Belarusian team

Problem No. 11

«Fingerprints»

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Formulation of the problem

Fill a glass with a liquid and hold it in your hands. If you look from above at the inner walls of the glass, you will notice that the only thing visible through the walls is a very bright and clear image of patterns on your fingertips. **Study and explain this phenomenon.**
The demonstration
Stages

1. Glass without a finger.
2. Fingerprints.
3. Changeable parameters
Goals

1. Explain why we do not see objects behind a glass.

2. Explain why the fingerprints are clearly visible.
Glass without a finger

1. We find the rays, which do not fall into the eye due to total reflection in the horizontal border between water and air

\[ \alpha = 48^\circ \] - angle of total internal reflection

Snell law:

\[ \sin \beta = \frac{n_{\text{wat}} \cos \alpha}{n_{\text{air}}} \]

\[ \beta = 63^\circ \]

Rays that are falling at an angle from 0° to 63° don’t reach the observer

Part 1: Glass without a finger - Part 2: Fingerprints
What will happen with the rays that can reach the observer?

How many percent of energy from the original will reach the observer?

The dependence of percentage of the passed energy on the angle of incidence on the glass

\[ I_i = A^2 \cdot \cos \varepsilon \cdot n \]
\[ I_r = R^2 \cdot \cos \varepsilon \cdot n \]
\[ I_t = T^2 \cdot \cos \varepsilon' \cdot n' \]
\[ \rho = \frac{R^2 (n \cos \varepsilon)^2}{A^2 (n \cos \varepsilon)^2} \]
\[ \tau = \frac{T^2 (n' \cos \varepsilon')^2}{A^2 (n \cos \varepsilon)^2} \]
\[ \rho + \tau = 1 \]

\[ \rho_\parallel = \frac{\tan^2 (\varepsilon - \varepsilon')}{\tan^2 (\varepsilon + \varepsilon')} \]
\[ \rho_\perp = \frac{\sin^2 (\varepsilon - \varepsilon')}{\sin^2 (\varepsilon + \varepsilon')} \]

The dependence of percentage of the passed energy on the angle of incidence on the glass

Graph is constructed with help of the Fresnel equations


Angle of view:

\[ \beta_1 = 64^\circ, \theta_1 = 74^\circ \]

\[ \beta_2 = 80^\circ, \theta_2 = 63^\circ \]
The image on the walls of the glass

The image on the walls of the glass

Conclusions for the first part

1. The thickness of the glass has minimal influence on the percentage of passed in a glass rays.

2. The optical density of the glass affect on the percentage of passed in a glass rays.

3. We "can't see" things behind the glass due to:
   • total internal reflection at the horizontal border between air and water
   • small percentage of energy that can reach the observer
   • complex condition which is necessary for the possibility of observing the object

Fingerprints

What is the surface of the finger?

What is the surface of the finger?

Next optical environment behind a glass is a finger, that is, no energy loss at the air-glass border.

There isn’t loss of energy
We see a finger

There is loss of energy
We see a reflection of a bottom

Different materials


without layer of air

layers of air
Scattering on the finger

blind zone

finger

scattered light

Experimental setup for observing blind zone

Blind zone for different materials

Blind zone for different materials
Experiment #2

φ is angle of blind zone

Blind zone for different materials

Part 1: Glass without a finger - Part 2. Fingerprints
Different angles of observation

Different angles of observation

Conclusions

1. Objects behind the glass, "not visible" due to total internal reflection at the air-water border and because of the small percentage of energy, still come to the observer.

2. On the walls of glass observer can see the reflection of the bottom.

3. Fingerprints are clearly visible due to lack of air layer between the finger and the glass.
Thank you for attention!