Physics 319 - Optics

Lab #4

The Fresnel Equations

(Spring 2026 version)

Procedure:

1. Make a quasi-planer beam along the optical bench by (1) placing an aperture mask over the incandescent source followed by (2) a variable aperture about 20 cm from the aperture mask followed by (3) a 252 mm convex lens about 20 cm after the variable aperture. A single polarizer should be attached to the same carrier as the lens to allow you to make light that is polarized either parallel or perpendicular to the plane of incidence. A glass prism is mounted on the rotating table with its longest face along the midline of the rotating table. The photometer probe is mounted in the table arm. Now you are ready to make measurements to verify (hopefully) reflection amplitude equations

$$r_{\perp} = \frac{n_i \cos\theta_i - n_t \cos\theta_t}{n_i \cos\theta_i + n_t \cos\theta_t} = -\frac{\sin(\theta_i - \theta_t)}{\sin(\theta_i + \theta_t)}$$

and

$$r_{\parallel} = \frac{n_t \cos\theta_i - n_i \cos\theta_t}{n_t \cos\theta_i + n_i \cos\theta_t} = \frac{\tan(\theta_i - \theta_t)}{\tan(\theta_i + \theta_t)}$$

Before recording any numbers, place the white screen on the table arm (in front of the photometer probe) and scan through as great a range of reflection angles as possible for both polarizations (parallel and perpendicular to the plane of incidence) to see roughly what the reflected beam looks like. You should find and record the polarizing angle by noting the extinction angle for the horizontal polarization.

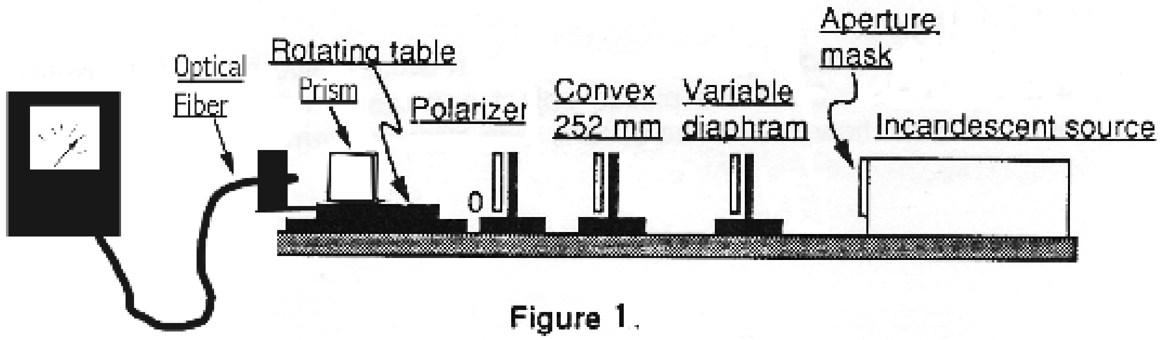


Figure 1.

2. Now try to be quantitative. For both polarizations, record the reflected intensity for at least 8 different angles of incidence. For both polarizations, measure the incident intensity on the glass plate. Plot a graph similar to the figures below in Hecht. Remember that intensity is proportional to the square of the electric vector and that the Fresnel equations give ratios of the reflected electric vector to the electric vector. A few things to be careful about experimentally: (i) be sure to re-zero the photometer when you change scales and (ii) be sure that no "funny" things are happening to your "beam" and the edge of the glass plate. You can investigate where your beam is by using a small piece of white paper to follow the beam in its travels.

