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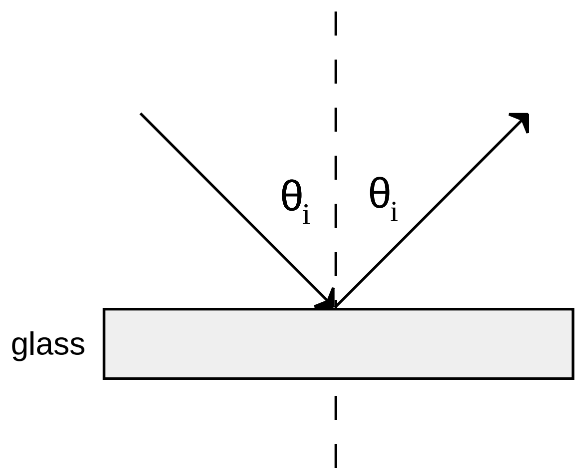
Fresnel Reflection Coefficients

The figure below shows a ray of light striking the surface of a piece of glass at incident angle θ_i. The ray is reflected making the same angle with the normal as the incident ray. There is also a refracted ray, not shown, which makes angle θ_r with respect to the normal which is given by Snell's Law:

$$\theta_r = \sin^{-1}\left[\frac{\sin\theta_i}{n}\right]$$

where n is the index of refraction of glass, which we take to be 4/3.

The incident ray, reflected ray and refracted ray lie in the same plane which we call the *plane of incidence*. The incident ray can be polarized with components *parallel* to and *perpendicular* to this plane.



Fresnel's equations for the fraction of light reflected for these two components are:

$$R_{perp} = \left[\frac{\sin(\theta_i - \theta_r)}{\sin(\theta_i + \theta_r)}\right]^2$$

$$R_{parallel} = \left[\frac{\tan(\theta_i - \theta_r)}{\tan(\theta_i + \theta_r)}\right]^2$$

For very small angles of incidence, the refracted angles are also small and we can use:

$$\sin\theta \approx \tan\theta \approx \theta$$

Remember that θ is given in radians. With this approximation:

$$R_{perp} \approx R_{parallel} \approx \frac{(n-1)^2}{(n+1)^2}$$

For glass this turns out to be about 2 %.

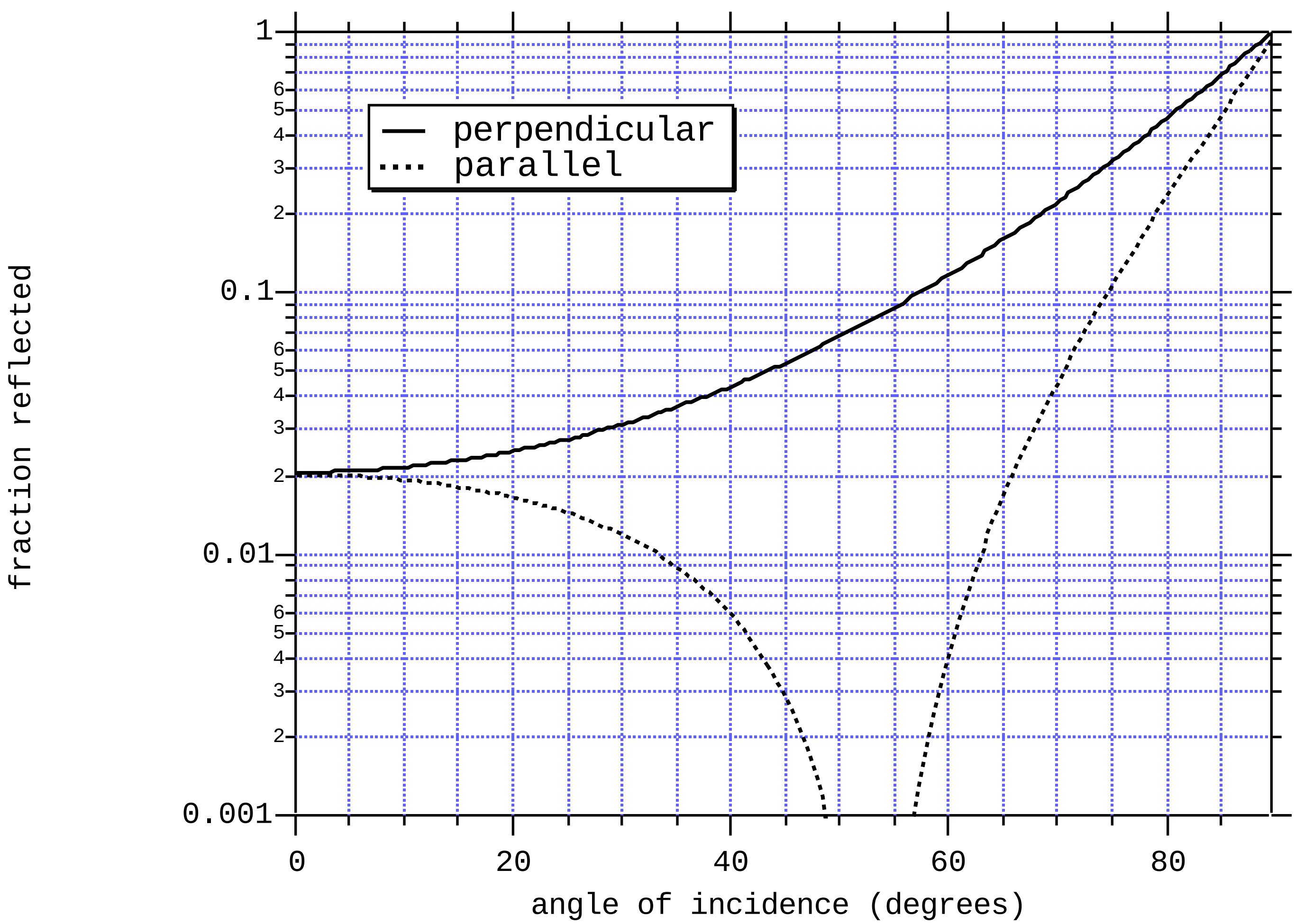
Also, $R_{parallel}$ vanishes for the so-called Brewster's angle, θ_B, given by:

