Engineering Optics

Lecture 22

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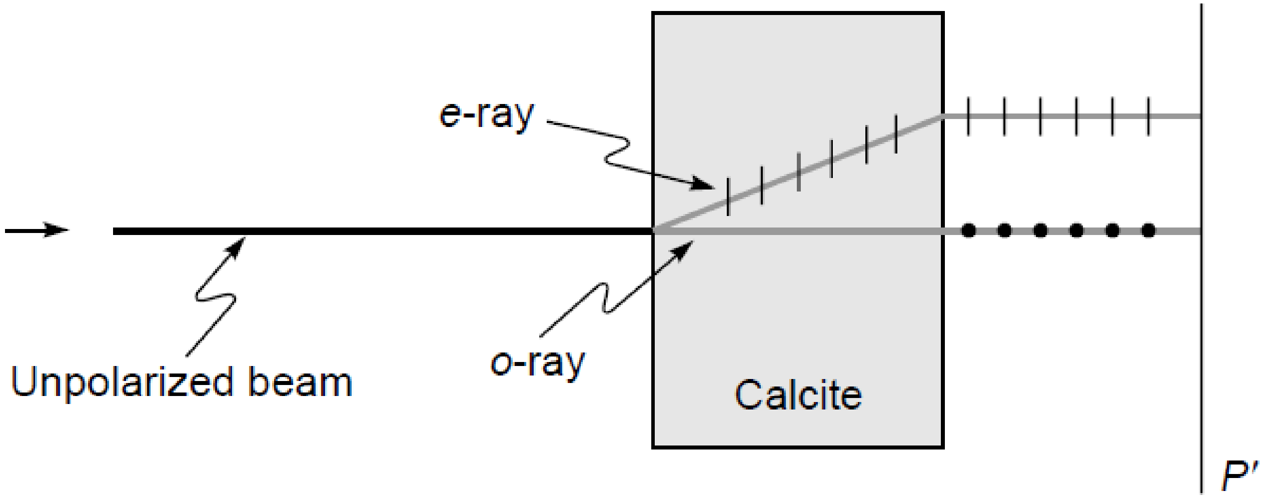
DOUBLE REFRACTION



when an unpolarized beam enters an **anisotropic** crystal, it splits up into two linearly polarized beams, each has a certain state of polarization, different velocities, and different refractive indices.

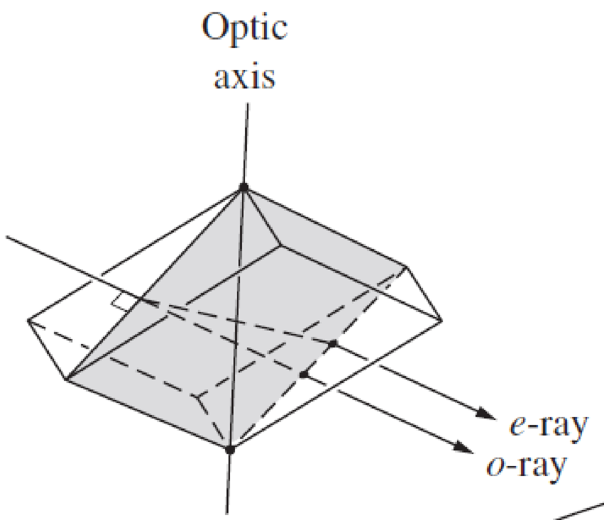
The beam which travels undeviated is known as the ordinary ray (O-ray) obeys Snell's laws of Refraction

the second beam, does not obey Snell's laws, is known as the extraordinary ray (E-ray).