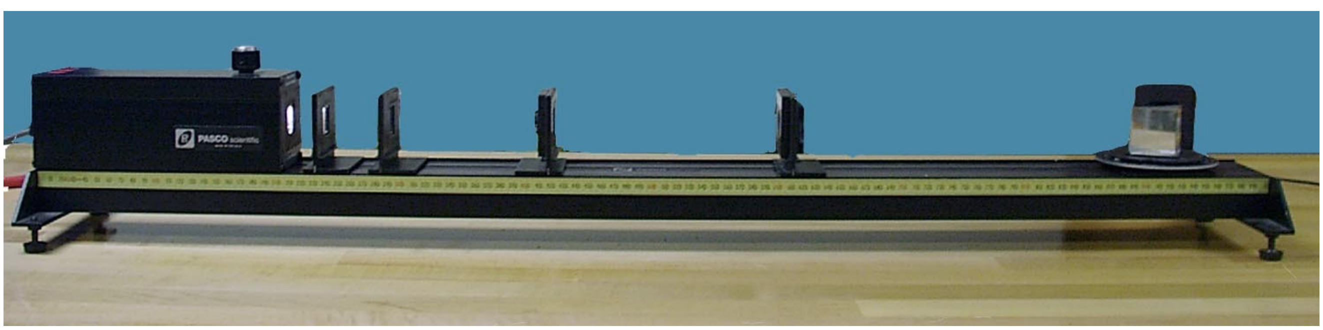


Figure 2

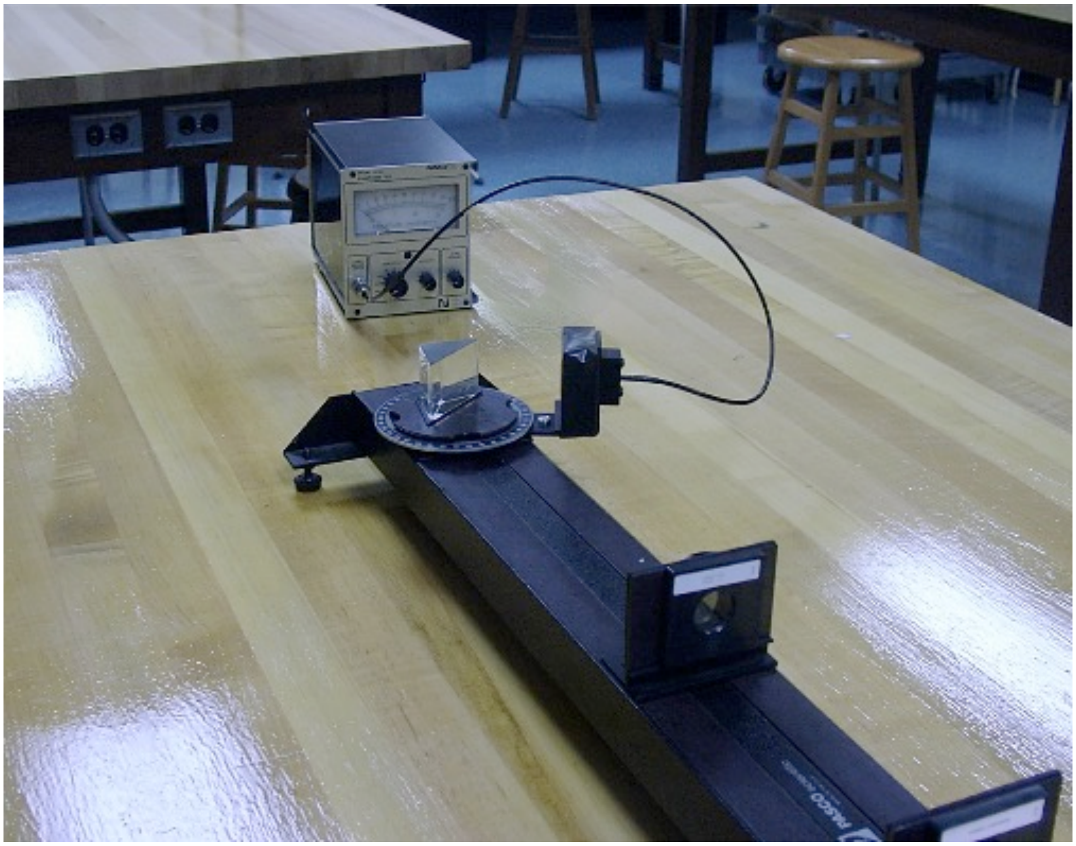


Figure 3

3. Some qualitative investigations of the Fresnel equations can be done with a glass slide. Set a slide on an open page of a book with text beneath it. Starting from normal incidence, rotate book and slide relative to your eye, thereby increasing the angle of incidence, and observe. Repeat leaving your book and eye stationary while changing the angle the slide makes to the page.

