Engineering Optics

Lecture 17

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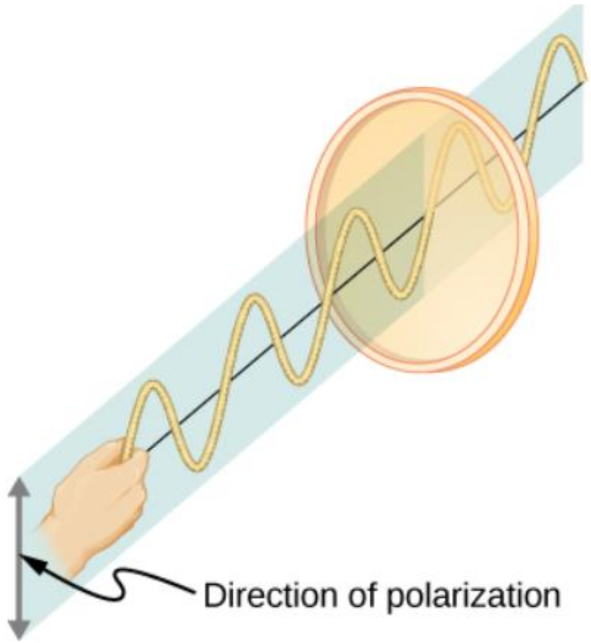
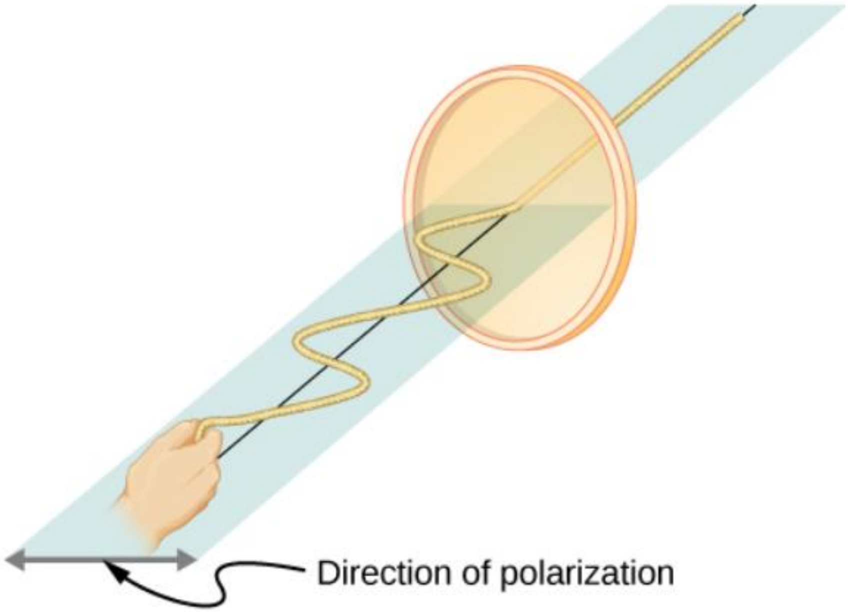
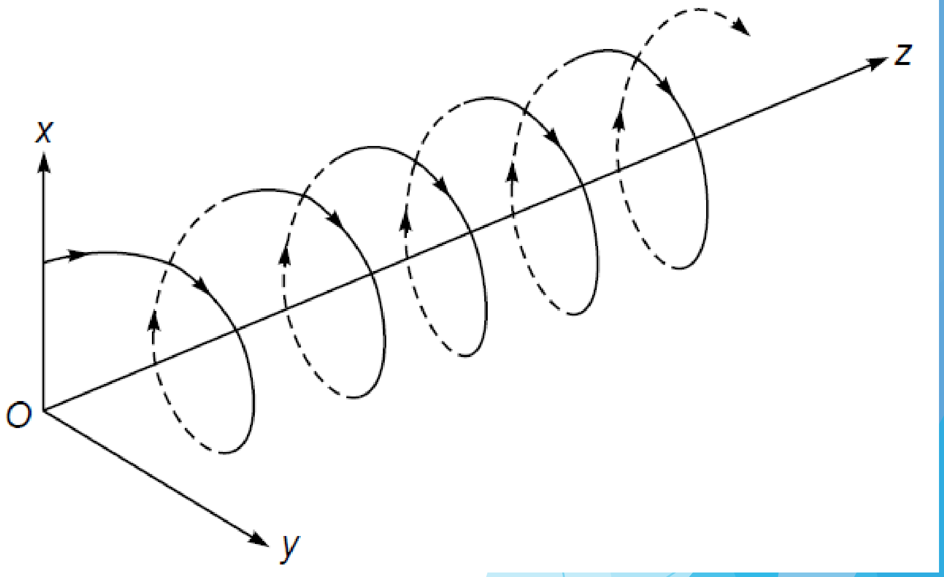
Polarized waves



