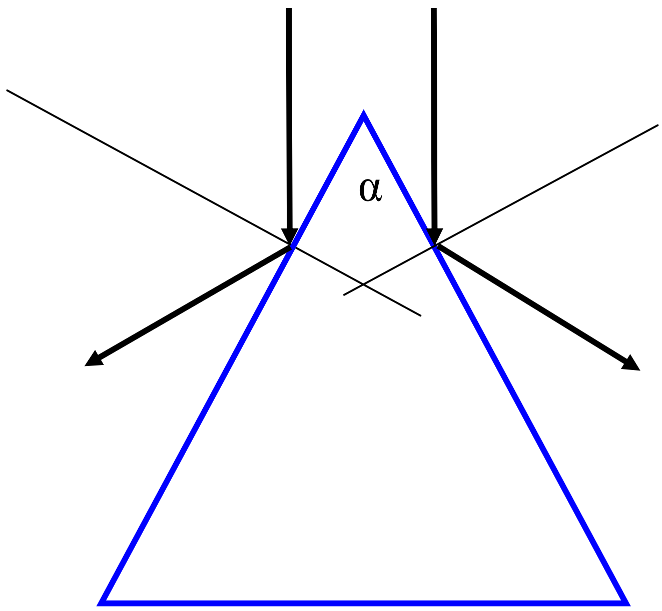
INF-GEO4310 2010
Exercises, Geometrical Optics, Part 1

1 Reflection by a symmetric triangular prism

Let α be the angle between the two faces of a symmetric triangular prism. Let the edge A where the two faces meet be perpendicular to the plane which contains the incident and emergent rays.



Two parallel beams of light are reflected off the two symmetric faces of the prism.

a. *Show that the angle between the two reflected beams is twice the angle between the two reflecting surfaces.*

2 Refraction in plane parallel slab of glass

a. *Verify the expressions for the displacements d and l in section 2.3.3.1*

3 Dispersion in a plane parallel slab of glass

Assume that a thin beam is incident on a plane parallel slab of glass in air, as in section 2.3.3.1. But now the beam is not monochromatic; it is white light, so the beam is spread out into a spectrum as it passes through the slab.

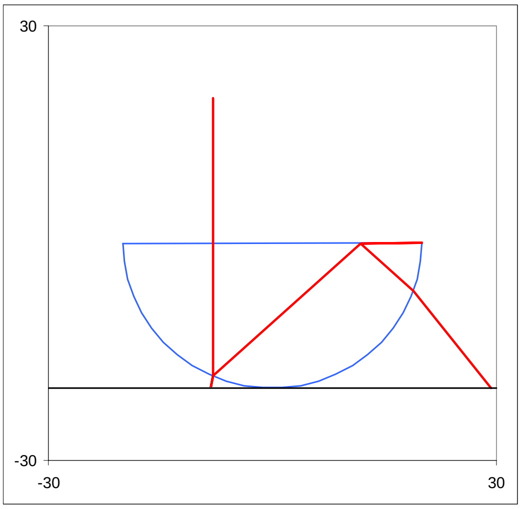
a. *Will the emerging rays of different colors be parallel or not?*
b. *What determines the thickness of the beam as it exits the slab?*

4 Critical angle and total internal reflection

Assume that we have a a semi-circular bowl of water at 25°C. A light-ray from a 632.8 nm laser enters perpendicular to the surface 4/10 of the radius from the bowl centre.

We want to obtain grazing refraction and total internal reflection of the light beam that is reflected towards the water / air interface.

a. Does the material of the bowl play any role in this?
b. How much do we have to raise the refractive index of the water by increasing the salinity?



5 Atmospheric refraction

Make the simplifying assumption that the Earth's atmosphere is uniform (thus having a uniform index of refraction), and that it extends to a height h. Beyond that, we assume that there is vacuum.The Earth's radius is R.

a. Verify that as we observe an object setting on the horizon, under these assumptions it is actually an angle δ below the horizon, given by

$$\delta = \arcsin\left(\frac{nR}{R+h}\right) - \arcsin\left(\frac{R}{R+h}\right)$$

b. Calculate δ for $R = 6378$ km and $h = 20$ km. Assume that $n = 1.0003$.
c. How does this compare to the statements about atmospheric refraction in section 2.3.3.9 ?

And then two questions taken from the 2009 written exam:

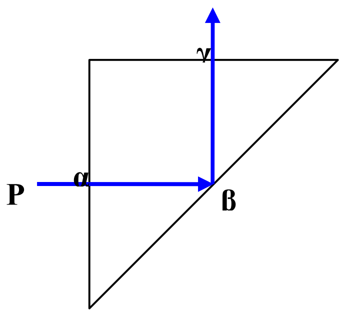
Multiple choice – geometrical optics

1. What do we mean by "critical angle" at a boundary between two optical media?

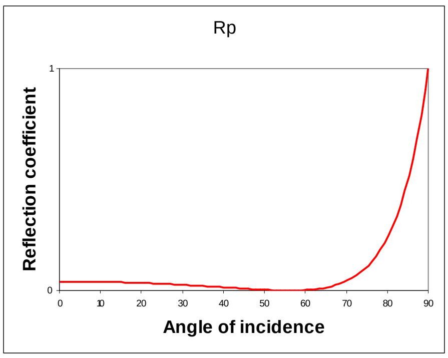
- ❑ The angle of incidence where equal parts of refraction and reflection occurs
- ❑ The largest angle of incidence where all light is reflected
- ❑ The smallest angle of incidence where no light is reflected
- ❑ The smallest angle of incidence where all light is refracted
- ❑ The angle of incidence where refracted light is tangent to the boundary

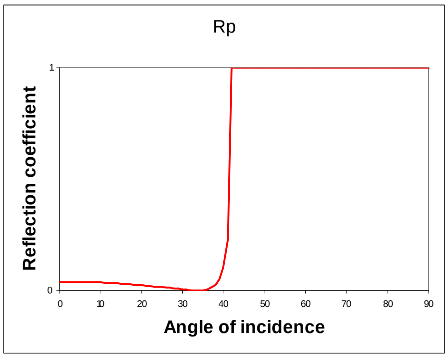
2. Geometrical optics (20 points).

We can use a number of optical prisms to alter the direction of a light beam. An equilateral right angle prism will change the direction by 90°, as shown in the sketch to the right.



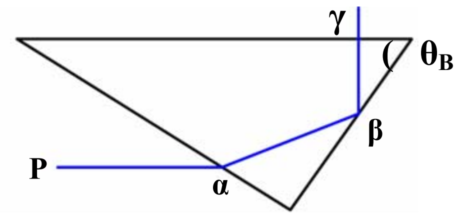
a) Below we give you two figures from the curriculum text showing the reflection coefficient of p-polarized light (polarized in the plane of the sketch) at the transition from air to glass (left) and glass to air (right).





Mark which part of the figures that describe the situation at points α, β, and γ in the first sketch. What do we call the phenomenon that occurs at the point β?

b) We substitute the prism above by a right angle *Brewster* prism, where one angle is given by $\theta_B = \text{arctg}(n_2/n_1)$, where n_2 is the refractive index of glass, and n_1 the refractive index of air. We place the prism in the light path from P, as shown in the figure to the right, so that the incidence angle is $\theta_i = \theta_B \approx 56°$.
Now the refraction angle θ_r is given by $\theta_i + \theta_r = \pi/2$.
Explain the path of the light beam through the prism.



c) How much light is reflected back to P in exercise b, compared to the equilateral prism in exercise a), if $n_1 = 1$ and $n_2 = 1.5$?

Good luck!