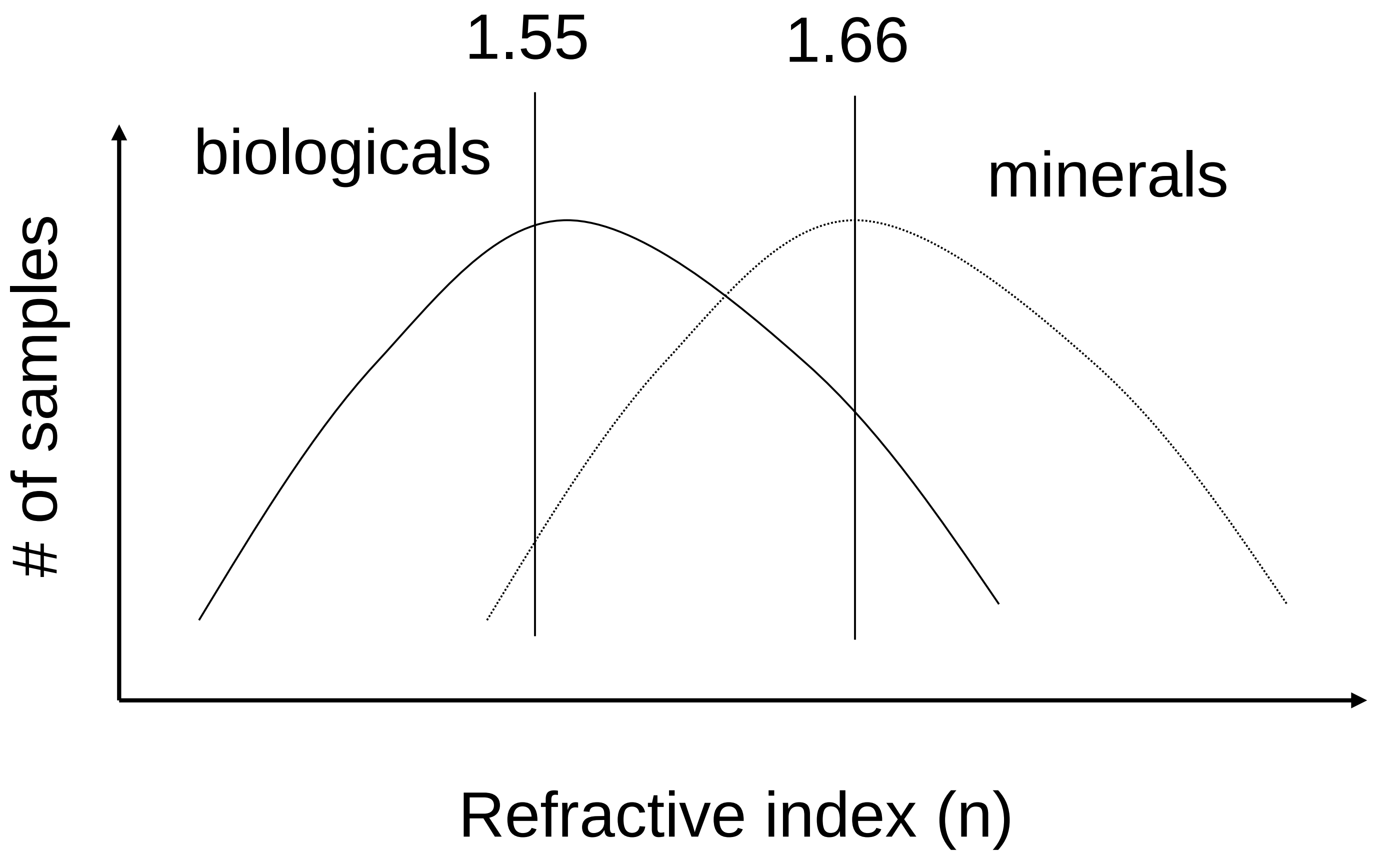
Lecture 8

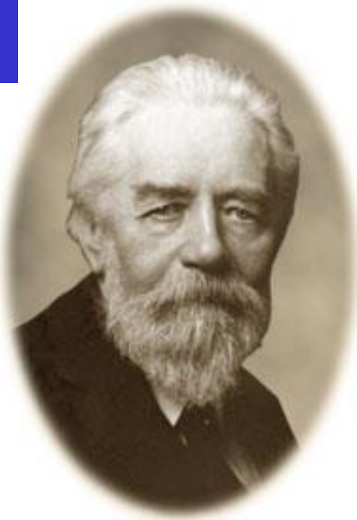
Measuring Refractive Index

Refractive Index

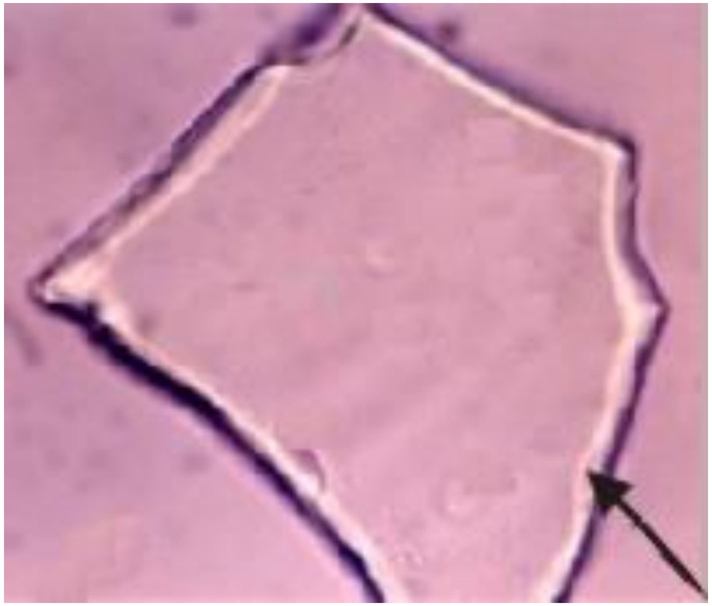


Becke Line Test

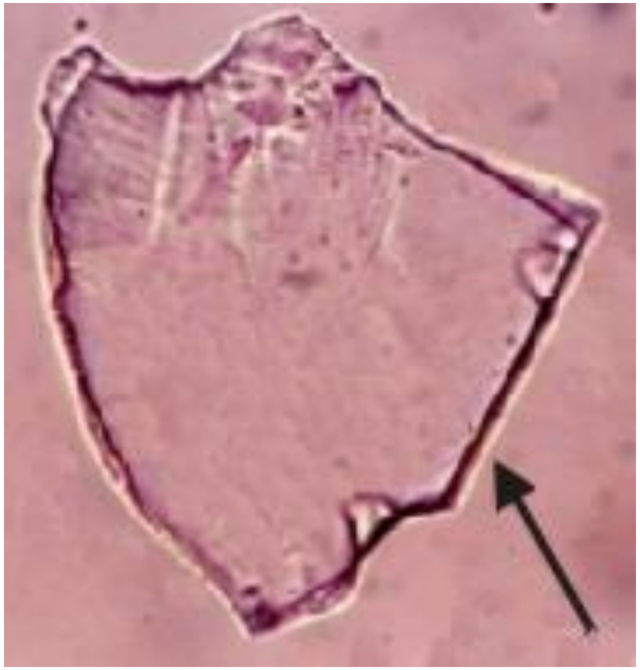
1. The indices of refraction of the particle and surrounding medium are different.
2. The microscope is defocused (on the sample).