4. Look at the whiteness of the page with and without a slide tying on it; repeat with increasing numbers of slides stacked on top of each other.

5. Now try to be quantitative, using a photometer setup similar to that used above, only looking at the intensity of the <u>transmitted</u> light at normal incidence as the number of slides is increased. According to the Fresnel equations, how much should the intensity decrease with the addition of each slide? See question 2 and construct the table.

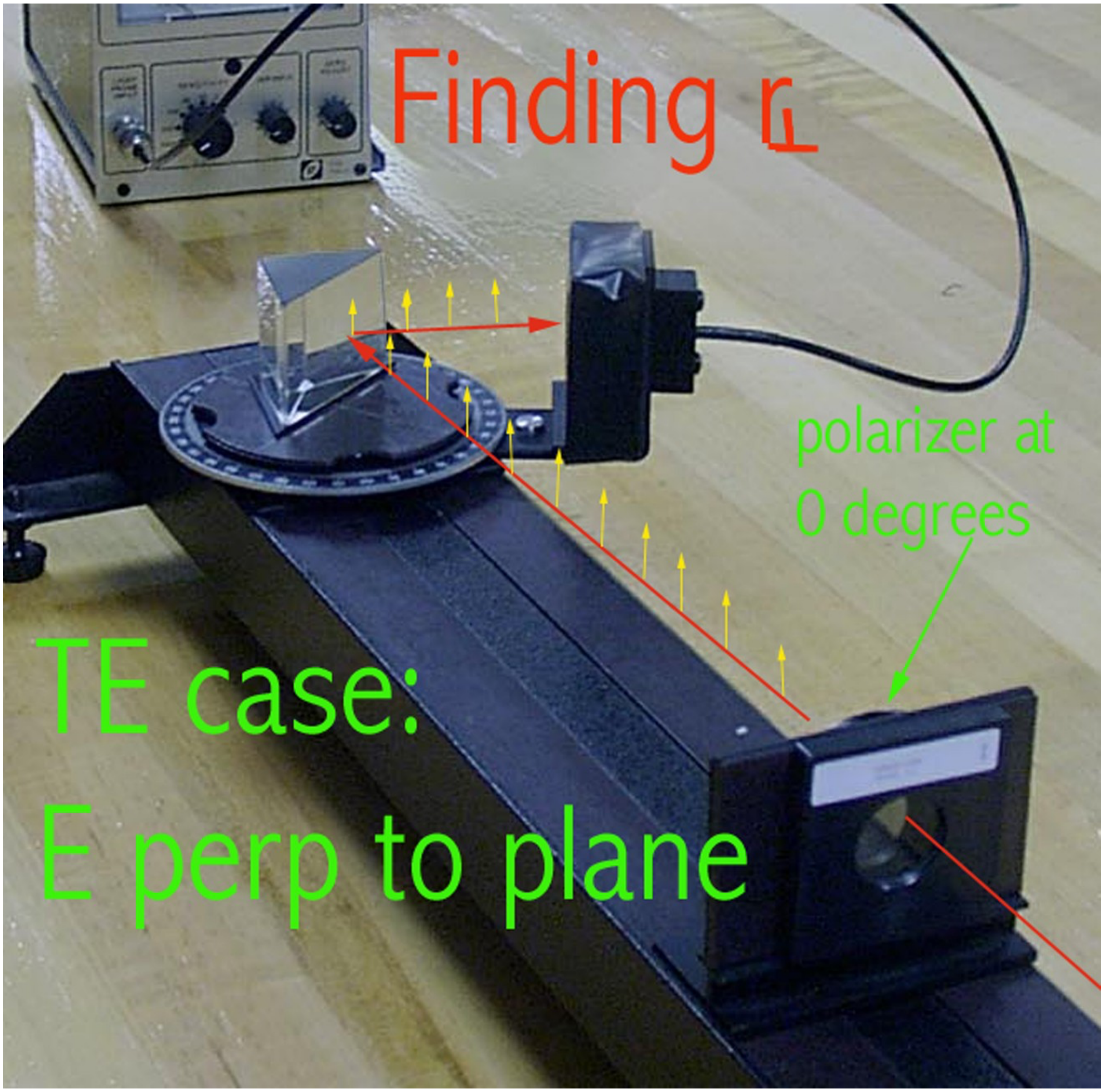


Figure 4

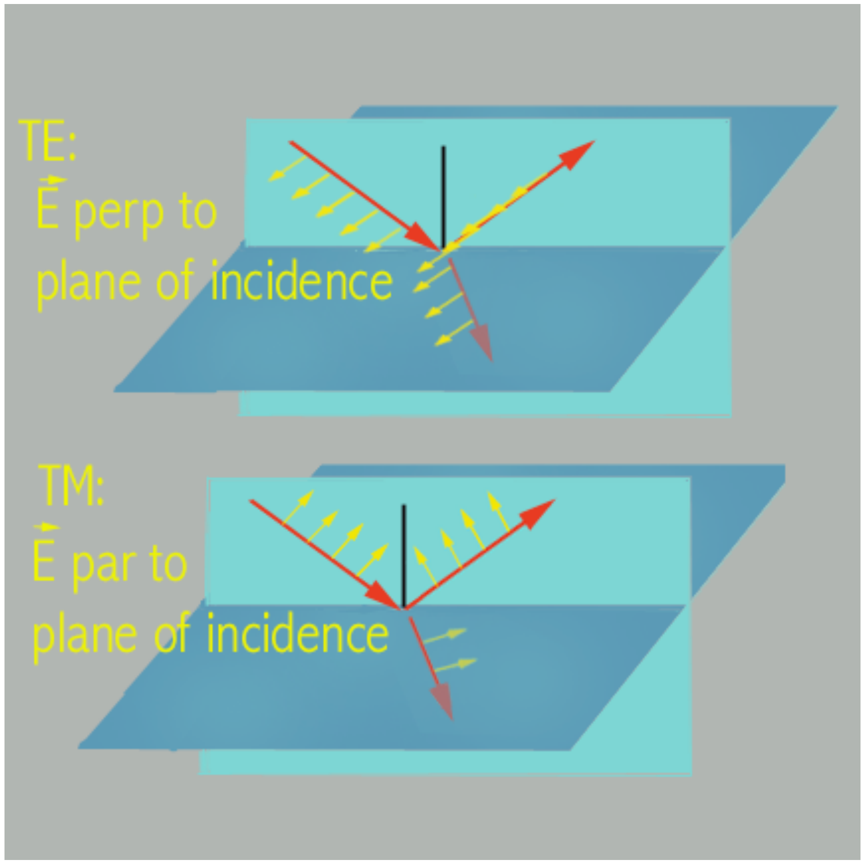


Figure 5

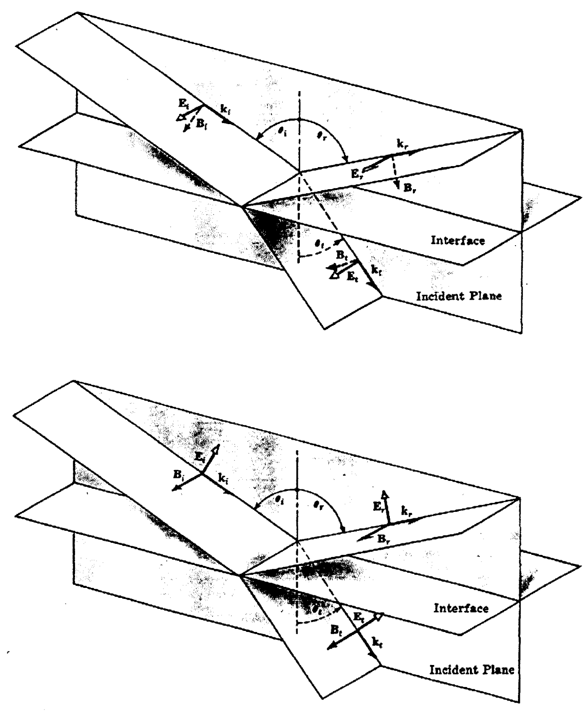
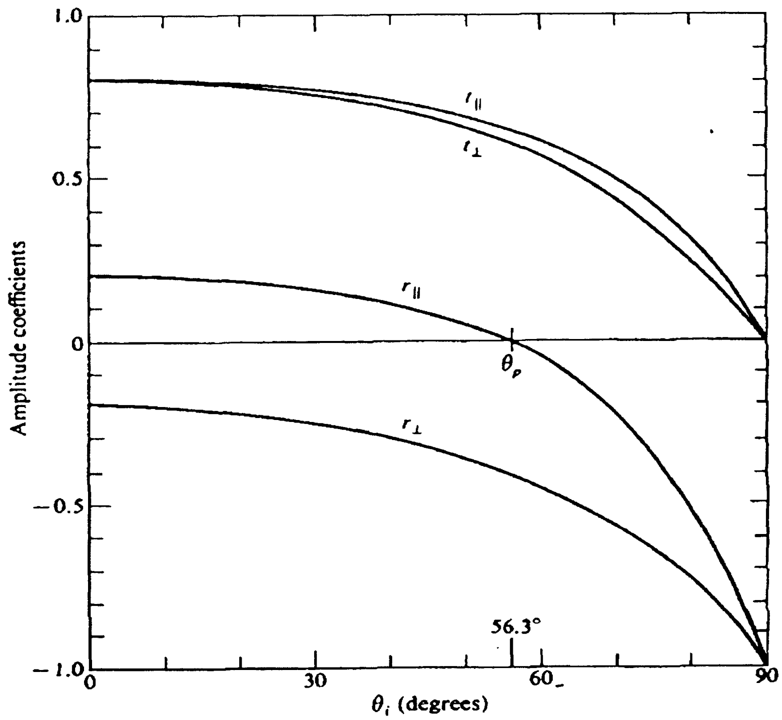


Figure 6



Post Lab Questions (Spring 2026 version)

1. a) What phenomena do the Fresnel Equations describe? b) What are some applications of these equations? c) What is a dielectric (compare to a conductor) d) What are some of the applications of dielectrics?

