Physics 1C Reading Quiz 2

1. The kinds of wave which can be polarized are

a) all waves ✗

(b) all transverse waves

(c) only electromagnetic waves

d) only visible light ✗

2. A beam of natural un-polarized light passes though an ideal polarizer. Ignoring losses due to reflection + absorption, the irradiance of the transmitted vs. incident beam is:

a) dependent on the angle of the polarizer

b) increased

(c) reduced

d) unchanged.

3. For two wave sources to be coherent, they must be

(a) in phase ("in step") with each other ✓

b) have the same amplitude ✗

c) be monochromatic ✗

d) All of the above ✗

(Hint: Coherent sources ⇒ a stable interference pattern)

4. Compared to the ideal human eye, a telescope produces a sharper image of (say) moon features because:

a) it collects more light

b) it magnifies the image

(c) it suffers less from diffraction

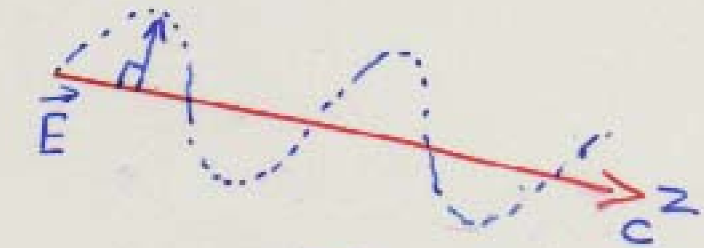
d) all of the above.

Physical Optics (Hecht ch. 25)

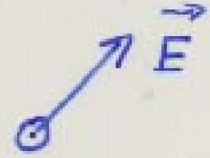
Polarization, Interference, Diffraction

Polarization:

For plane transverse EM wave, $\vec{E}$ ⊥ to motion:



Viewed end on:



$\vec{E}$ defines a plane of polarization in space as it oscillates. In general:

$$\vec{E} = \vec{E}_x + \vec{E}_y$$

If $\vec{E}$ has constant direction, the EM radiation is <u>linearly polarized</u>.

c.f. radio (vertical) and TV (horizontal) antennas.

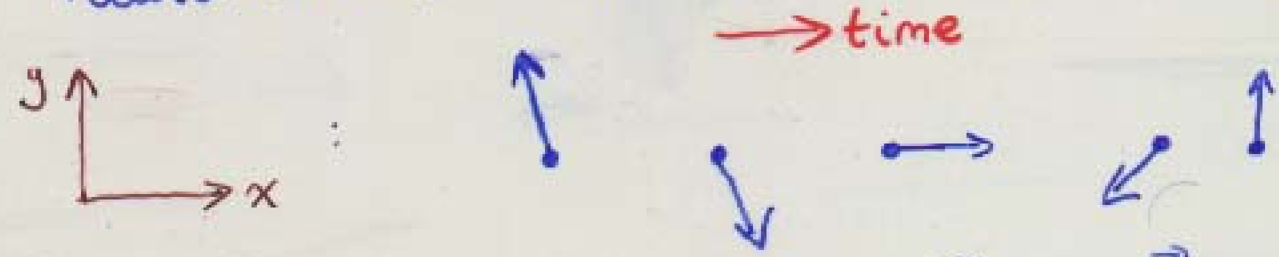
If $\vec{E}_x, \vec{E}_y$ are <u>out of phase</u>

$\Rightarrow$ <u>circular polarization</u> : $\vec{E}$ rotates

once per wavelength:

Unpolarized ("natural" light)