$$x(z,t) = a\cos(kz - \omega t + \phi_1)$$
$$y(z,t) = 0$$



$$y(z,t) = a\cos(kz - \omega t + \phi_2)$$
$$x(z,t) = 0$$

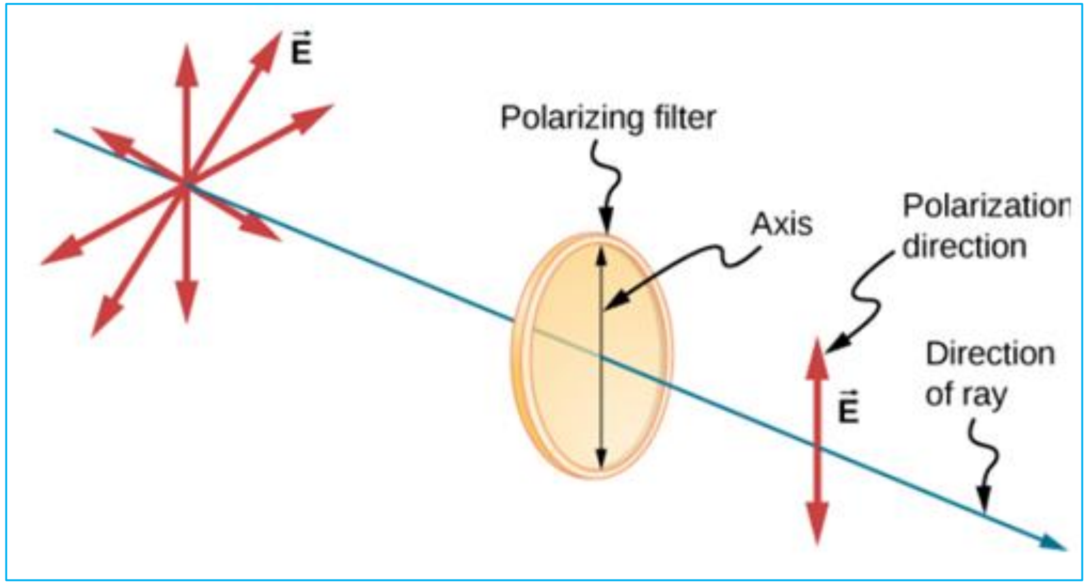


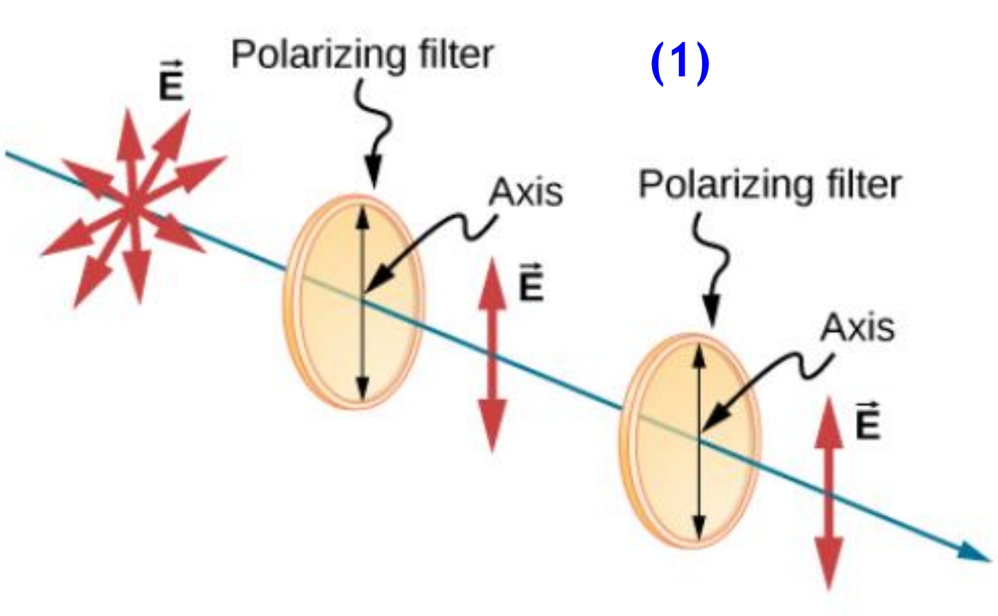
$$x(z,t) = a\cos(kz - \omega t + \phi)$$
$$y(z,t) = a\sin(kz - \omega t + \phi)$$