2. Derive the relationship for Brewster's angle using the Fresnel equations (more specifically, using equation 4.40 **of Hecht,** 4th ed- page 115). The basic steps can be found in section **8.6 Polarization by reflection** of optics text on page 348.

You are to start with Fresnel equation 4.40 and explain your suppositions as well as show your work.

Use the derived relationship to find Brewster's angle for light in air incident onto water.

3. Given figures 1 & 2 on the last page determine the relative intensity of both parallel and perpendicular polarized light from a heads-up display projector that is **reflected into the driver's eyes**. This can be done as follows **(You are to show all work on diagrams & turn in the diagrams):**

1st- Find 'normal line' (w.r.t., the reflected light ray and windshield) by measuring appropriate 'bounce' angle and dividing by 2. This will give you your incident and reflected angle. **Show all lines**

(including the normal) and label all angles on diagram. *You only need to do this for large angle. Ignore the first bounce.*

2nd- Using incident angle and figure 2 determine the amplitude coefficients of both $r_{parallel}$ and $r_{perpendicular}$. Draw both pair of vertical and horizontal lines on figure 2 to show how answer was obtained.

3rd Square your answers above to obtain relative intensity from the for both components from figure 2 on diagram page. Show work by drawing the lines.

Be sure and explain why heads-up displays are hard to see when wearing polarized sunglasses.

4. In step 5 of procedure you were to measure the intensity of light through zero (0) to ten (10) microscope slides**. If you did not do so or ran out of time**- you have been provided with the following set of data below from an EXCEL spreadsheet.

The data consists of the theoretical and measured transmittance of light through both zero (0) to ten (10) microscope cover slips and zero (0) to ten (10) microscope slides.

The thickness of a microscope cover slip is approximately 0.225mm and the thickness of a microscope slide is approximately 1.0 mm (or~4 ½ times as thick).