Viewed end on, $\vec{E}$ field direction changes randomly

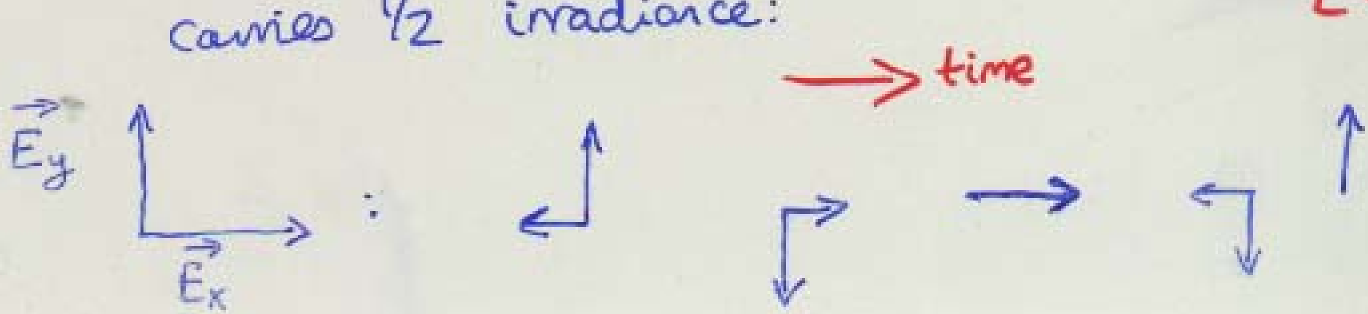


Can resolve $\vec{E}$ at any instant into $\vec{E}_x$ and $\vec{E}_y$ components

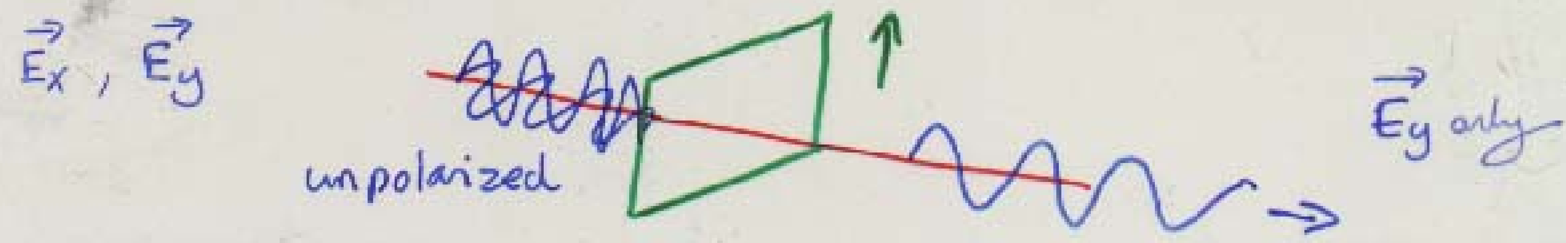
ie. $\vec{E}$ equivalent to two ⊥ polarized EM waves

varying randomly. On average, each wave

carries 1/2 irradiance: [W/m^2]



Polarizers allow only one plane of $\underset{\sim}{\vec{E}}$ to get through – they define a transmission axis:



Irradiance:

$I_0 = \frac{1}{2} c \varepsilon_0 E^2$

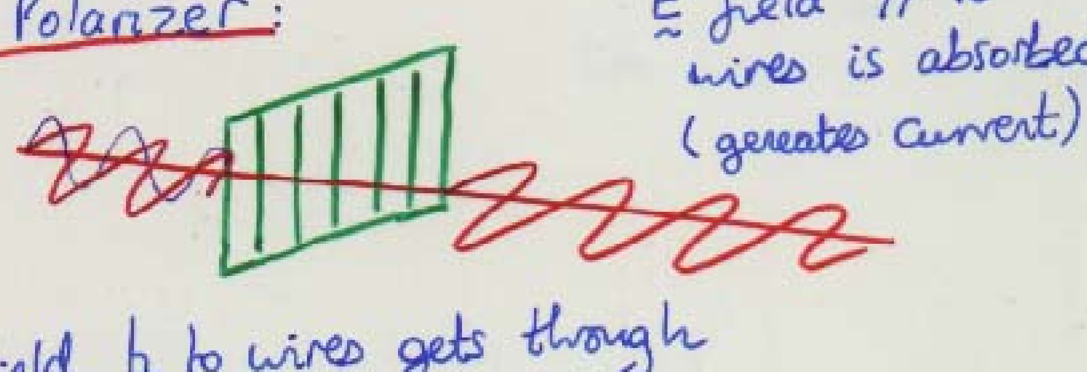
$= \frac{1}{2} c \varepsilon_0 (E_x^2 + E_y^2)$

$I_1 = \frac{1}{2} c \varepsilon_0 E_y^2$

Since irradiance shared between E_x, E_y,

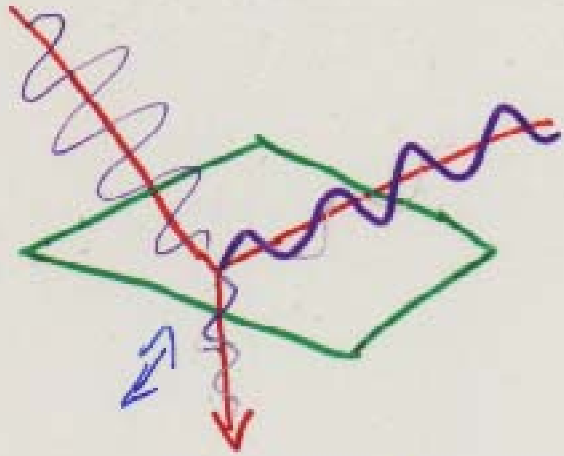
after polaizer : $I_1 = \frac{1}{2} c \varepsilon_0 E_y^2 = \frac{1}{2} I_0$