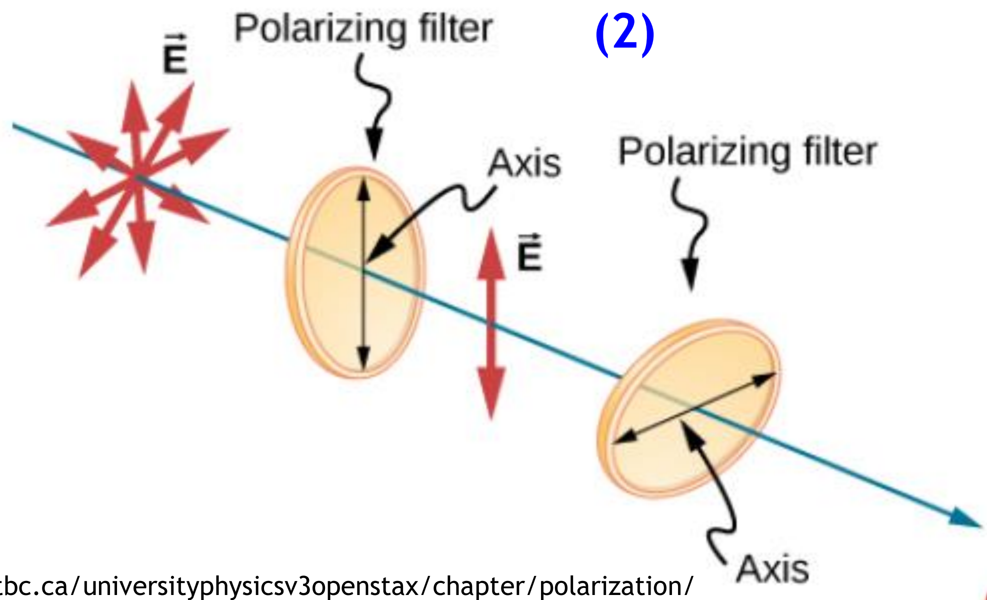
$$x^2 + y^2 = a^2$$

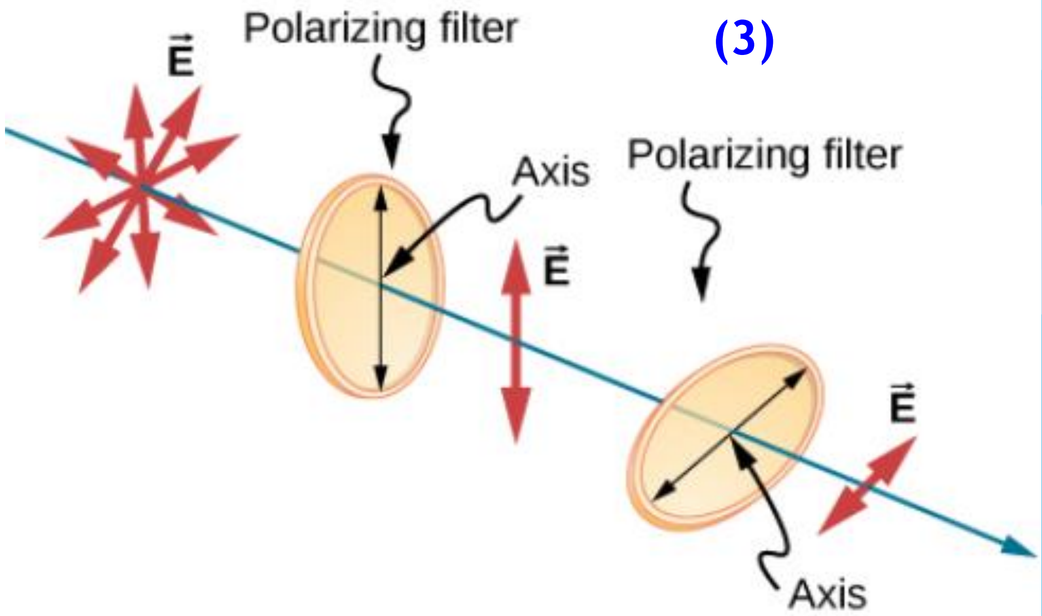
https://opentextbc.ca/universityphysicsv3openstax/chapter/polarization/

