

The Fresnel Relations

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Abstract

This paper is written as the first of four mandatory reports during the course *Experimental Physics II*. In this experiment we will be working with the Fresnel relations, and an comparison of theory and experiment is the primordial purpose.

1 Introduction

We look at reflection and refraction of a beam of light at the surface of a transparent dielectric. The laws of reflection and refraction (*Snell's law*) determine the directions of the reflected and refracted beams. But they are purely geometrical, and no information of intensity nor polarization is given. These are given by the *Fresnel Relations*. This exercise studies the Fresnel relations in detail, and experimental data will be compared with the well known theory of Snell's Law.

2 Theory

In this report we are working with the Fresnel relations, which describe the amount of *s*- and *p*-polarized light transmitted and reflected at the boundary of a dielectric surface. Generally

we remind ourselves of the relation between the angles of the incoming light θ , the reflected light θ_1 and refracted light θ_2 . The angles are measured from the normal of the dielectric surface. The relation between the incoming and reflected beam is given by the simple relation:

$$\theta = \theta_1$$

The relation between the angles of incidence and refraction is given by Snell's law:

$$n_1 \sin \theta = n_2 \sin \theta_2$$

where n_1 and n_2 are the refractive indices of the materials at the boundary of the incoming and reflected light beam.

Polarization

The plane spanned by the normal vector to our dielectric surface $\hat{\mathbf{n}}$ and the wave vector \mathbf{k} , which is in the direction of the propagation of the light,

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is called *the plane of incidence*. The direction of the \mathbf{E} -field relative to this plane then determines the polarization of the light, if \mathbf{E} is parallel to the plane of incidence the light is *p* polarized and if \mathbf{E} is perpendicular to the plane of incidence then the light is *s*-polarized. Light from normal light sources has

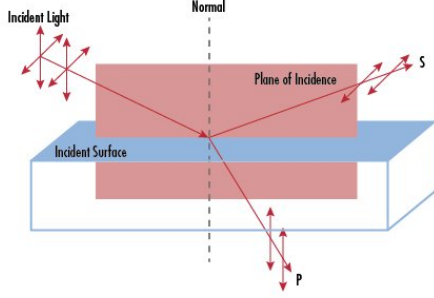


Figure 1: P and S linear polarizations defined by their relative orientation to the plane of incidence.

a mixture of all possible directions of polarization but the generally any polarization can be given as a linear combination in a basis of electric field with *s*- and *p*-polarization. Using a polarizer one can filter one kind of polarization of a beam.

Fresnel relations

When a beam of light interacts with the surface of a dielectricum a certain percentage of the light will be reflected as well as transmitted. The percentage of light reflected is denoted R and the percentage transmitted is denoted T . As the light is either transmitted or reflected it is natural to conclude that:

$$R + T = 1$$

To make things easier for ourselves we define $R = r^2$ and $T = \frac{n_2 \cos \theta_2}{n_1 \cos \theta_1} t^2$

where $r = \frac{E'_1}{E_1}$ and $t = \frac{E_2}{E_1}$ with E_1 denoting the magnitude of the incoming \mathbf{E} -field, E'_1 denoting the magnitude of the reflected \mathbf{E} -field and E_2 denoting the magnitude of the transmitted \mathbf{E} -field. As the direction of the \mathbf{E} -field can be written in the basis of *s*- and *p*-polarization we can define our reflection and transmission indexes for *p* and *s* polarized light separately. Our r_p, r_s, t_p and t_s given as functions of θ_1 and θ_2 are:

$$r_p = \frac{n_2 \cos(\theta_1) - n_1 \cos(\theta_2)}{n_2 \cos(\theta_1) + n_1 \cos(\theta_2)} = \frac{\tan(\theta_1 - \theta_2)}{\tan(\theta_1 + \theta_2)}$$

$$t_p = \frac{2n_1 \cos(\theta_1)}{n_2 \cos(\theta_1) + n_2 \cos(\theta_2)} = \frac{2 \cos(\theta_1) \sin(\theta_2)}{\sin(\theta_1 + \theta_2) \cos(\theta_1 - \theta_2)}$$

$$r_s = \frac{n_1 \cos(\theta_1) - n_2 \cos(\theta_2)}{n_1 \cos(\theta_1) + n_2 \cos(\theta_2)} = -\frac{\sin(\theta_1 - \theta_2)}{\sin(\theta_1 + \theta_2)}$$

$$t_s = \frac{2n_1 \cos(\theta_1)}{n_1 \cos(\theta_1) + n_2 \cos(\theta_2)} = \frac{2 \cos(\theta_1) \sin(\theta_2)}{\sin(\theta_1 + \theta_2)}$$

Then we find:

$$R_p = \frac{\tan(\theta_1 - \theta_2)^2}{\tan(\theta_1 + \theta_2)^2}$$

$$T_p = \frac{\sin(2\theta_1) \sin(2\theta_2)}{\sin^2(\theta_1 + \theta_2) \cos^2(\theta_1 - \theta_2)}$$

$$R_s = \frac{\sin^2(\theta_1 - \theta_2)}{\sin^2(\theta_1 + \theta_2)}$$

$$T_s = \frac{\sin(2\theta_1) \sin(2\theta_2)}{\sin^2(\theta_1 + \theta_2)}$$

3 Experimental Setup

The light source For the beams size we used a collimating slit of five variable widths.