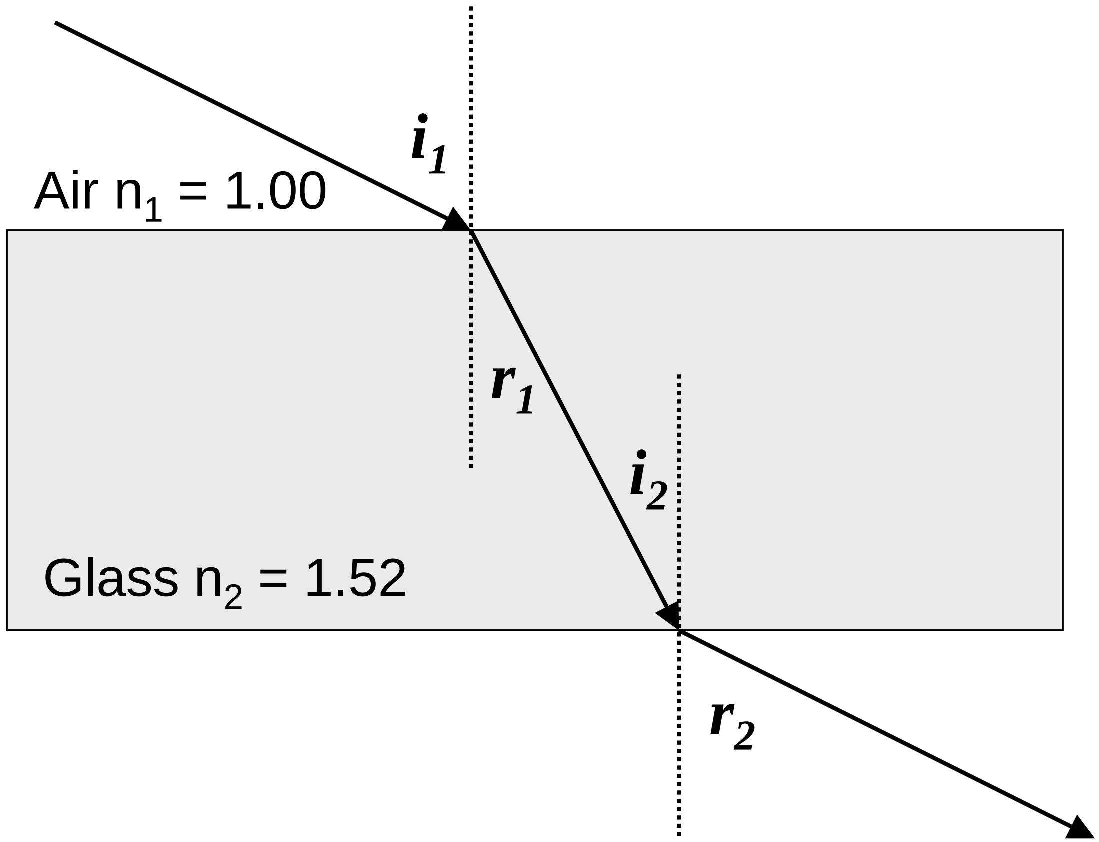
Friedrich Becke
(1855-1931)



Becke line

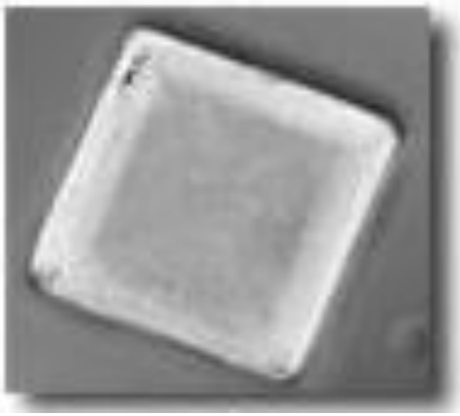


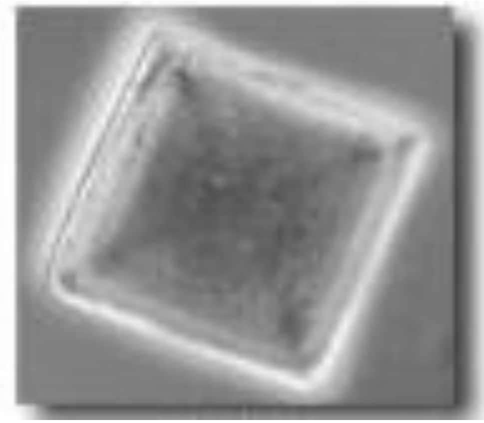
Refraction of Light

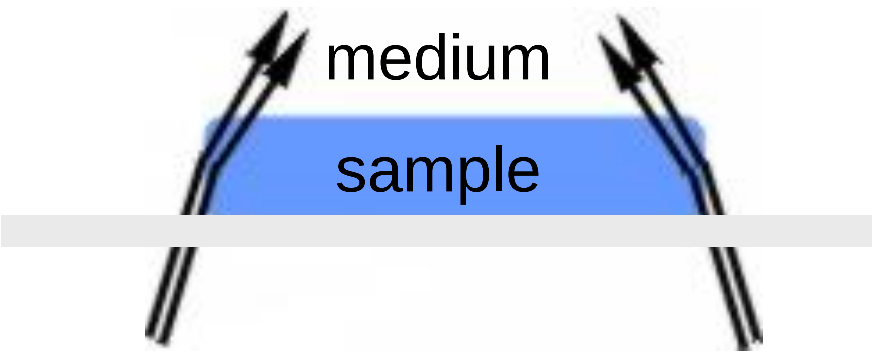


Light bends toward (or away) from surface normal.

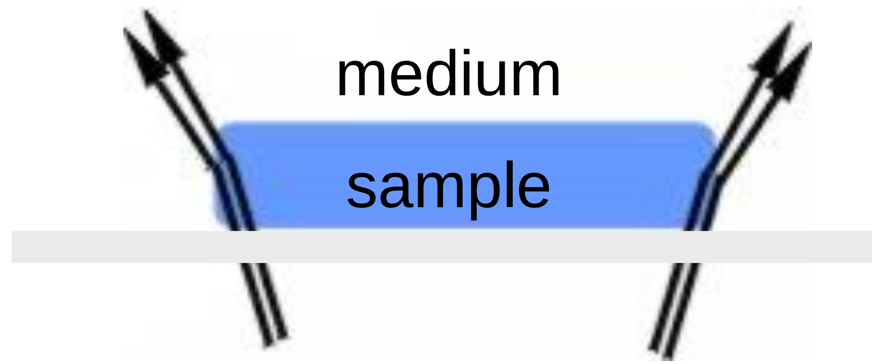
Formation of Becke Line







$n_{medium} < n_{sample}$



$n_{medium} > n_{sample}$

Can be used to find refractive index of unknown materials using standard liquids

How to Check Becke Line

1. Prepare a series of samples in media with different refractive indices

2. High contrast > close down condenser aperture

3. Control wavelength > yellow is best > use orange filter

4. Raise the focus > lower the stage > rotate toward you

5. Decide the refractive index depending on the position of Becke line

Refractive Index Measurements via Becke Line Test

1. One unknown sample

2. Choose standard refractive index liquids (1.4 and 1.8)

3. Decide whether refractive index is equal, greater, or less than refractive index you choose

Recrystallization of Inorganic/Organic Salts

1. Sublimation

2. Evaporation
   - 10X Objective
   - Supersaturation

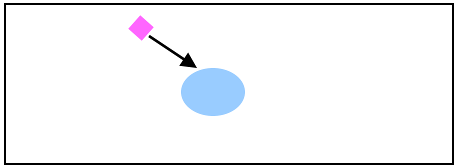
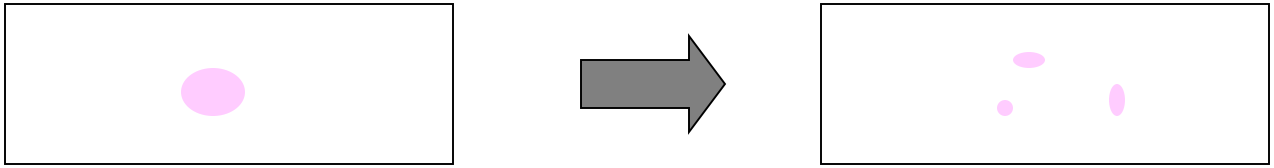