Anisotropic crystals: Calcite, Quartz etc.
Dichroic crystal: Tourmaline

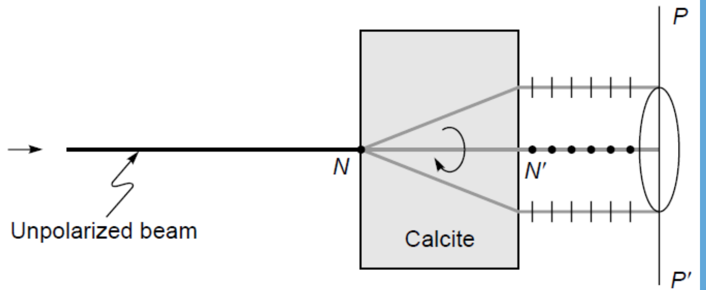
Optics, Ghatak

Optic axis, E-ray and O-ray

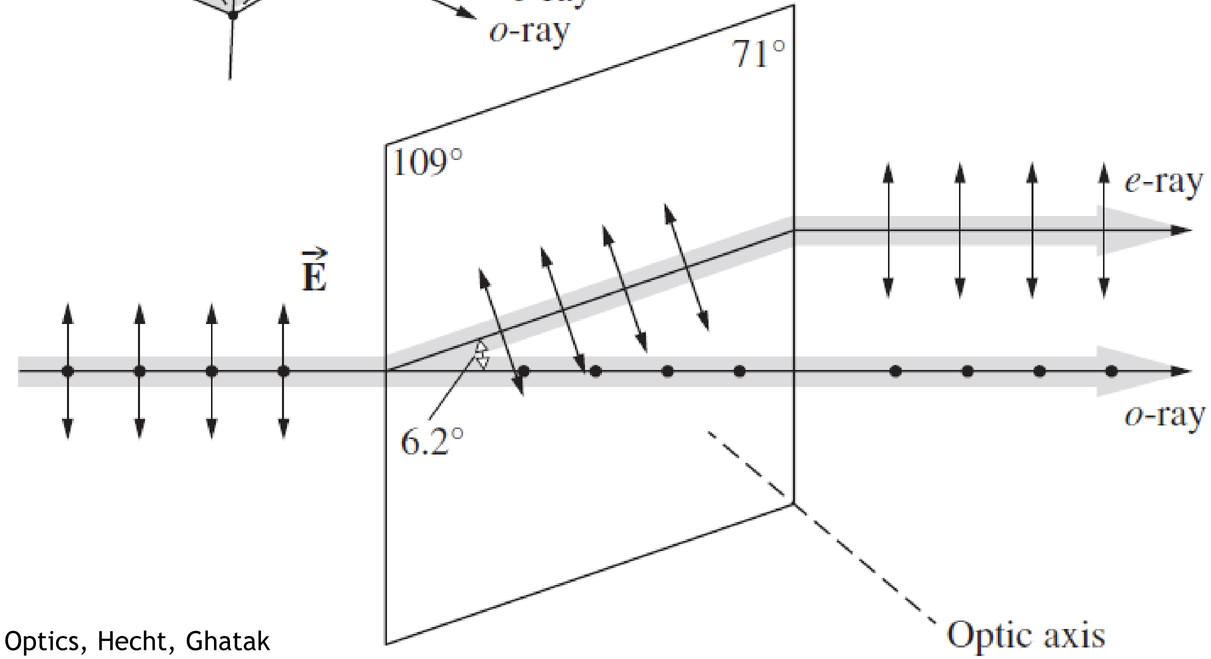


$$v_{ro} = \frac{c}{n_o}$$ ordinary ray

$$\frac{1}{v_{re}^2} = \frac{\sin^2\theta}{(c/n_e)^2} + \frac{\cos^2\theta}{(c/n_o)^2}$$ extraordinary ray



we rotate the crystal about NN,′ then the e-ray will rotate about NN'.



- v_{ro} → same in all direction
- v_{re} → different
- Both same along one direction in anisotrpic crystal → **optic axis**
- Calcite → $v_{ro} = v_{re}$ along 1 direction → optic axis → Uniaxial crystal

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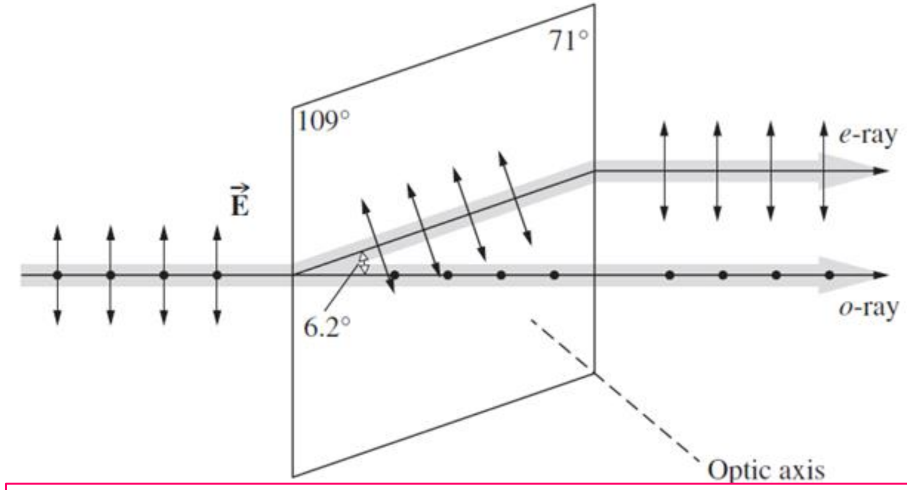
E-ray and O-ray continued