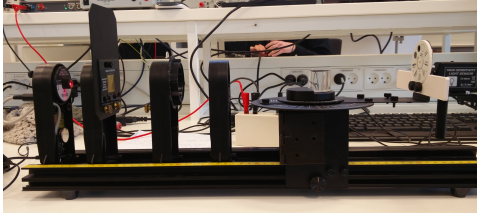


Figure 2: Experimental setup. From left to right: Laser, collimating slit, polarizer, lense, glass, polarizer, photo-sensor. See logbook for description.

4 Data

5 Snell's Law

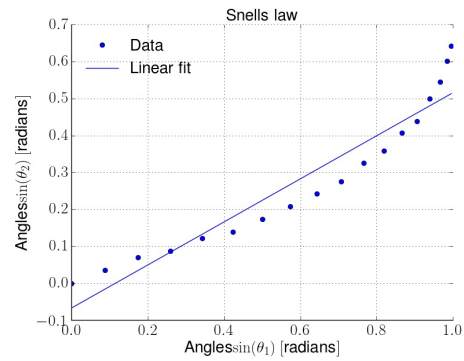


Figure 3: Dat...

6 Reflection

p-polarized

s-polarized

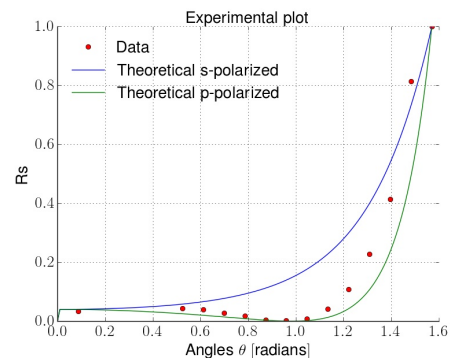


Figure 4: Dat...

7 Transmission

p-polarized

s-polarized

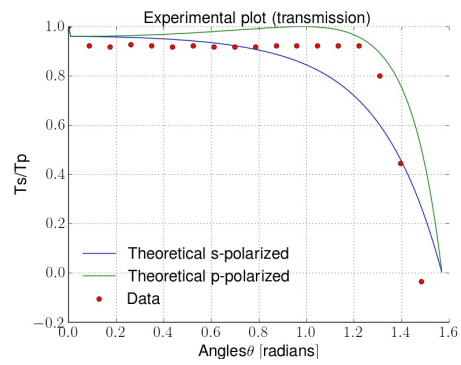


Figure 5: Dat...

Logbook

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1 Problem

Research method #1

Optical detector...

Planning

Beamsize: We used a slit of variable width. 1, 2, 3, 4, 5

Experimental Equipment Available

- Ruler
-
- Collimating slits with 5 slits
- Polarizer with rotational mount
- Polarizer
- Collimating lens
- Rotational mount
- High sensitivity light sensor
- PicoScope

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Critical issues

Intensity of light is half s- and p-polarized. Alignment of detector and laser-beam.

Strategy

Setup

Laboratory setyp

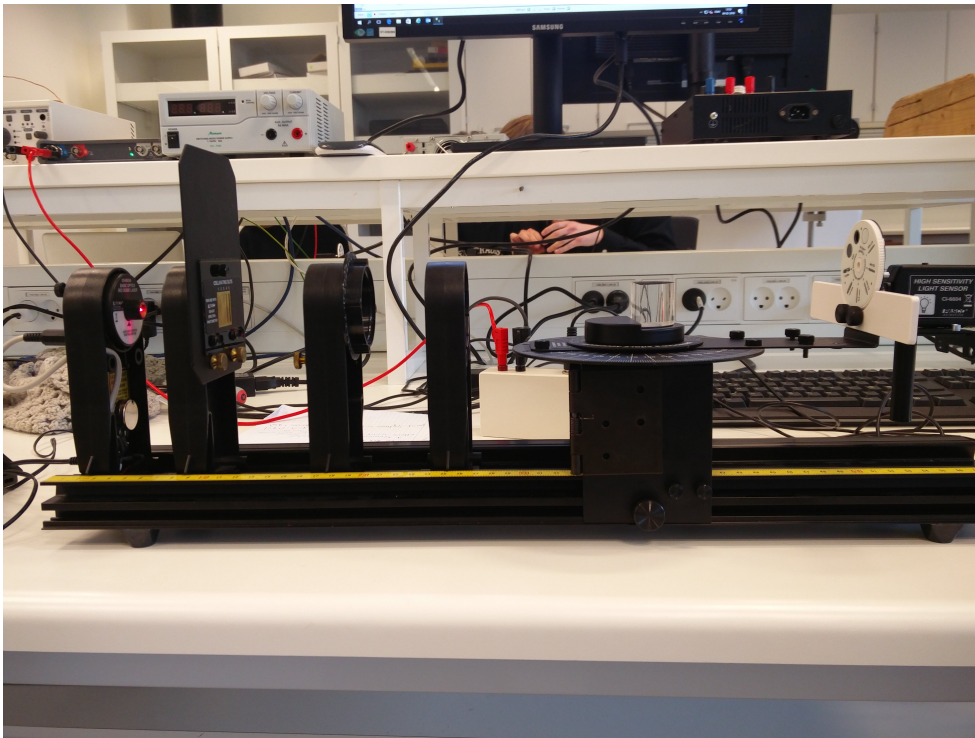


Figure 1: Look at me I am a caption!

Raw data

Fast analysis

Conclusion

Her og der og alle vegne, som du kan se på listing 1

Listing 1: Caption

```
1 # Preamble
2 import numpy as np
```

```
3 import matplotlib.pyplot as plt
4
5 # Matplotlib koerer TeX
```

Bibliography

Griffiths, David J. *Introduction to Electrodynamics*. Cambridge, 2017. ISBN: 978-1-108-42041-9.

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