Polarization of light









https://opentextbc.ca/universityphysicsv3openstax/chapter/polarization/

Production of linearly polarized light

The Wire Grid Polarizer

- Large number of thin copper wires placed parallel to one another
- When an unpolarized electromagnetic wave is incident on it, then the component of the electric vector along the length of the wire is absorbed.
- electric field does work on the electrons inside the thin wires, and the energy associated with the electric field is lost in the Joule heating of the wires
- wires are assumed to be very thin, **which E component will pass through? Component blocked?**
- Thus the emergent wave is linearly polarized
- To completely block a component spacing between wires ≤ λ
- **3 cm microwave: spacing has to be < 3 cm**

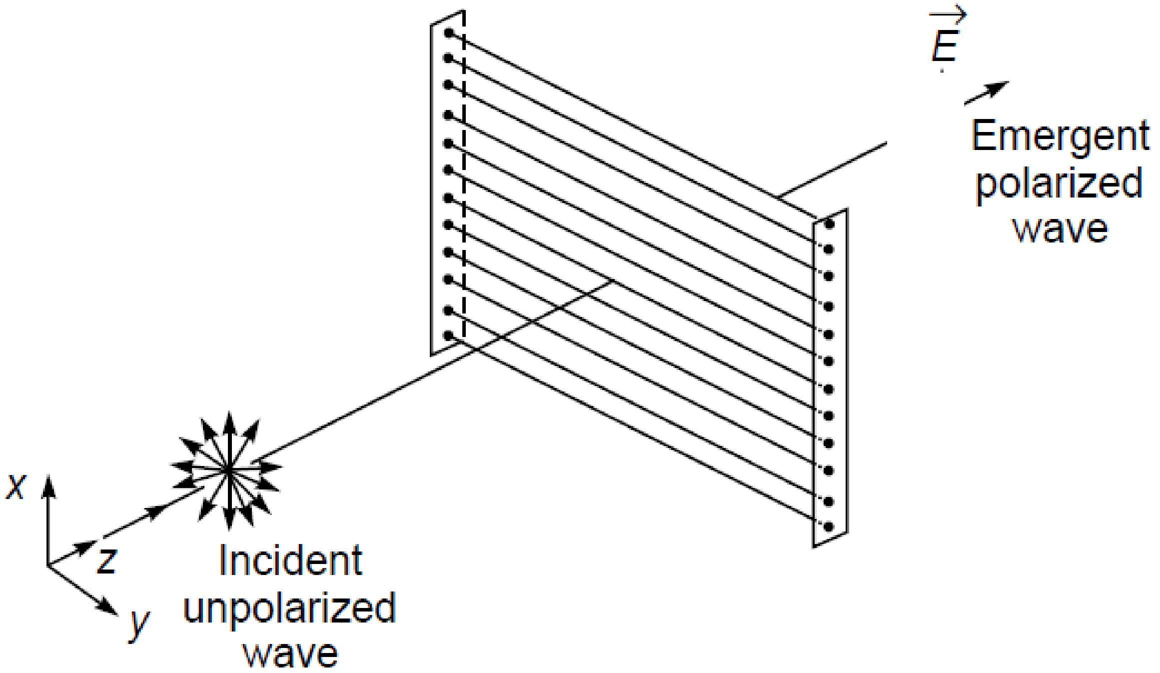


Fig. 22.8 The wire grid polarizer.