Wire Grid Polarizer:



Polaroid : Uses long-chain hydrocarbon molecules as conducting "wires"

Polarization by Reflection (Ch 25.3)



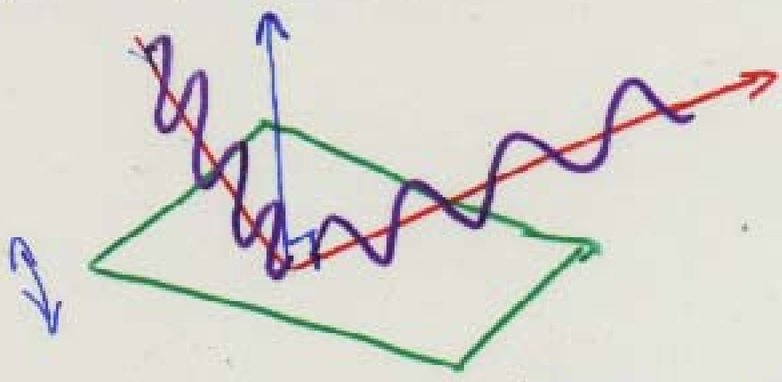
For plane-polarized beam incident on surface,

if polarization plane $\perp$ plane of reflection

⇒ molecules in surface driven to oscillate $\parallel$ to surface ("easy")

⇒ plane polarized beam in reflection.

BUT



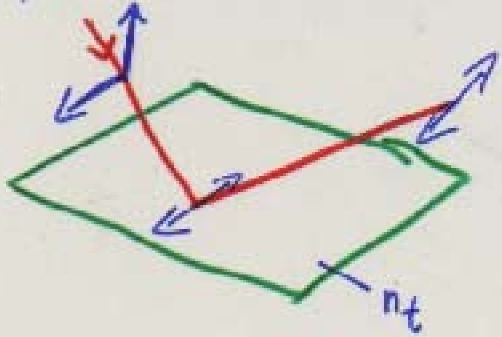
If polarization plane $\parallel$ reflection plane, molecules oscillate $\perp$ to surface ("difficult")

⇒ EM wave mostly absorbed.

Reflection contd:

So unpolarized beam incident on surface

$\Rightarrow$ partial polarized beam reflected



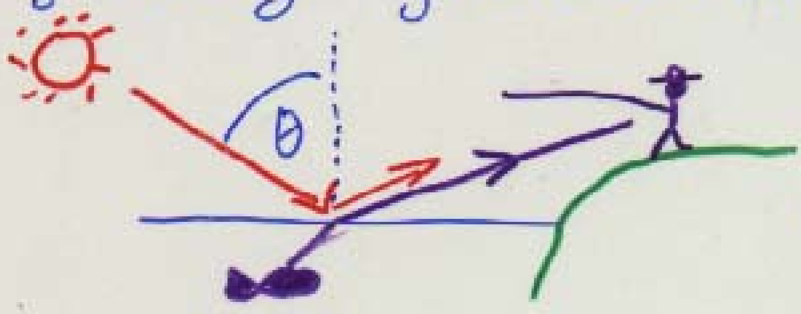
Polarization plane $\perp$ plane of incidence.

At the Brewster angle θ_p

$$\boxed{\tan\theta_p = \frac{n_t}{n_i}}$$, reflected beam is 100% polarized

Note: Polarized sunglasses should have vertical transmission axis; reduces "glare" from horizontal surfaces

(e.g. used by anglers to see into water).