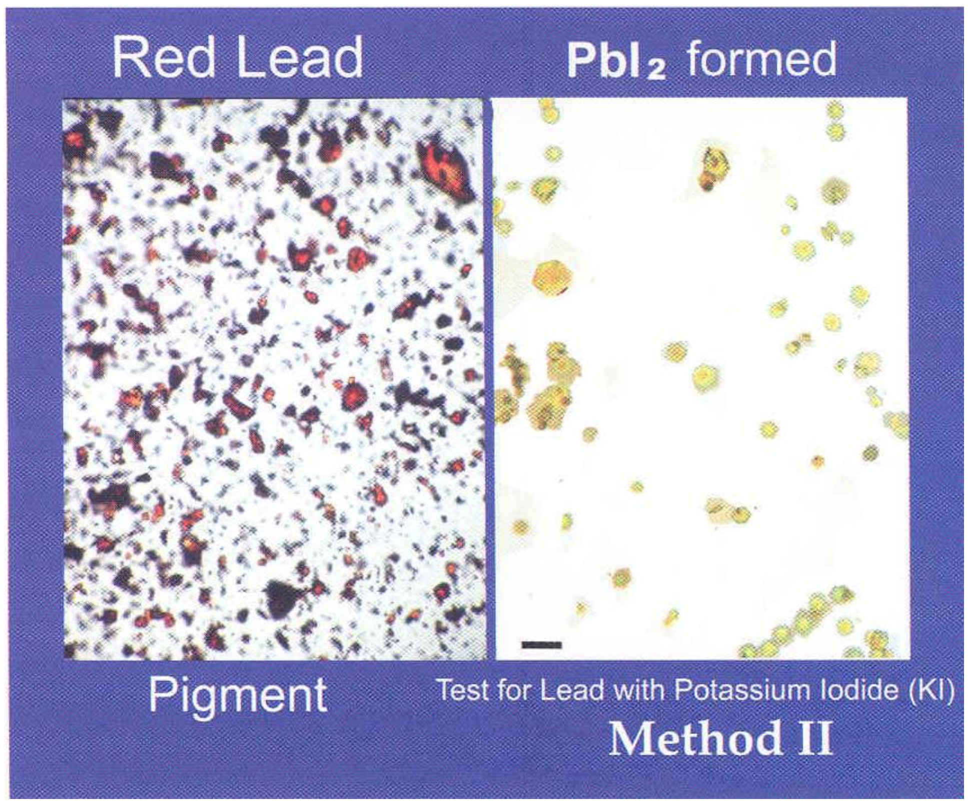
Figure 1

3. Transfer saturated solution "Huffing"

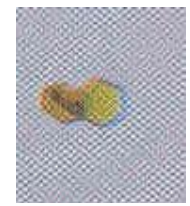


Detection of Lead

KI $Pb(NO_3)_2$ KI $Pb(NO_3)_2$



PbI_2



Exercise 5: Fiber Sample Preparation (see handout)

1. Three samples (hair and two fibers)

2. Your hair (cut one or two hair of ~ 1”)

3. Choose your sample in the list

4. Label your samples with marker (initial and sample name) on the slide glass

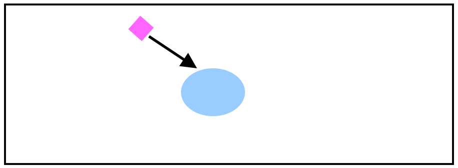
5. Cure them for a week

6. Place them in your assigned positions in a sample box by next week

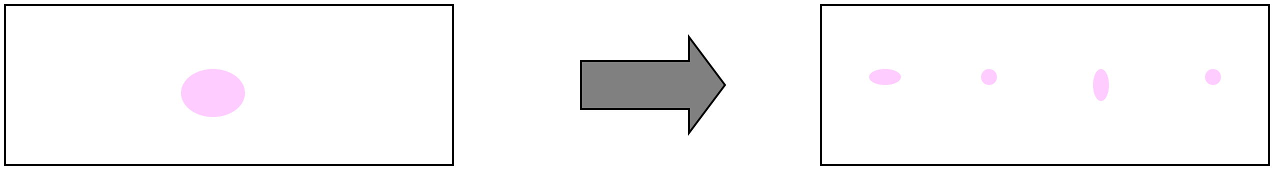
Exercise 6: Mineral Sample Preparation (see handout)

1. DO NOT contaminate your sample
2. Use very small portion of your sample

3. Evaporation



4. Transfer saturated solution "Huffing"



Lecture 9

Crystal Optics

http://www.brocku.ca/earthsciences/people/gfinn/optical/222lect.htm

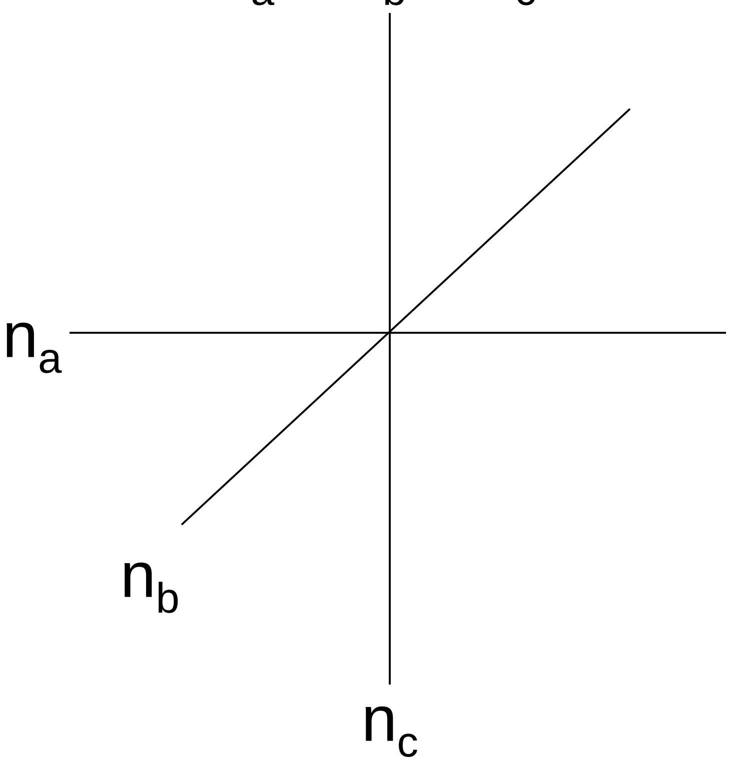
Isotropic vs Anisotropic

Refractive index: interaction between electromagnetic light and materials (ions and molecules)

Isotropic: Equal refractive index in all directions (one n)

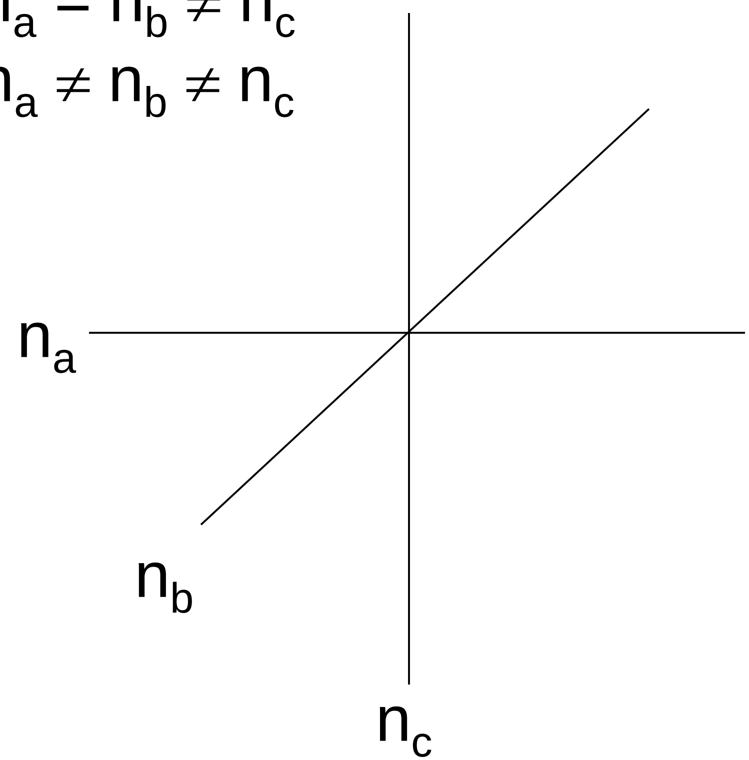
Anisotropic: Not equal refractive index in all directions (two or three n)