The Wire Grid Polarizer

- Large number of thin copper wires placed parallel to one another
- When an unpolarized electromagnetic wave is incident on it, then the component of the electric vector along the length of the wire is absorbed.
- electric field does work on the electrons inside the thin wires, and the energy associated with the electric field is lost in the Joule heating of the wires
- wires are assumed to be very thin, **E_x → passes through** **E_y→ blocked**
- Thus the emergent wave is linearly polarized with the electric vector along the x axis.
- To completely block a component spacing between wires ≤ λ
- **3 cm microwave: spacing has to be < 3 cm**

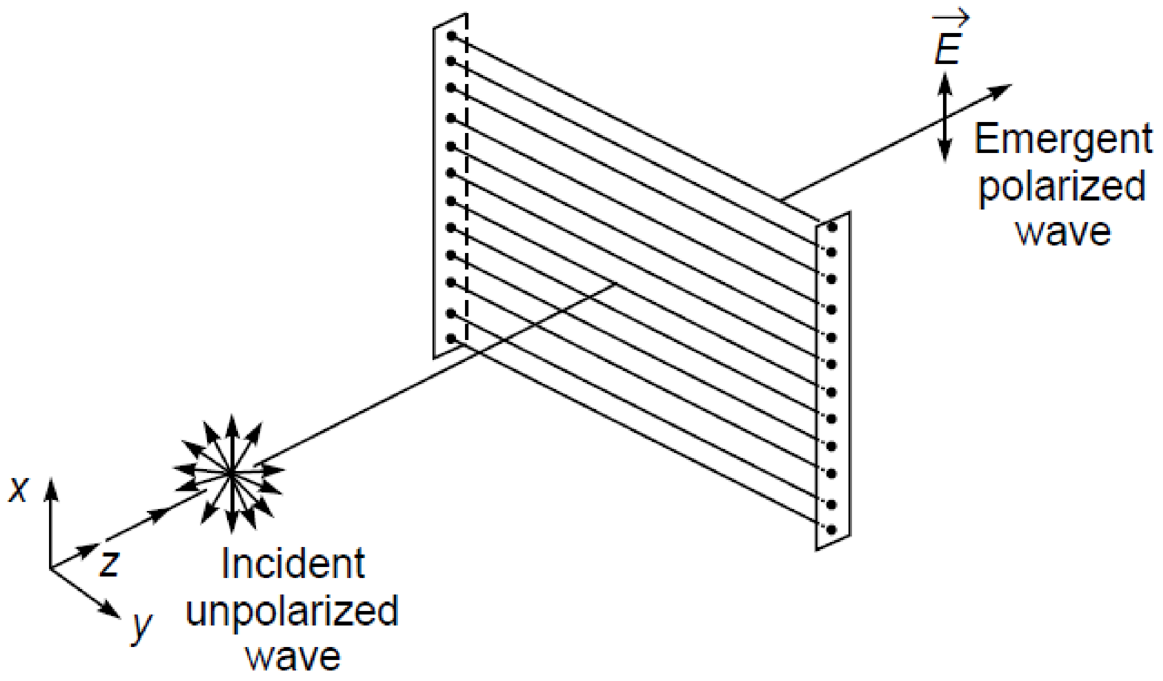


Fig. 22.8 The wire grid polarizer.

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What about visible light ?

- Use long chain polymer molecules aligned almost parallel to one another
- *High conductivity*

A sheet containing such long chain polymer molecules (which are aligned parallel to one another) is known as a *Polaroid*.

When a light beam is incident on such a Polaroid, the molecules absorb the component of electric field which is parallel to the direction of alignment because of the high conductivity provided by the iodine atoms; the component perpendicular to it passes through.

spacing between two adjacent long chain molecules is small compared to the optical wavelength, the Polaroid is usually very effective in producing linearly polarized light.