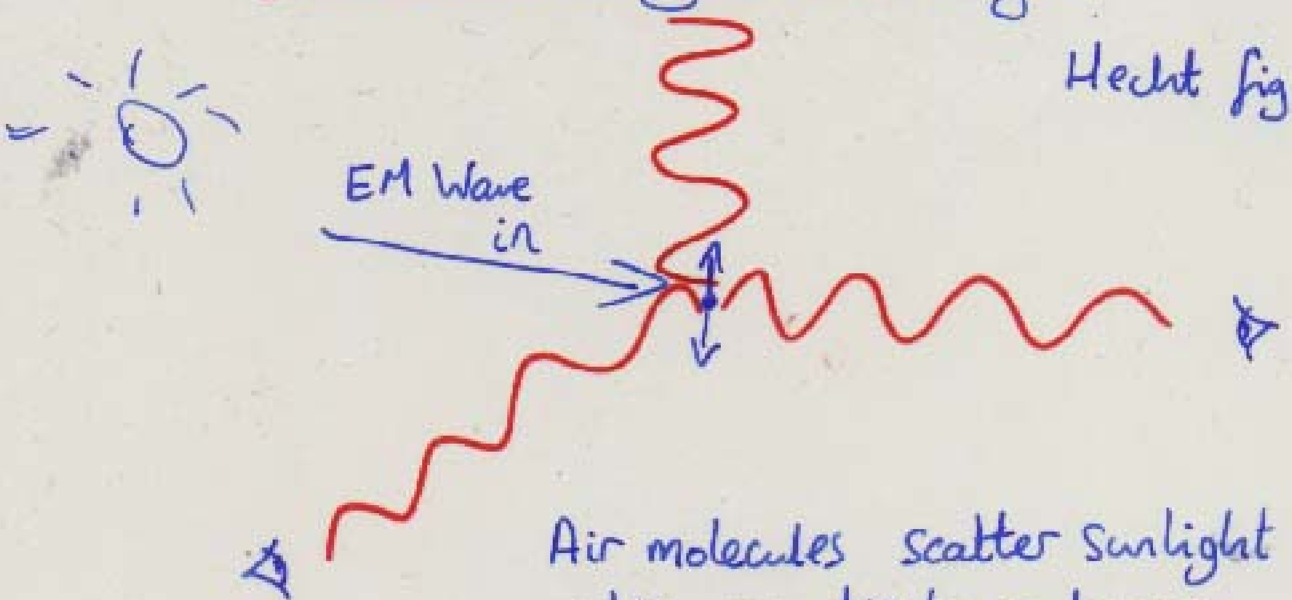
For water/air

$$\tan\theta_p = \frac{n_t}{n_i} = \frac{1.33}{1.0}$$

$\therefore \theta_p = 53.1°$

Polarization by Scattering

Hecht fig. 25.12

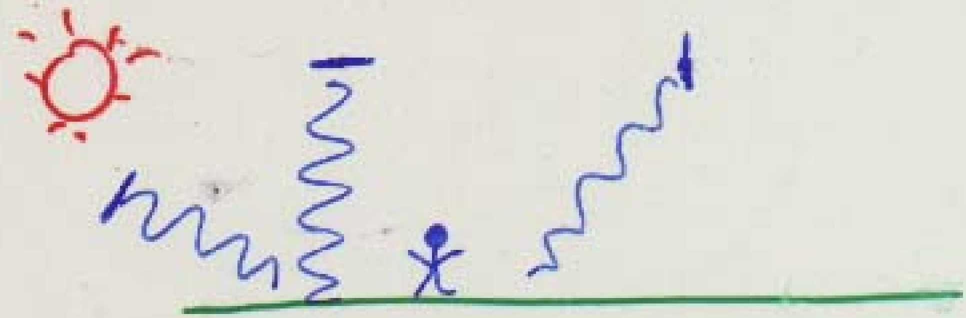


Air molecules scatter sunlight by acting as dipole antennas

- no scattered radiation along dipole axis

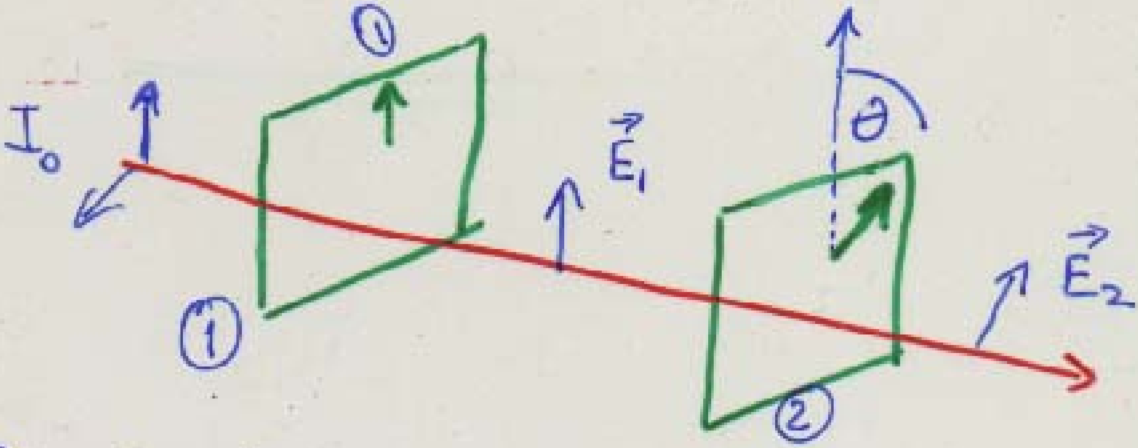
⇒ partial polarization of scattered beam.
plane of polarization ⊥ scattering plane

