WEL01 POLARIZATION OF LIGHT

SPH4U

CH 10 (KEY IDEAS)

- describe polarized light in terms of its properties and behaviour and how it is applied in everyday applications
- explain single-slit diffraction and diffraction grating interference patterns, both qualitatively and quantitatively
- explain the operation of the spectroscope and the interferometer in terms of the wave properties of light
- describe how the wave properties of light are important in resolution of optical instruments and how these properties are applied in various applications of thin-film interference, for example: Newton’s rings, colours in thin films, coated surfaces, CDs, and DVDs
- explain the basic concepts holography
- describe electromagnetic waves in terms of their properties and where they belong in the electromagnetic spectrum

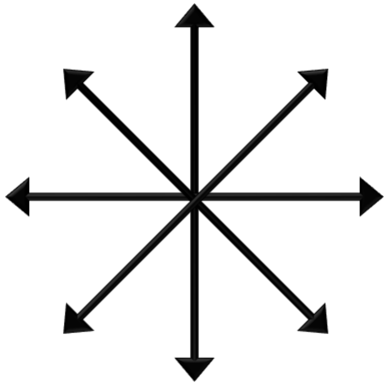
EQUATIONS

- Malus' Law

$$I = I_0 \cos^2 \theta$$

POLARIZATION OF LIGHT

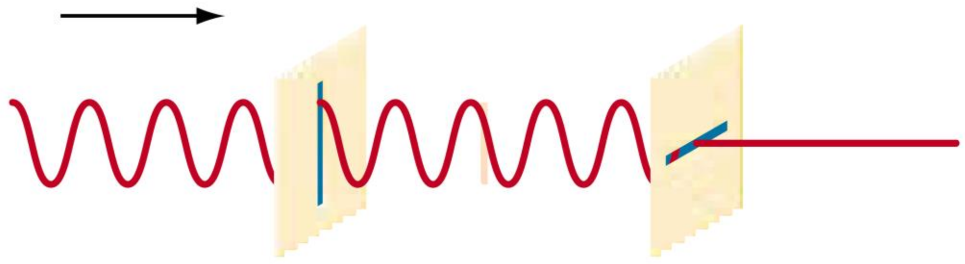
- Light emitted from a source usually travels in all directions
- Oscillations also occur in all different orientations
- We draw a beam of light as a set of double-headed arrows to indicate the multiple directionality



- When a wave is oscillating in one plane, we draw only one arrow 

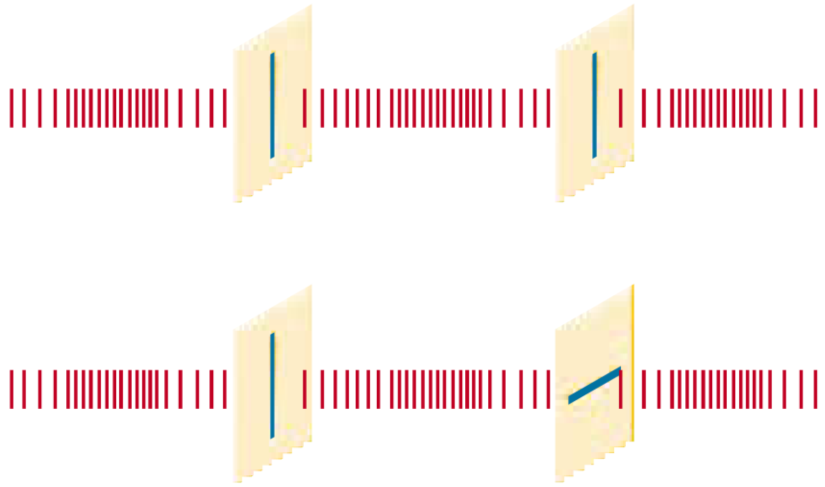
POLARIZING WAVES

- Most light that is emitted from a source is unpolarized
  - **Unpolarized:** a wave that vibrates in all directions perpendicular to the direction of travel
- By passing through a polarizer, waves (including light) moving perpendicular to the polarizer will be blocked, while those moving parallel will pass through
  - **Polarizer:** a natural (e.g., clouds) or artificial (e.g., filters) means to achieve polarization
  - **Polarization:** confining the vibrations of a wave to one direction



POLARIZING WAVES – CONT.

