Lab 10 – Plane wave reflection and refraction

In this lab we examine basic properties of plane waves using waves in the optical region of the spectrum which covers wavelengths of 400 to 700 nm. The source of the plane wave is a Helium Neon gas laser emitting at 633 nm, and the wave power is detected using your own sensors (eyes) or optical power meters (silicon photo diodes).

Part I: Reflection and transmission of plane waves

In this part of the lab you will use Snell’s law to find the unknown permittivity of a material. Use the rectangular piece of gelatin as the medium with a permittivity different than air. The jello is not flavored – do not try to eat it, its taste is not appealing. Measure the angle of refraction as a function of the angle of incidence and fill out the table below. The HeNe laser beam is polarized but in this part of the lab we will not consider the wave polarization.

<table>
<thead>
<tr>
<th>Incident $\theta_i$</th>
<th>15 degrees</th>
<th>30 degrees</th>
<th>45 degrees</th>
<th>60 degrees</th>
<th>Any others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmitted $\theta_{trans}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Index of refraction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative permittivity</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

![Figure 1. Experimental setup for measuring permittivity at optical frequencies.](image)

L10.1. Based on the angle measurements, find the relative permittivity and index of refraction of the gelatin. This value for the permittivity is very different than the ~80 we used for water in our electrostatics chapters. Why?
L10.2. Calculate the accuracy of your measurement from the permittivity data obtained for different angles. (Explain how you define the measure of accuracy.)

L10.3. Observe the angle of the beam transmitted back out into air (on the far side of the gelatin). This may not be perfect due to the low optical quality of gelatin. How does this angle change as you change the incidence angle? Explain this using Snell’s Law (twice). Use this to explain why looking through a glass window does not distort the image due to refraction in the glass.

L10.4. Use your optical power meter to measure the total power of the incident beam. Compare this to a typical light-bulb – what makes the laser light so different? Set your gelatin for nearly normal incidence and measure the reflected and transmitted power. Calculate the reflection coefficient from this experiment and using your permittivity data from 10.2. Compare the results. Calculate the absorption coefficient, $\alpha$ [1/m]. Remember to correct for the reflected power loss at both surfaces. If you used gelatin as a transmission medium for communication, how far could you go before you lost 20 dB (a factor of 100) of the light? For comparison, the 20 dB loss distance of glass optical fiber is about 133 km!

L10.5. Calculate the angle of total internal reflection (TIR) from the mean value of the permittivity from your measurement. Think of a way to measure the TIR angle of the gelatin and sketch your method. How close is the measured angle to the calculation? Is the reflection “total” in that no light escapes? Speculate as to why or why not.

Part II: Polarization of plane waves

In this part of the lab, you will examine the polarization of plane waves (light).

L10.6. Insert a polarizer between the laser and your power meter. Using the scale on the polarizer, rotate it in 15 degree increments and record the transmitted optical power. Plot your results.

- Why is the maximum transmitted power not equal to the total laser power you measured previously?
- Why is the minimum transmitted power not zero? There are at least three potential answers.
- What is the periodicity of your measurement and why?
- Using simple vector math, show that the curve you measured has the expected shape.