$n_a = n_b = n_c$



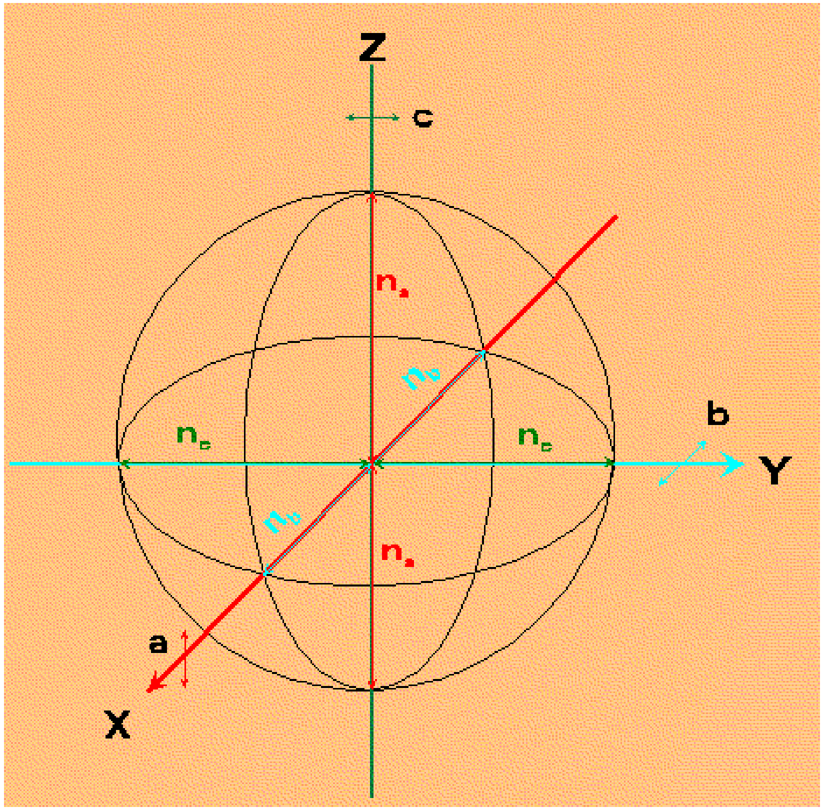
$n_a = n_b \neq n_c$

$n_a \neq n_b \neq n_c$



Cubic (Isotropic) Indicatrix

- Same refractive index in all directions
- Light travelling in all directions has same speed
- Cross sections are always circle (radius n)
- <u>Cubic crystal system only</u>



$$n = n_a = n_b = n_c$$

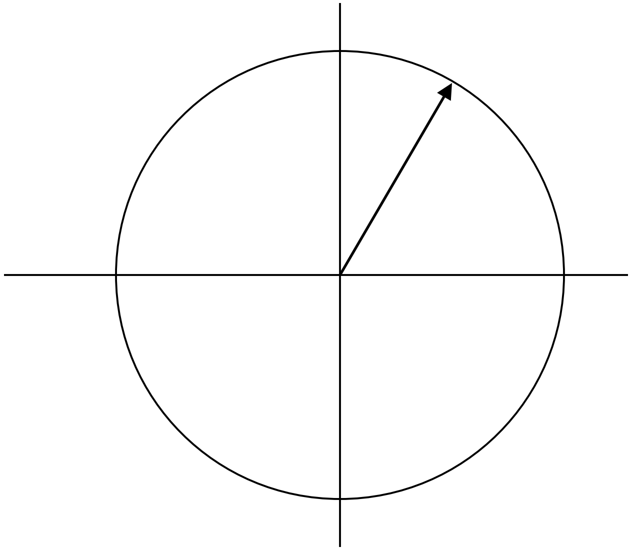
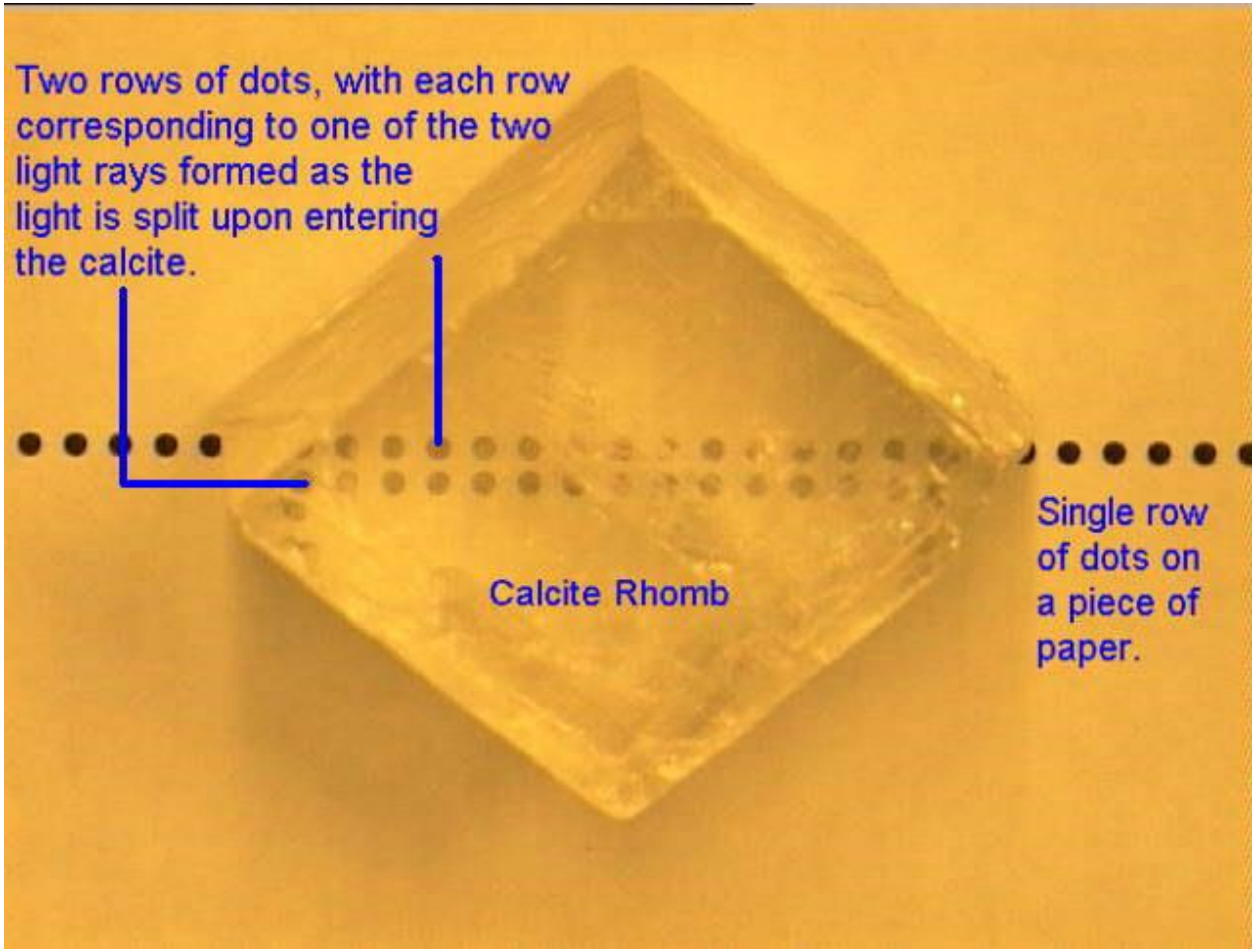


Image though Calcite



Uniaxial Indicatrix 1

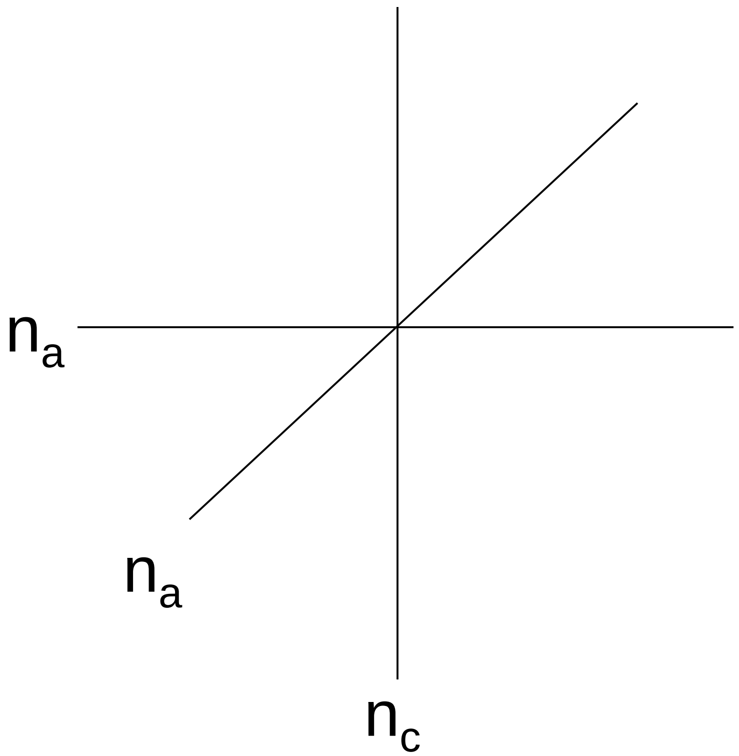
- Two refractive indices
- $n_a = n_b$ (ω) $\neq n_c$ (ε)
- Light travels in different speed depending on directions

