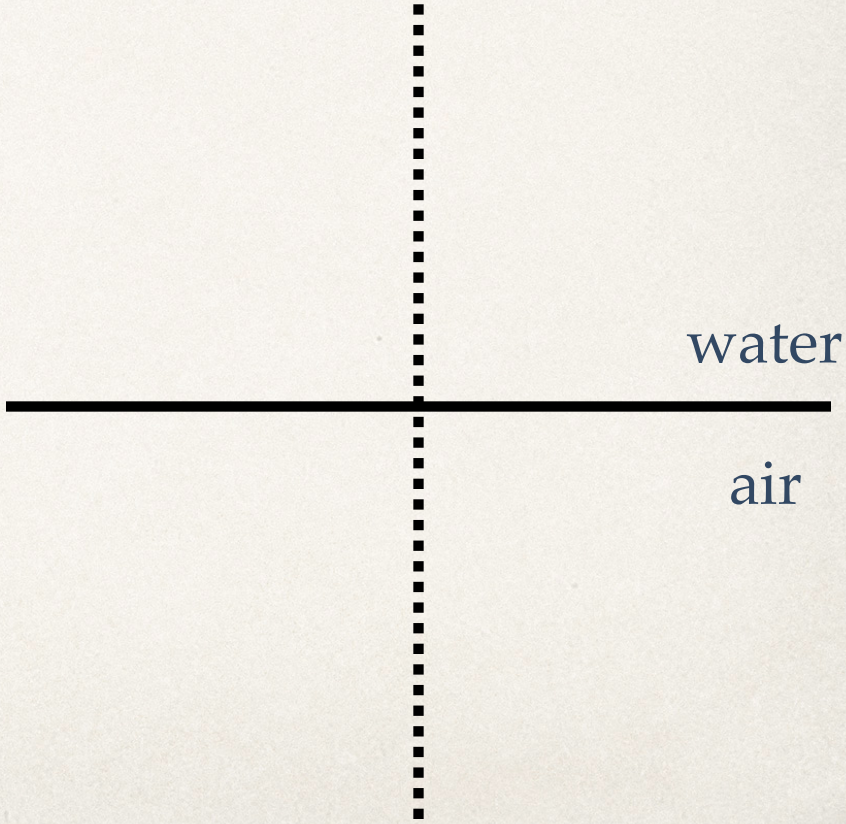
$$n_1 \cdot \sin(\theta_1) = n_2 \cdot \sin(\theta_2)$$

$$1.333 \cdot \sin(30°) = 1.0 \cdot \sin(\theta_2)$$

$$\frac{1.333 \cdot \sin(30°)}{1.0} = \sin(\theta_2)$$

$$\theta_2 = \sin^{-1}(0.6665)$$

$$\boxed{\theta_2 = 41.8°}$$



Index of Refraction

- How does light behave when passing from low-n to high-n materials?

It bends towards the Normal.

- How does light behave when passing from high-n to low-n materials

It bends away from the Normal.

Group Problem

- Find the path of light through the rectangular slab of glass if $\theta_i = 60.0°$

Air (n = 1.00)

Glass (n = 1.50)

Index of Refraction

Glass (n = 1.50)

- Find the path of light through the rectangular slab of glass if $\theta_i = 60.0°$