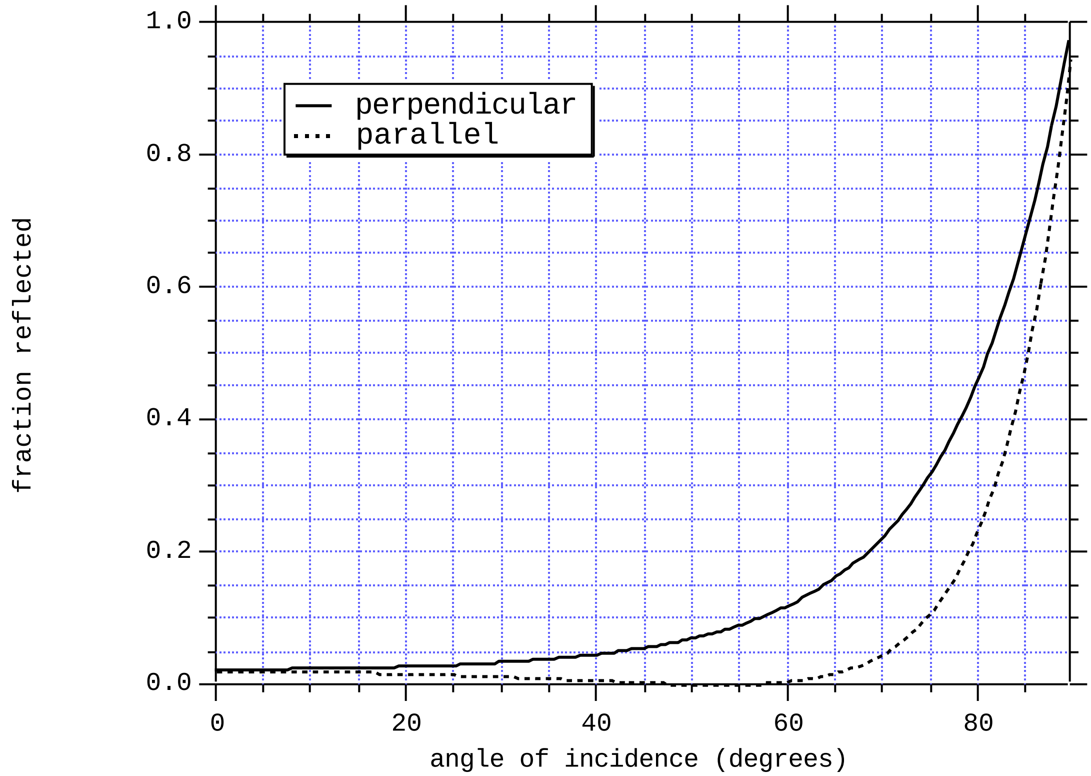
$$\tan\theta_B = n$$

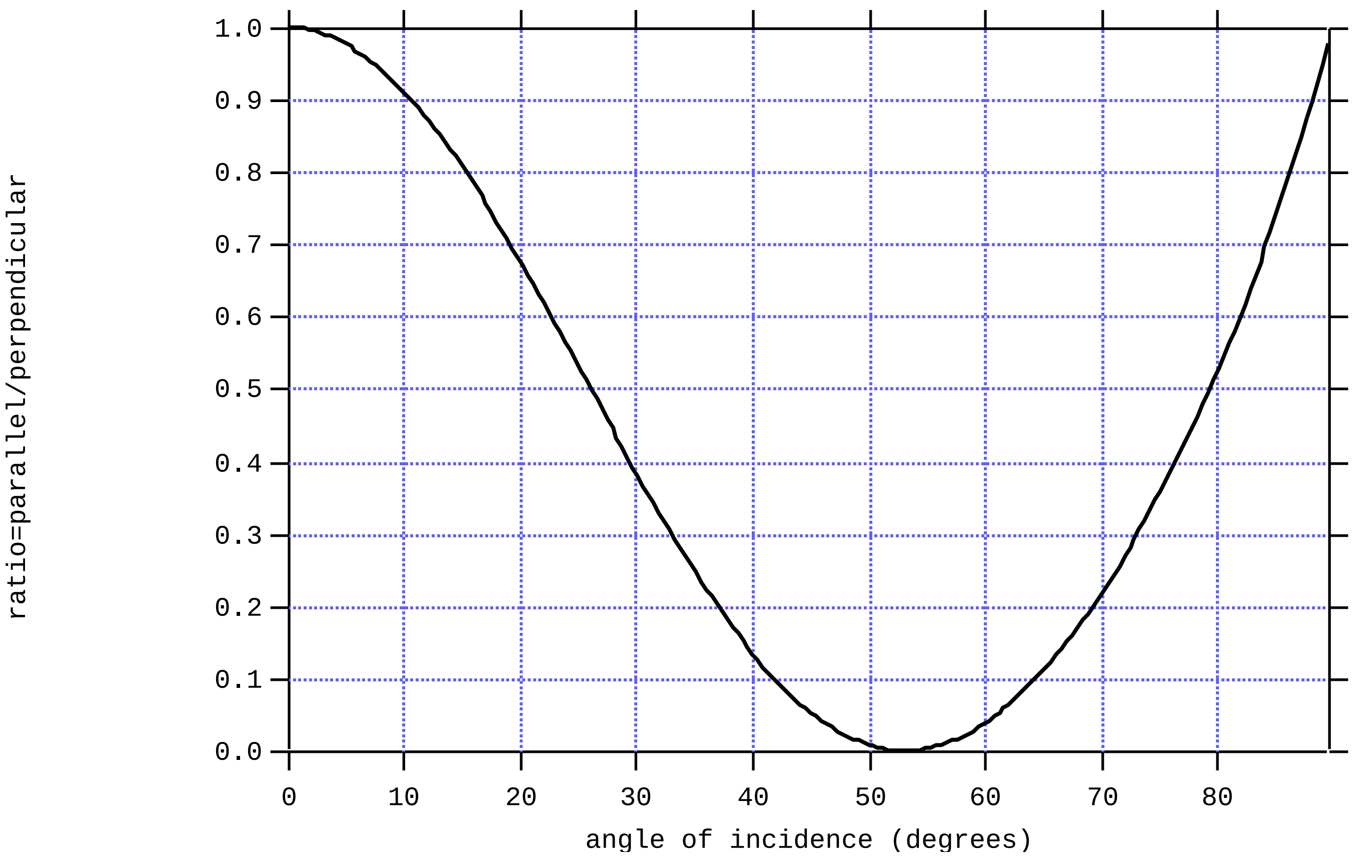
So when unpolarized light is incident at Brewster's angle, the reflected light is polarized perpendicular to the plane of incidence. Equivalently, if the incident light is polarized parallel of the plane of incidence, when the light is incident at Brewster's angle, there is no reflected light. For glass, $\theta_B \approx 53^o$.

Plots of the Coefficients and Ratio

Shown below are plots of the reflection coefficients (fraction of light reflected) for both polarizations. I show the coefficients on both linear and logarithmic scales. I also show the ratio: $R_{parallel} / R_{perp}$.




1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
fraction reflected
angle of incidence (degrees)
perpendicular
parallel


1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
10
20
30
40
50
60
70
80
ratio=parallel/perpendicular
angle of incidence (degrees)

Measurements

Since it is difficult to measure the reflection coefficients directly, the ratio will be measured. For a given setting of the incident angle, after carefully making sure that you are have optimized the alignment of the beam and stage which holds the fiber, make measurements for the two polarizations and compute their ratio. Plot this as a function of incident angle.