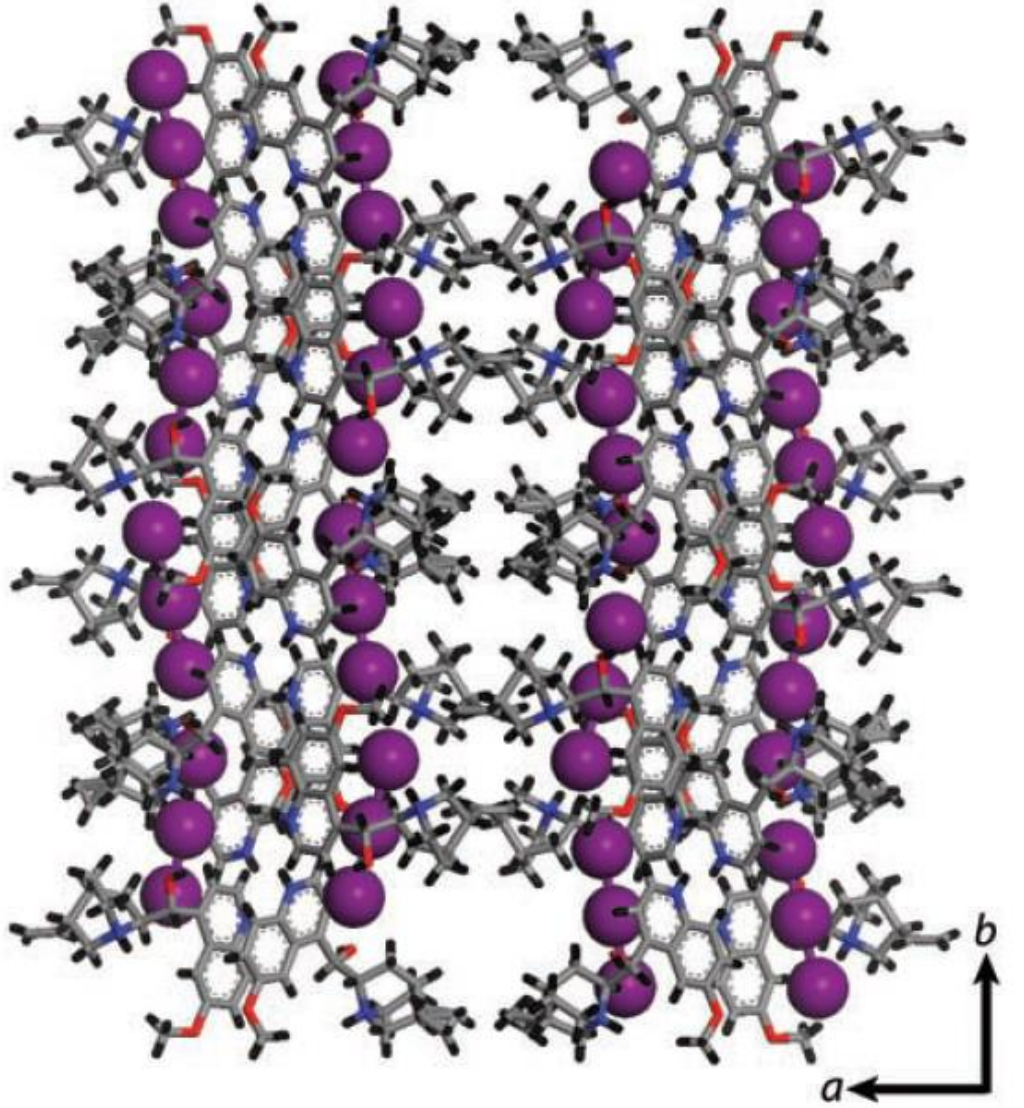


Fig. 1. The crystal structure of herapathite. Iodine atoms are purple spheres. The absorbing axis is vertical. Solvent molecules and sulfate ions have been removed for clarity. See also figs. S2 and S3.

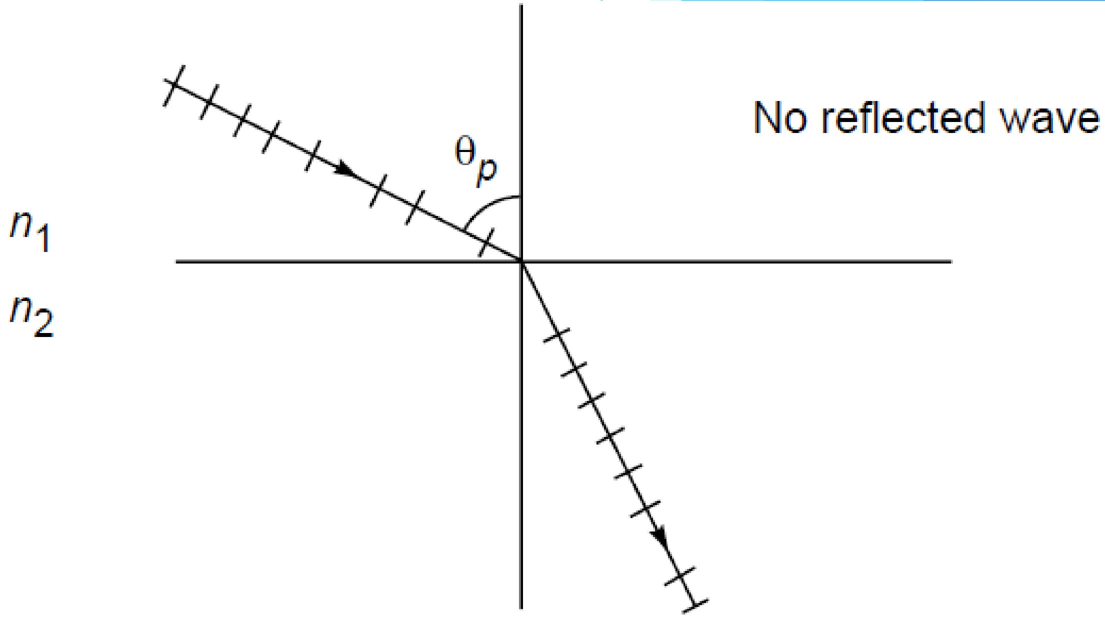
B. Kahe, *et al.*, SCIENCE VOL 324 12 JUNE 2009