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

$$1.00 \cdot \sin(60°) = 1.5 \cdot \sin(\theta_2)$$

$$\frac{1.00 \cdot \sin(60°)}{1.5} = \sin(\theta_2)$$

$$\theta_2 = \sin^{-1}(0.5774)$$

$$\boxed{\theta_2 = 35.3°}$$

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

$$1.5 \cdot \sin(35.3°) = 1.0 \cdot \sin(\theta_2)$$

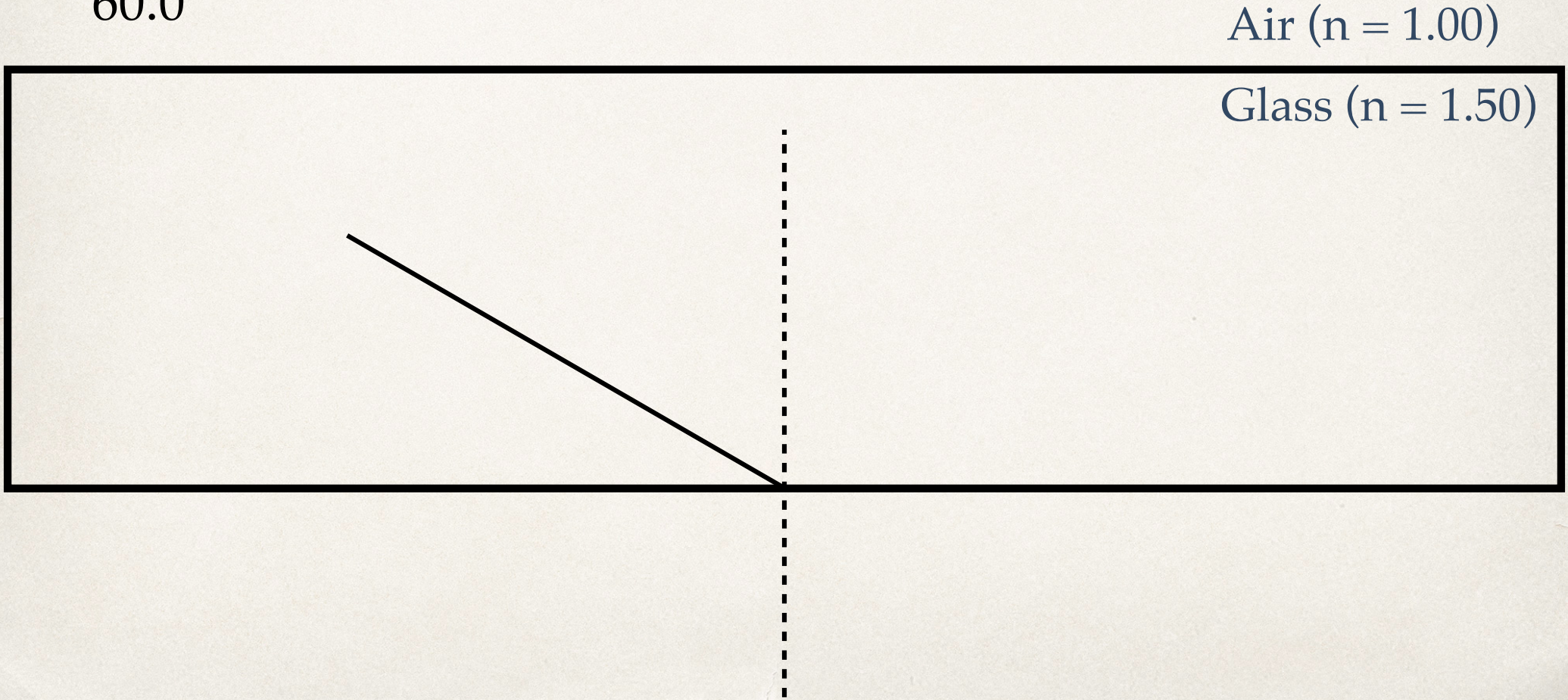
$$\frac{1.5 \cdot \sin(35.3°)}{1.0} = \sin(\theta_2)$$

$$\theta_2 = \sin^{-1}(0.8668)$$

$$\boxed{\theta_2 = 60.0°}$$

Index of Refraction

- What happens if light hit the Glass-Air boundary at θ_i = 60.0°



Index of Refraction

Glass (n = 1.50)

- Find the path of light through the rectangular slab of glass if $\theta_i = 60.0°$

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

$$1.5 \cdot \sin(60.0°) = 1.0 \cdot \sin(\theta_2)$$

$$\frac{1.5 \cdot \sin(60.0°)}{1.0} = \sin(\theta_2)$$

$$\theta_2 = \sin^{-1}(1.2990)$$

$$\boxed{\theta_2 = ERROR???}$$

Total Internal Reflection

- Occurs when θ_2 is equal to, or greater than 90°.
  - Only possible if $n_2 < n_1$
  - Only reflection happens if the incident angle is too large.
  - Critical angle is the angle at which total internal reflection begins.

Critical Angle

- Occurs when θ_2 is exactly equal to 90°.

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

$$n_1 \cdot \sin(\theta_1) = n_2 \cdot \sin(90°)$$

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

$$\theta_1 = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$

$$\boxed{\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)}$$