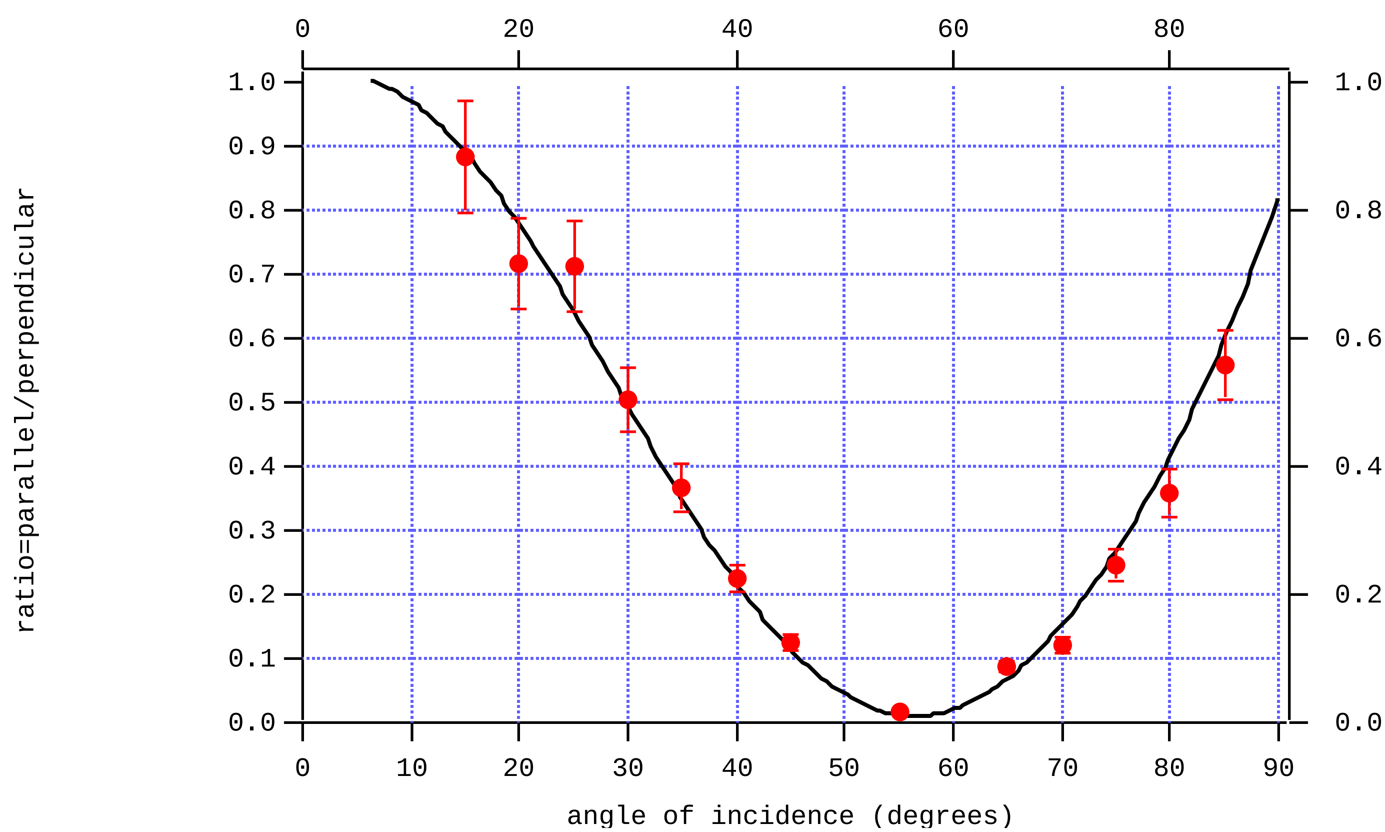
Insert a polaroid at 45^o in the beam. Now prepare two place setters with polaroids at 0^o and 180^o to define the polarizations perpendicular to and parallel to the plane of incidence. You should verify that the intensity of the unreflected beam is the same in both cases - if not exactly the same, apply this correction to the data.

Recall that you will be seeing two reflected beams, one from the front surface of the glass and one from the back surface. You only want the front surface reflection. What does the presence of this second reflection imply for your measurements ? Can you eliminate the second reflection ?

How small and how large an angle of incidence can you measure ?

What is your estimate of the errors.

Make enough measurements to probe the structure of the ratio plot.



data taken by Matt Bravander and Alex Dzierba on March 28, 2000