- <u>Hexagonal and tetragonal crystal systems</u>

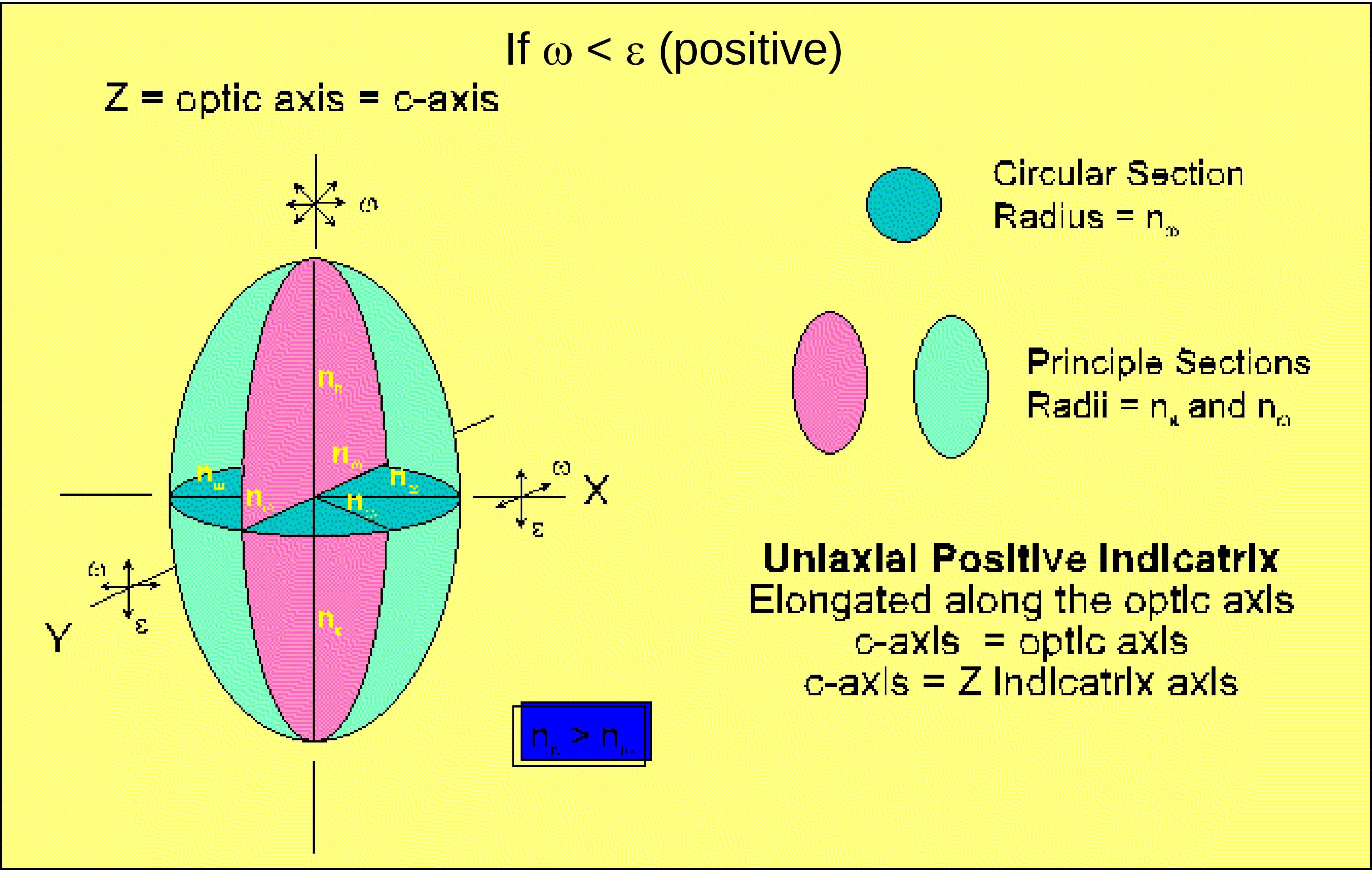
$n_a = n_b$ (ω) $\neq n_c$ (ε)

$\omega < \varepsilon$ or

$\omega > \varepsilon$

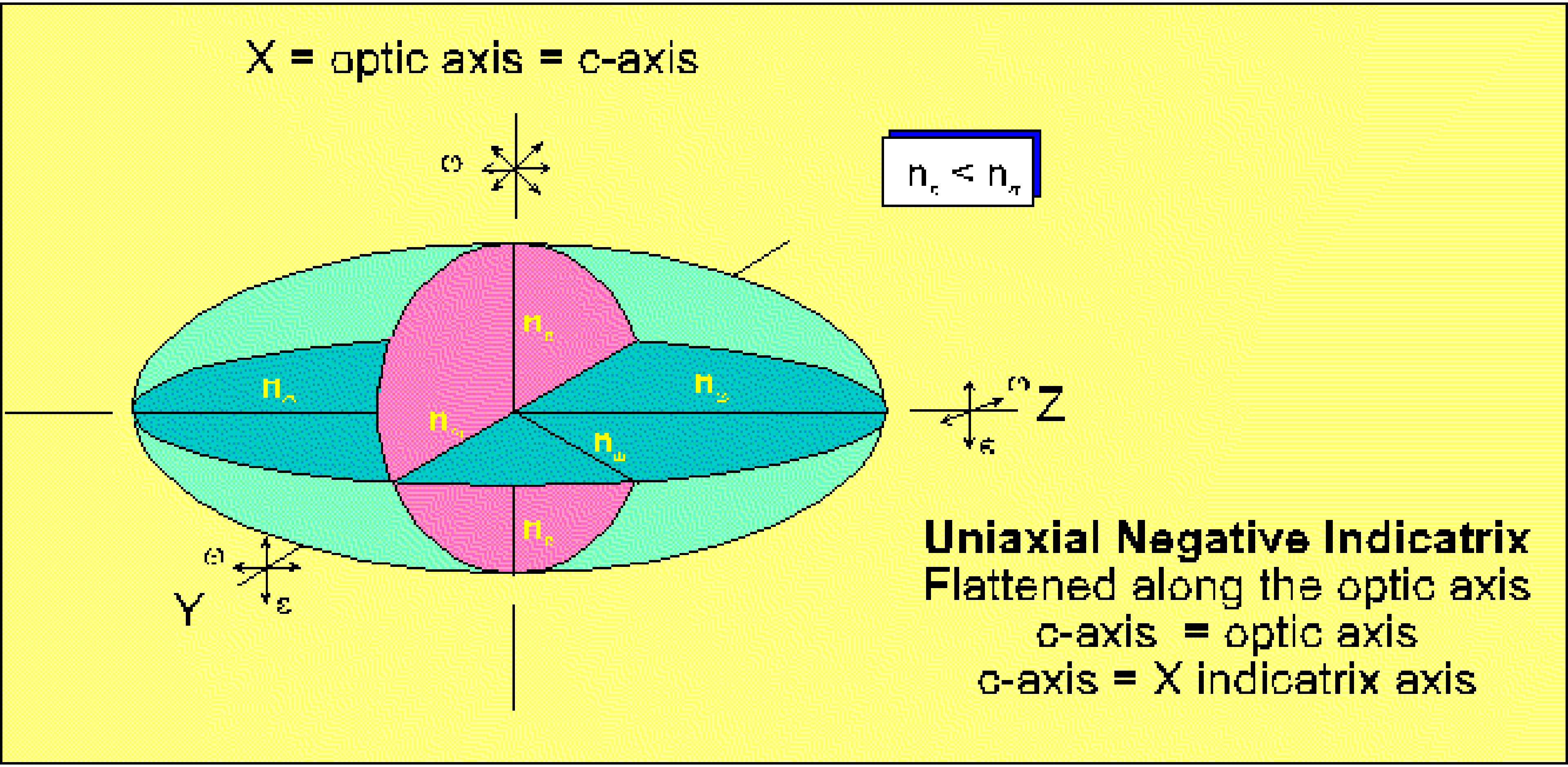


Uniaxial Indicatrix (Positive)