Polarization by Reflection

Let us consider the incidence of a plane wave on a dielectric. We assume that the electric vector associated with the incident wave lies in the plane of incidence as shown in Fig. 22.9. It will be shown in Sec. 24.2 that if the angle of incidence θ is such that

$$\theta = \theta_p = \tan^{-1}\left(\frac{n_2}{n_1}\right)$$

then the reflection coefficient is zero.



If a linearly polarized wave (with its **E** in the plane of incidence) is incident on the interface of two dielectrics with the angle of incidence equal to θ_p [$= \tan^{-1}(n_2/n_1)$], then the reflection coefficient is zero.

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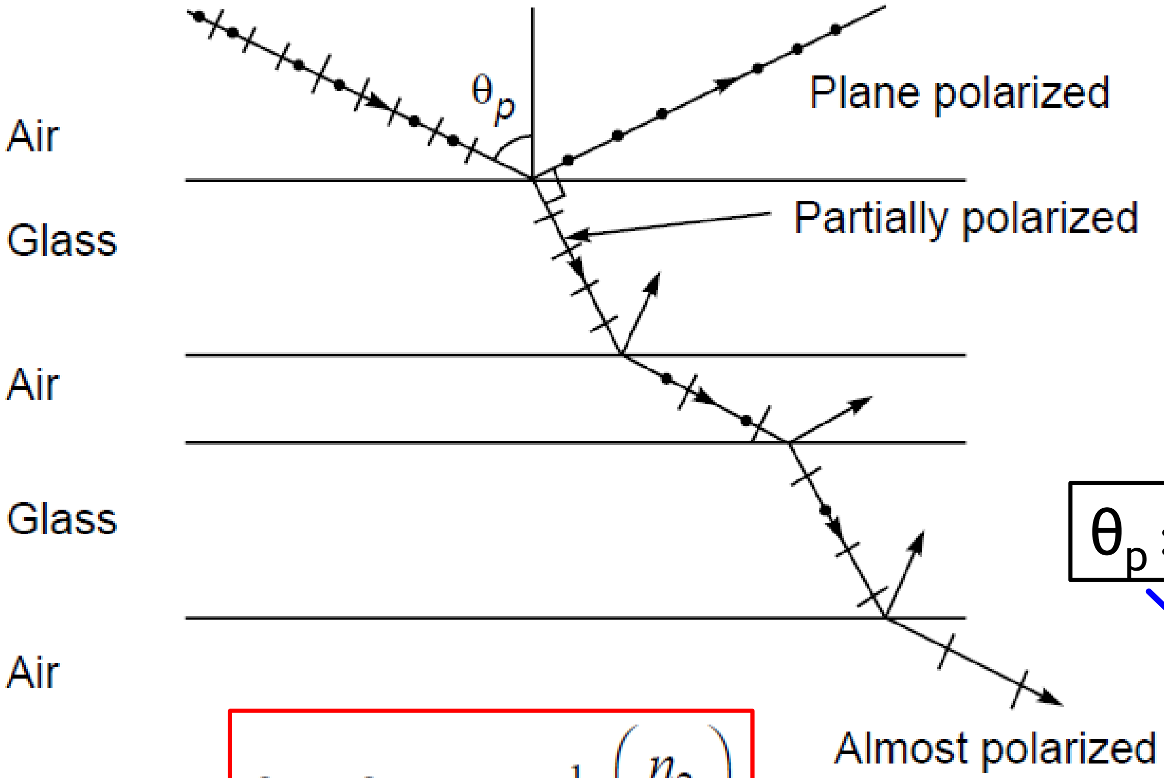
Brewster's law