You are reminded that the Fresnel equations describe what happen at an interface only- See Question 4.72 on page 147 of text for transmittance relationship which **assumes no absorption in the glass.**

Question 4.73 on same page describes what happens when light passes through a medium that absorbs some of the incident light. The equation on this question is the equation above in 4.72 with an absorption term. ***Please note that since the thickness of a slide is 1.0 mm- the total thickness d of slides. is equal to N- The number of slides.***

a) **You are to also show how the 'Theoretical (Fresnel) Transmittance' are values are obtained in both tables by doing** two calculations for "cover Slips" and two calculations for "Microscope slides"- Label them as "Sample Calculations" in your answers- Any two pairs of values are good to use.

b) **How are the normalized values obtained.** Show one calculation.

c) You are to explain whether the measured data is consistent with what was measured in lab and what the theory says. There is some discrepancy in the 2nd set due to photometer issues. No calculations necessary.

Cover slips

N	Theoretical (Fresnel) Transmittance (Interfaces only with no absorbtion) T = (1-R)^2N	Measured light intensity through microscope cover slips Intensity	Normalized intensity Microscope cover slips Transmittance (%)
0	1	0.31	1.000
1	0.922	0.285	0.919
2	0.849	0.255	0.823
3	0.783	0.232	0.748
4	0.721	0.214	0.690
5	0.665	0.195	0.629
6	0.613	0.19	0.613
7	0.565	0.17	0.548
8	0.520	0.16	0.516
9	0.480	0.154	0.497
10	0.442	0.143	0.461

Slides

N	Theory (Fresnel)Transmittance with absorbtion T = ((1-R)^2N)*(T1^N)	Measured light intensity through microscope slides Intensity I(N)	Normalized intensity Microscope slides Transmittance (%)
0	1	0.66	1.000
1	0.848	0.56	0.848
2	0.719	0.42	0.636
3	0.610	0.36	0.545
4	0.517	0.28	0.424
5	0.438	0.23	0.348
6	0.372	0.21	0.318
7	0.315	0.185	0.280
8	0.267	0.155	0.235
9	0.226	0.13	0.197
10	0.192	0.115	0.174

Turn in diagrams below (with work indicated) with the questions

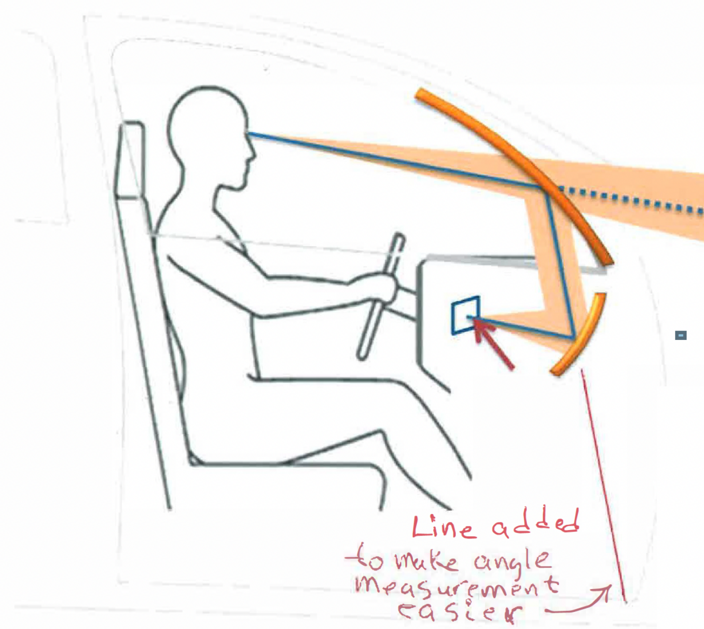


Figure 1

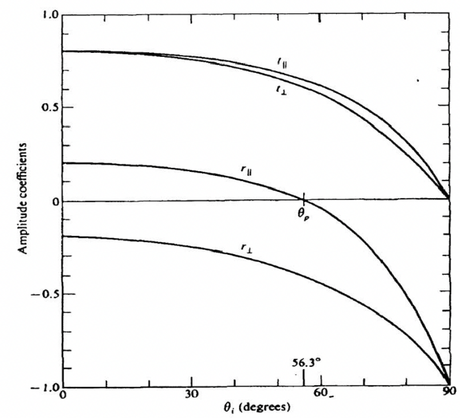


Figure 2