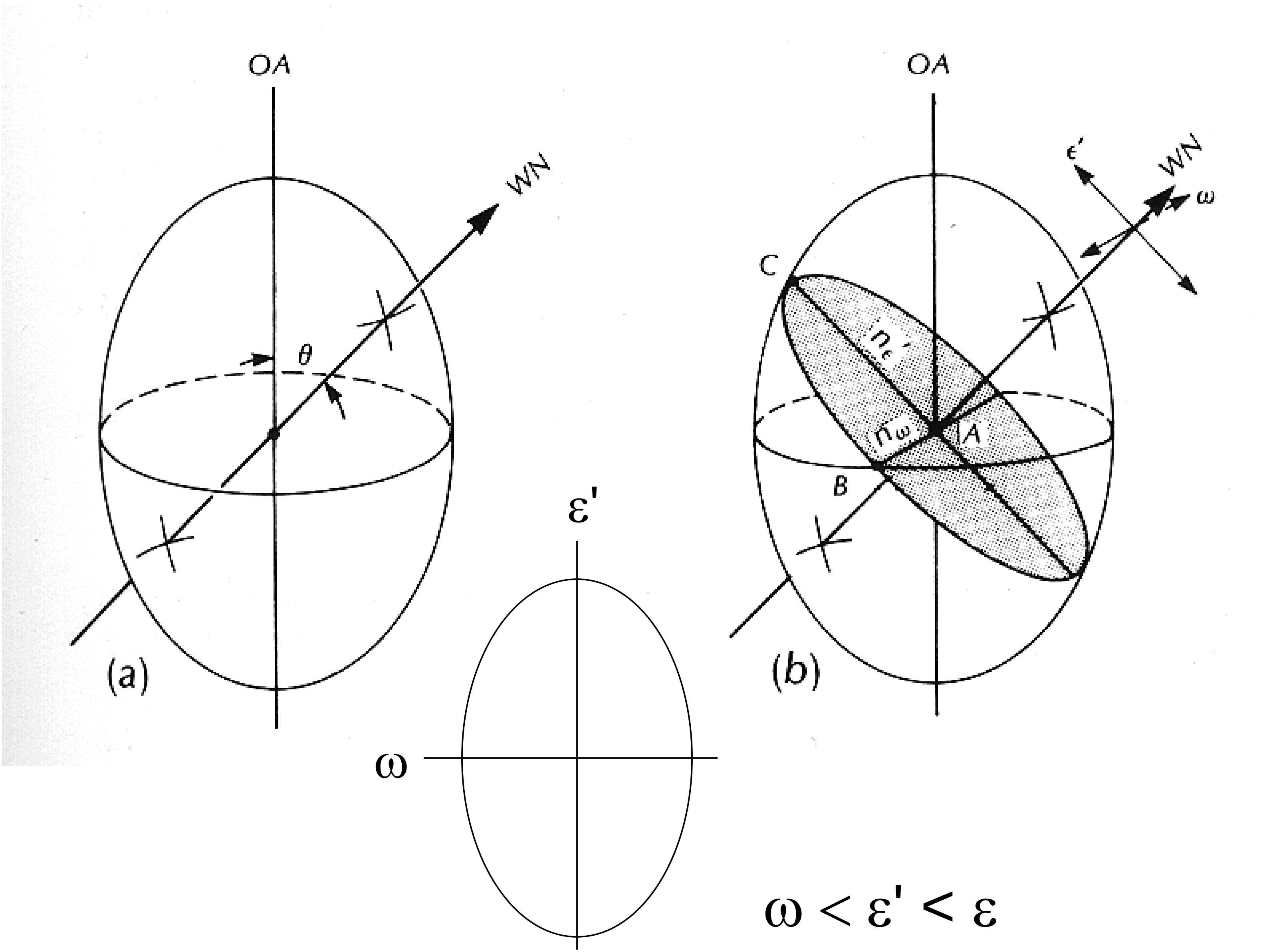


Uniaxial Indicatrix (Negative)

If ω > ε (negative)