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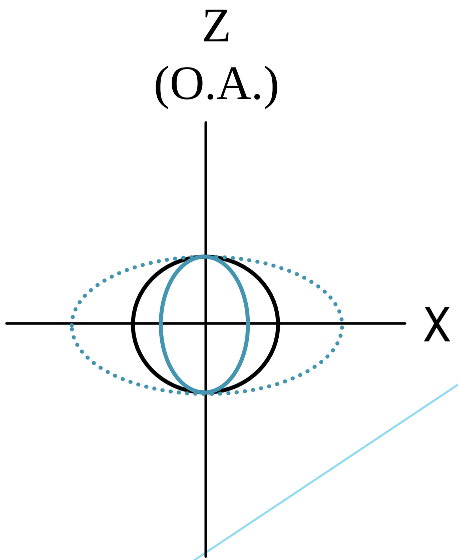
$$\frac{z^2}{a^2} + \frac{x^2}{b^2} = 1 \quad \text{OR} \quad \frac{1}{\rho^2} = \frac{\cos^2\theta}{a^2} + \frac{\sin^2\theta}{b^2}$$

$$z = \rho\cos\theta \qquad x = \rho\sin\theta$$

n_o and n_e are constants of the crystal and θ is the angle that the ray makes with the optic axis (z)
with the optic axis as the axis of revolution

- plot v_{re} as a function of θ
- plot v_{ro} as a function of θ



Which one is correct:
1. Sphere inside or
2. Ellipse inside ??

Optics, Ghatak

Positive and negative crystals

Along the optic axis $$v_{ro} = v_{re} = \frac{c}{n_o}$$

Along a direction perpendicular to optic axis ??

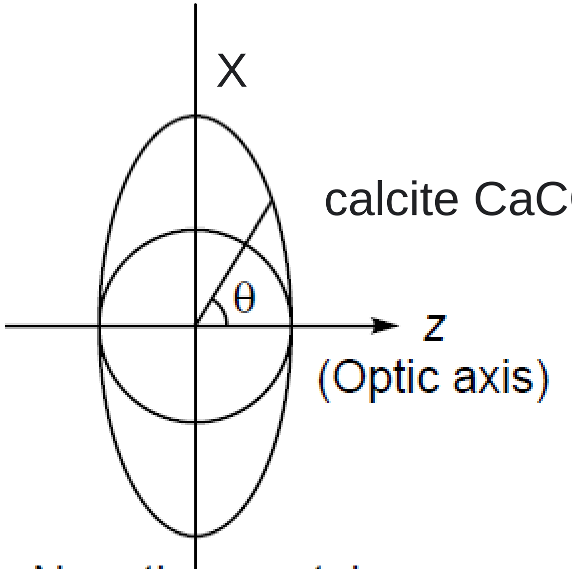
Fast axis and slow axis

For a negative crystal $n_e < n_o$

$$v_{re}\left(\theta = \frac{\pi}{2}\right) = \frac{c}{n_e} > v_{ro}$$

On the other hand, for a positive crystal $n_e > n_o$

$$v_{re}\left(\theta = \frac{\pi}{2}\right) = \frac{c}{n_e} < v_{ro}$$

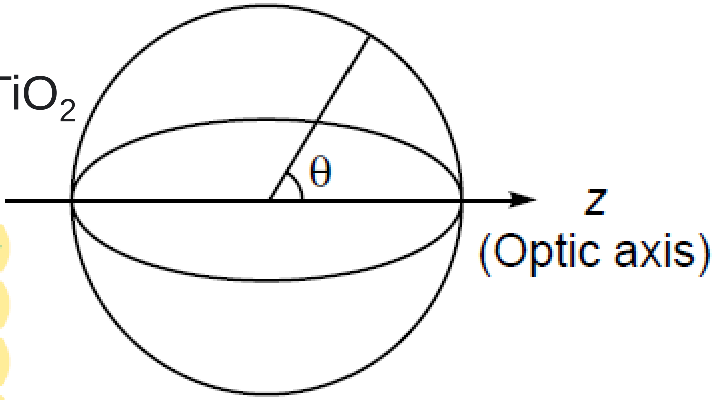


Negative crystal

(a)

calcite $CaCO_3$, ruby Al_2O_3

quartz SiO_2, rutile TiO_2



Positive crystal

(b)

(a) In a negative crystal, the ellipsoid of revolution (which corresponds to the extra ordinary ray) lies outside the sphere; the sphere corresponds to the ordinary ray. (b) In a positive crystal, the ellipsoid of revolution (which corresponds to the extraordinary ray) lies inside the sphere.

Optics, Ghatak

Thank You