- Once a wave has passed through a polarizer, it is plane-polarized
  - **Plane-Polarized:** a wave that can vibrate in one plane only
- NOTE: polarization only occurs with transverse waves
  - Longitudinal waves are unaffected by polarizers

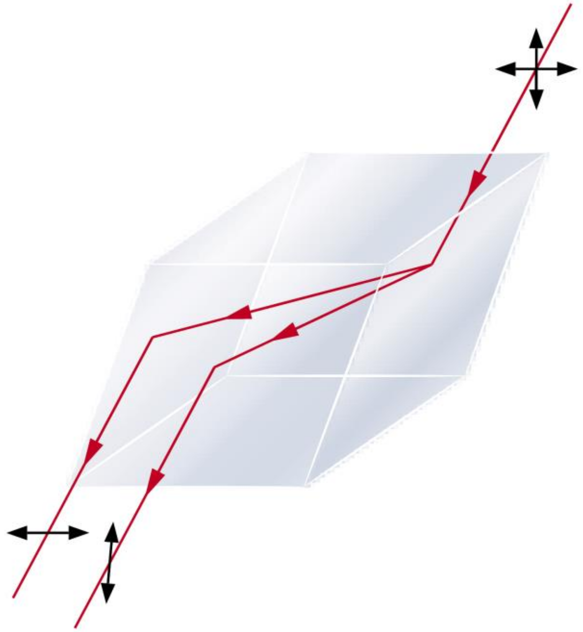


METHODS OF POLARIZATION

- Polarization can occur four ways
  1. Double refraction
  2. Reflection
  3. Scattering
  4. Polarizing Filter

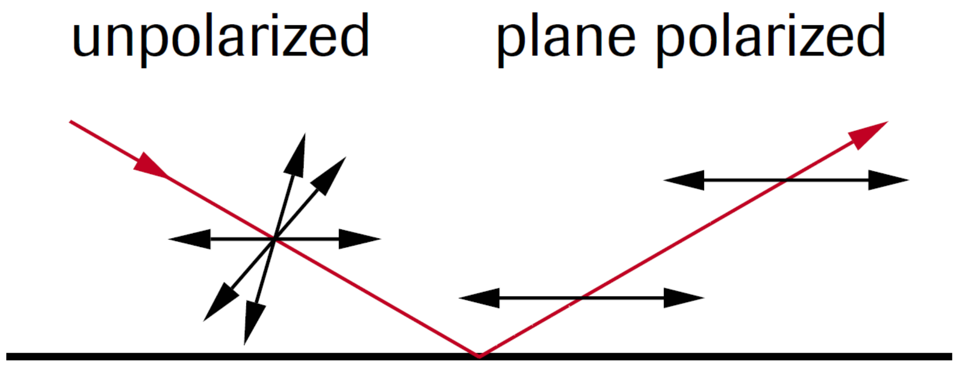
DOUBLE REFRACTION

- **Double Refraction:** the property of certain crystals to split an incident beam of light into two
- **Monochromatic:** of one colour, or one wavelength
- Certain crystals have planes within their structure, which influence how light travels through them
- When a beam of <u>monochromatic</u> light travels through calcite it goes through <u>double refraction</u>
  - One orientation of light refracts in the straightforward manner with an index of 1.66
  - The other refracts with an index between 1.49 and 1.66, depending on the angle of incidence