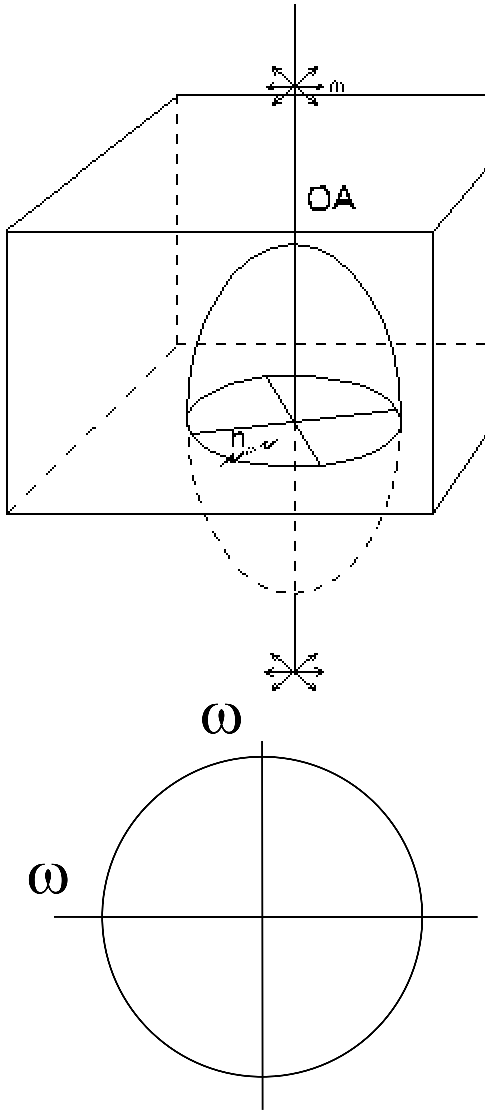
Random Section Vibration Directions



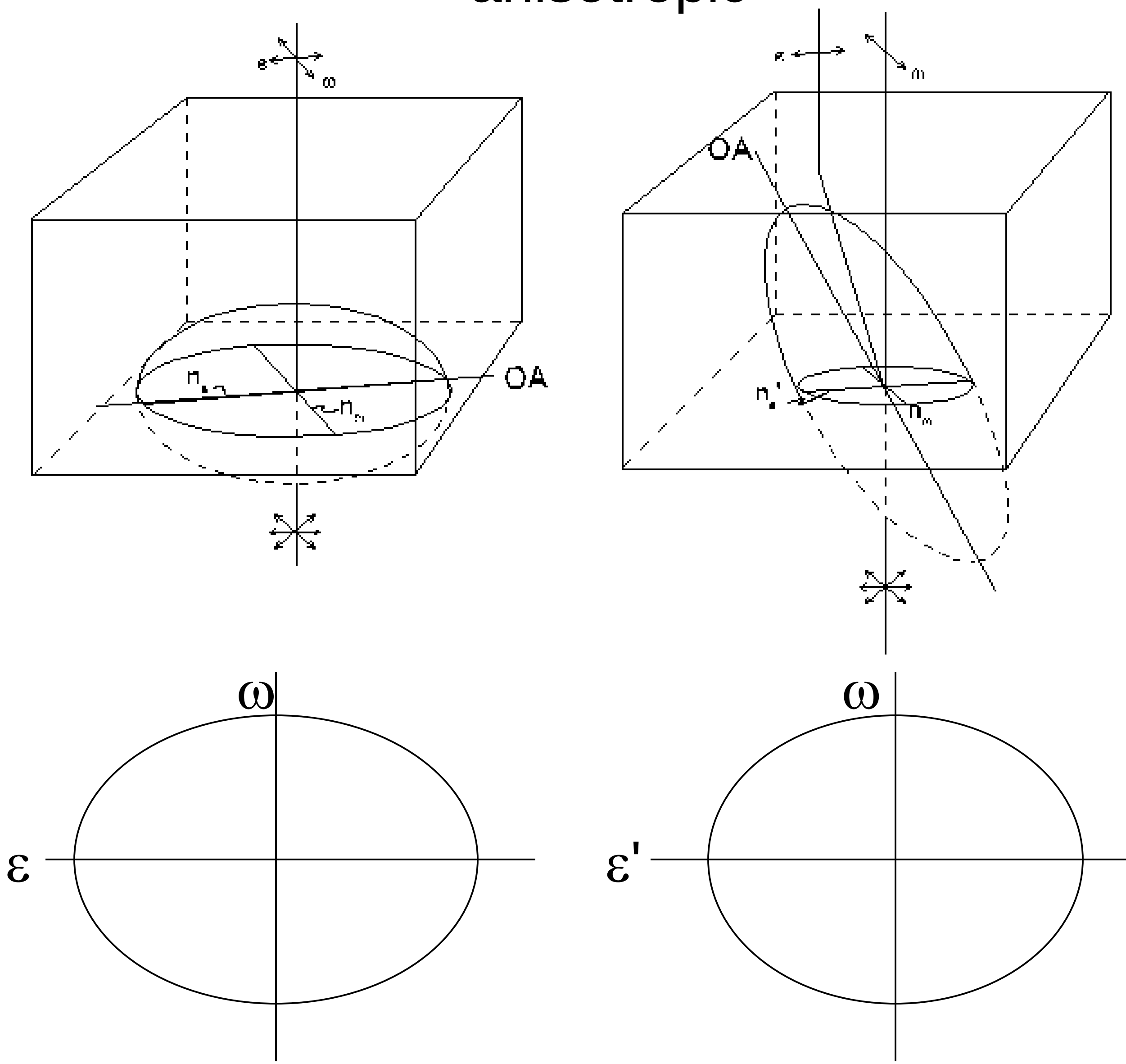
$\omega < \varepsilon' < \varepsilon$

Uniaxial Crystal: Orientation-Dependence

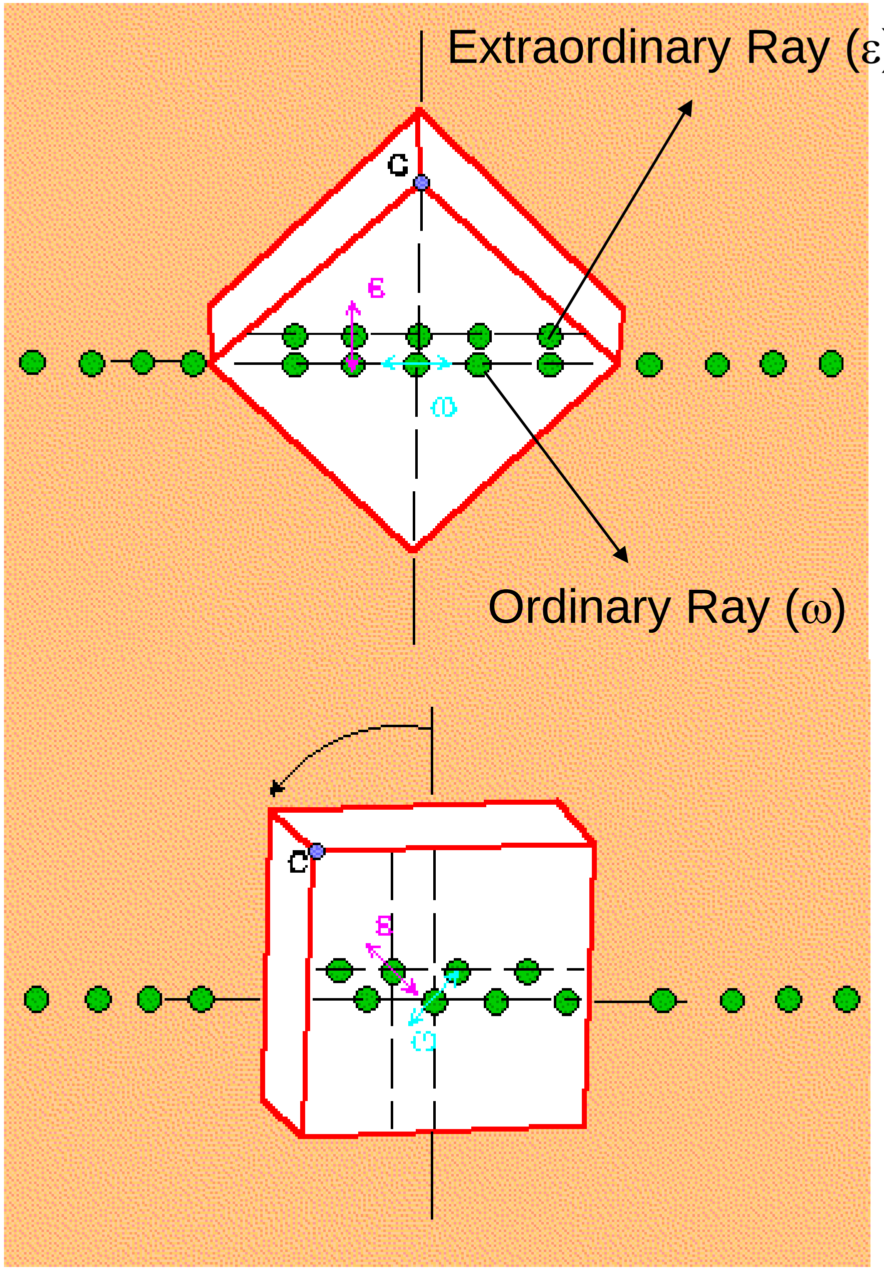
isotropic

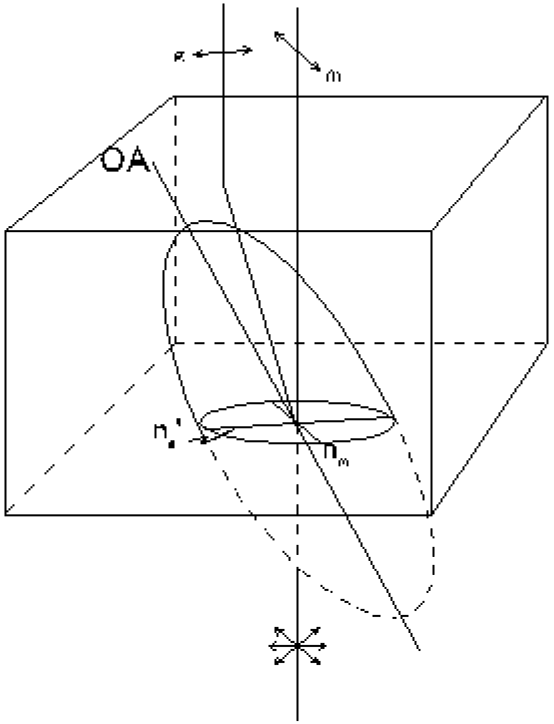


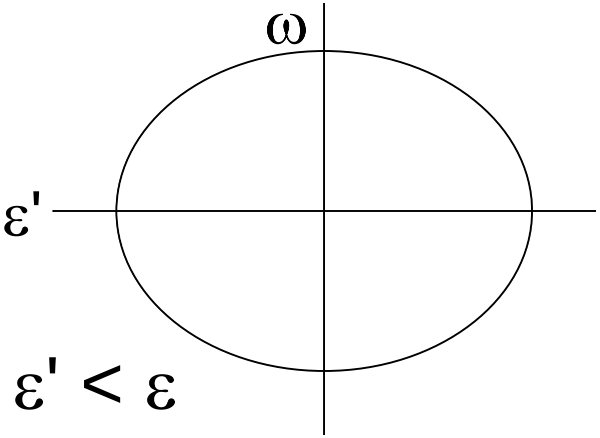
anisotropic



Calcite Double Refraction







$\omega < \varepsilon' < \varepsilon$

Birefringence: Double Refraction

Materisl with two (or more) refractive indices

For calcite,

n_{omega} = 1.658 (parallel to c axis, ordinary ray, regardless of the direction).
$n_{epsilon}$ = 1.486 to 1.658 (perpendicular to c axis extraordinary ray, dependant on the direction)

calcite, Δn = 0.172 (two images with very large separation
quartz, Δn = 0.009 (two images with very little separation)