If an unpolarized beam is incident with an angle of incidence equal to θ_p, the reflected beam is plane polarized whose electric vector is perpendicular to the plane of incidence. The transmitted beam is partially polarized, and if this beam is made to undergo several reflections, then the emergent beam is almost plane polarized with its electric vector in the plane of incidence.

θ_p : reflected and transmitted rays are at right angles

polarizing angle or the ***Brewster angle***

$$\boxed{\theta = \theta_p = \tan^{-1}\left(\frac{n_2}{n_1}\right)}$$

Brewster's law

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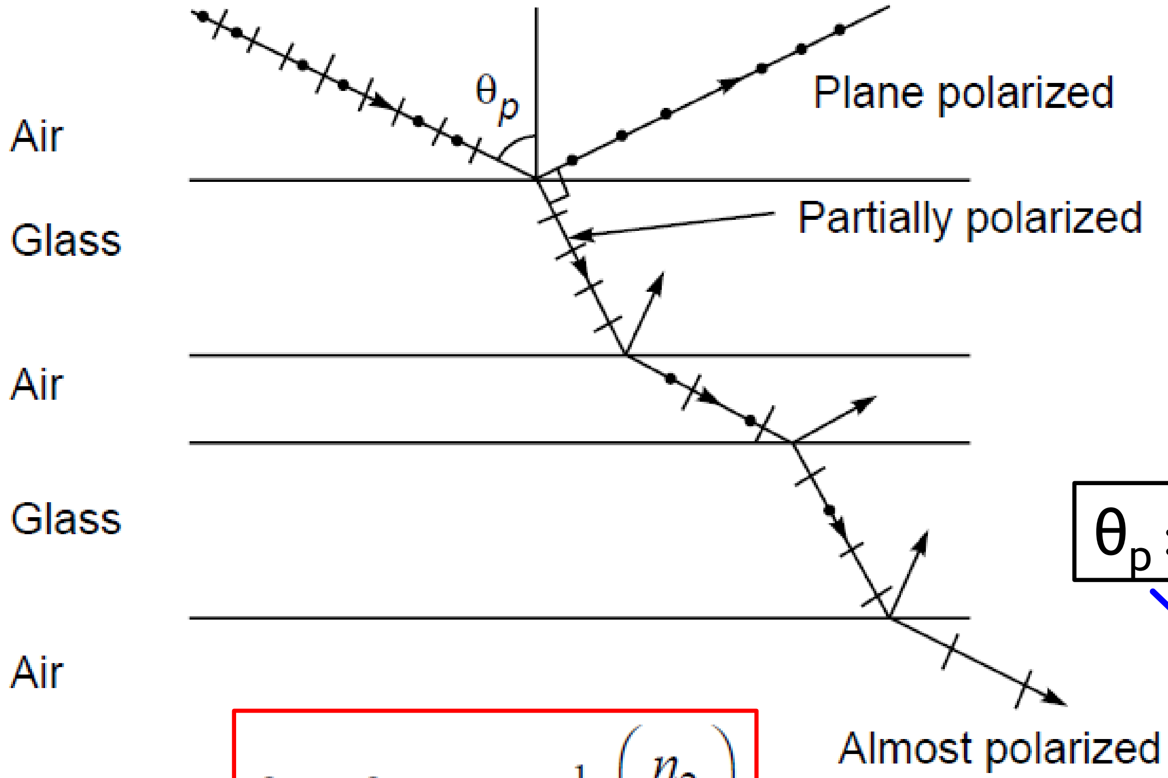
1. Air-glass interface. θ_p = ?
2. θ_p = 53° Air-__(?) interface?

Brewster's law



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polarizing angle or the ***Brewster angle***

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Brewster's law

For the air-glass interface, $n_1 = 1$ and $n_2 \approx 1.5$, giving $\theta_p \approx 57^0$.

For the air-water interface, $n_1 \approx 1$ and $n_2 \approx 1.33$ and the polarizing angle $\theta_p \approx 53°$.

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Thank You