Blue light in daytime sky is partially polarized by Rayleigh scattering. Polarization plane depends on angle between line of sight and sun.



(used by pigeons for navigation)

Combining Polarizers - Malus' Law

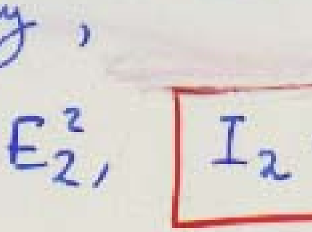


Take 2 polarizers with transmission axes misaligned at angle θ

Unpolarized light of irradiance I_0 incident on ①

$\Rightarrow$ new irradiance $I_1 = \frac{1}{2} I_0$, plane polarized beam. Take transmission axis of ② as the y axis:

$$\vec{E}_1 = \vec{E}_x + \vec{E}_y$$



with $\vec{E}_x$ absorbed,

$\Rightarrow \vec{E}_2 = \vec{E}_y$ only, with $E_y = E_1 \cos\theta$

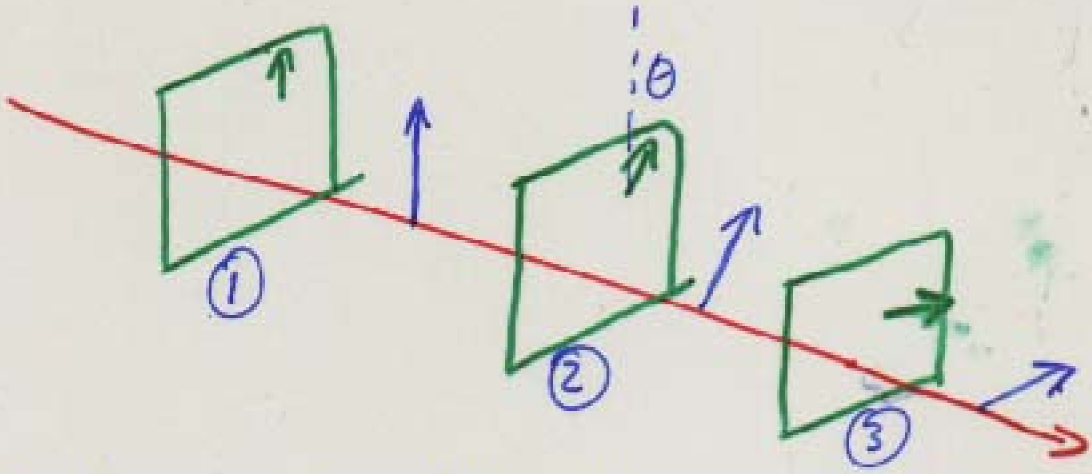
So since $I_2 \propto E_2^2$,

$$I_2 = I_1 \cos^2\theta \text{ : Malus' Law}$$

$\Rightarrow$ convenient way to vary irradiance of source without changing its color.

3 Polarizers, first and last at 90°

(Hecht ex. 25.2)



Can use 3 polarizers to rotate plane by 90°

$I_2 = I_1 \cos^2\theta$, transmitted at θ to the vertical.

After polarizer (3), $I_3 = I_2 \cos^2(90° - \theta)$

i.e. $I_3 \neq 0$ if $\theta \neq 0$.

e.g. if $I_0 = 800\ W/m^2$, $\theta = 30°$

After (1) : $I_1 = \frac{1}{2} I_0 = 400\ W/m^2$

After (2) : $I_2 = I_1 \cos^2 30° = \left(\frac{\sqrt{3}}{2}\right)^2 I_1 = \frac{3}{4} I_1 = \frac{3}{8} I_0$

After (3) : $I_3 = I_2 \cos^2 60° = \left(\frac{1}{2}\right)^2 I_2 = \frac{1}{4} I_2 = \frac{3}{16} I_0$

$\Rightarrow I_1 = 400\ W/m^2$, $I_2 = 300\ W/m^2$, $I_3 = 75\ W/m^2$