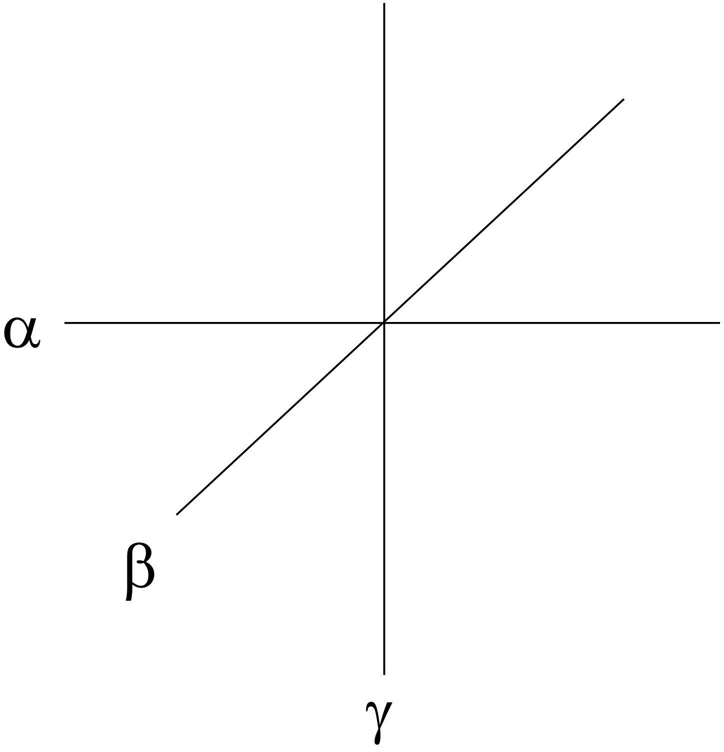
Crystal name	ω	ε
rock crystal (quartz)	1.5443	1.5534
calcite	1.6584	1.4864
sapphire	1.768	1.760

Biaxial Indicatrix 1

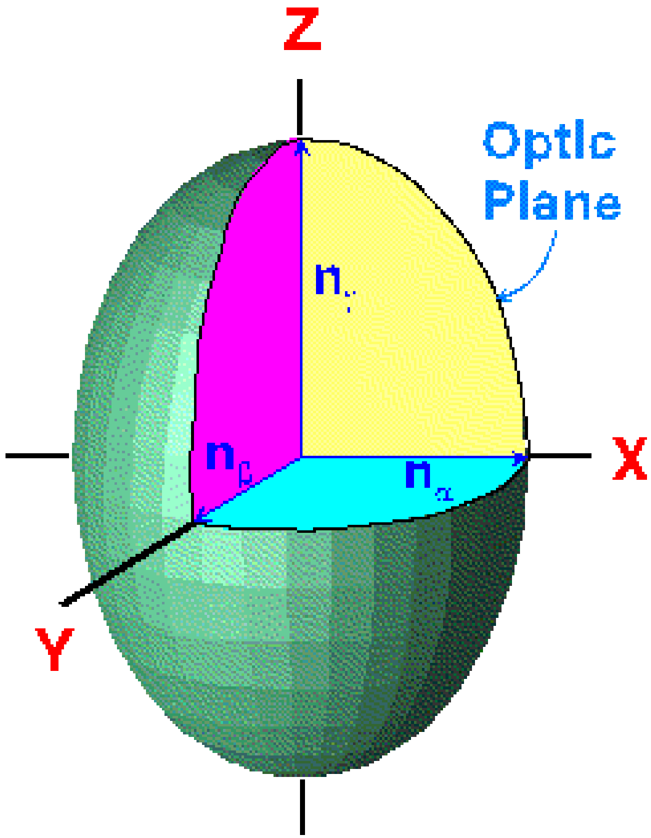
- Three refractive indices
- $n_a(\alpha) \neq n_b(\beta) \neq n_c(\gamma)$
- Light travels in different speed depending on directions
- Orthorhombic, monoclic, and triclinic crystal systems

- by definition, $\gamma > \beta > \alpha$

- $\gamma - \beta > \beta - \alpha$ (+): positive
- $\gamma - \beta < \beta - \alpha$ (-): negative



Biaxial Indicatrix 2



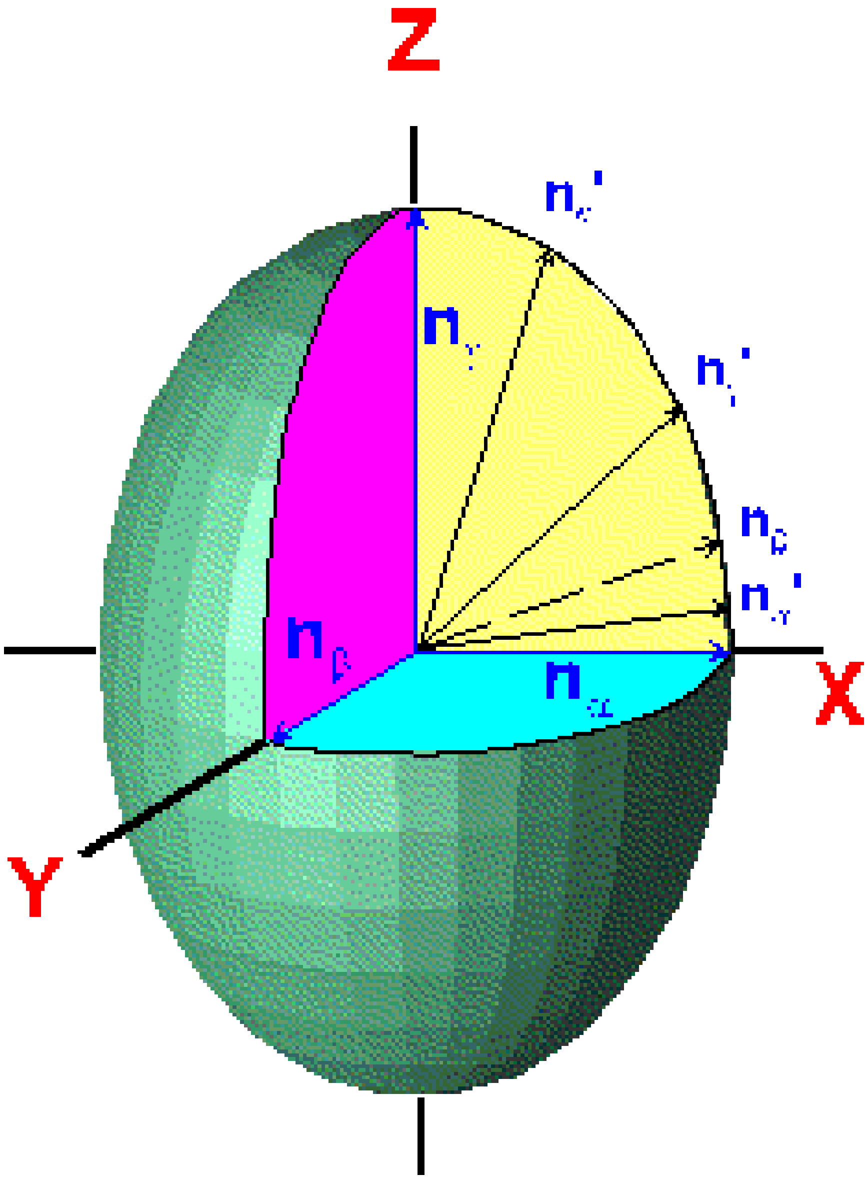
Biaxial minerals have three indices of refraction, (n_α, n_β, n_γ) each of which is measured along an indicatrix axis as shown on the left, such that the following relationship holds: $n_\alpha < n_\beta < n_\gamma$.

XZ plane with axes n_α and n_γ

YZ plane with axes n_β and n_γ

XY plane with axes n_α and n_γ

Biaxial Crystal: Orientation-Dependence



- γ and β for YZ plan
- γ and α for XZ plan
- α and β for XY plan

Random orientation

- γ , γ', β, β', α, and α' depending on the orientation

Biaxial Crystal: Orientation-Dependence