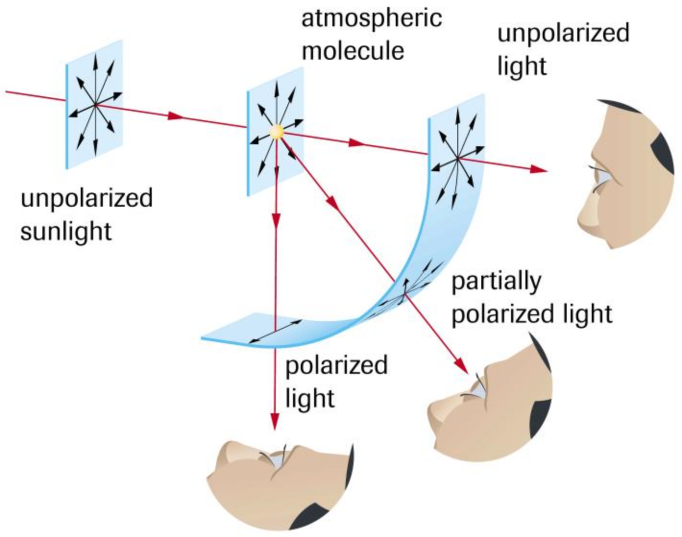
REFLECTION

- Light that is incident on a surface can undergo partial polarization
- Some of the light is absorbed by the surface while the rest is reflected
- Reflected light is polarized parallel to the reflecting surface
- Sunglasses with vertical polarization can help decrease the glare from reflecting light



SCATTERING

- **Scattering:** the change in direction of particles or waves as a result of collisions with particles
- When light comes into our atmosphere from the Sun, it collides with the gas particles and is scattered across the sky
  - Shorter wavelengths (blue and violet) scatter more than larger wavelengths (red and orange) – this is why the sky is blue!
- Scattering causes light to be polarized, with greatest polarization perpendicular to the direction of propagation

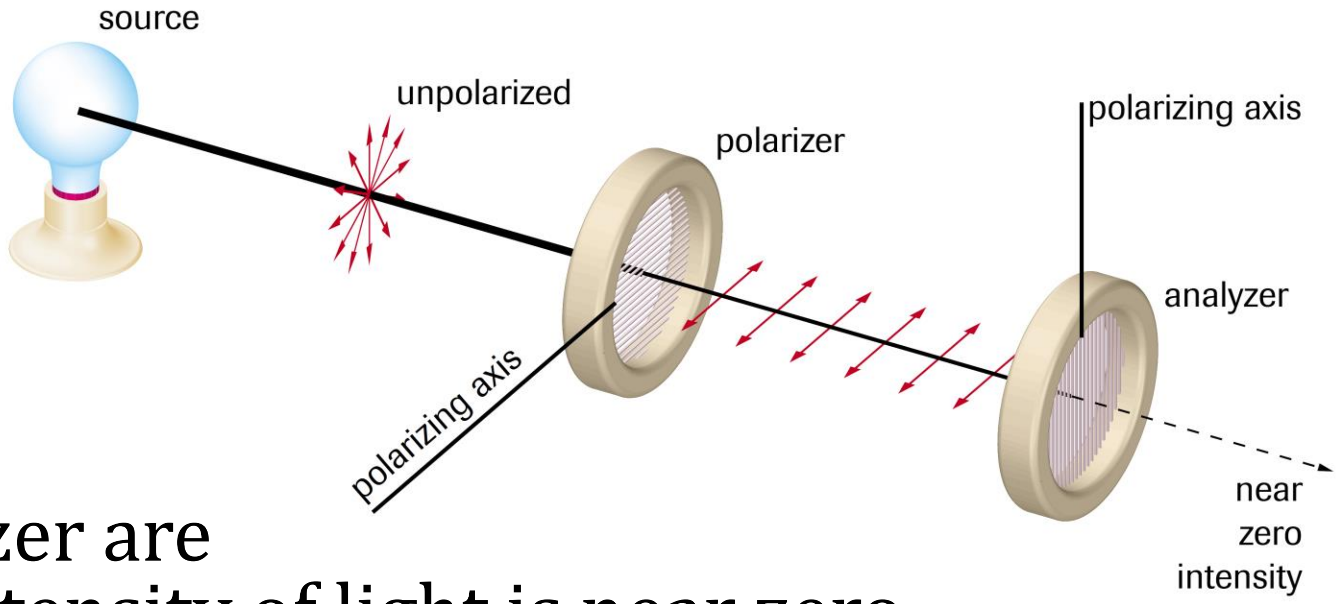


PICTURES TAKEN WITHOUT AND WITH POLARIZING FILTERS

(a) (b)

POLARIZING FILTERS

- A polarizer only allows light through that is parallel to the polarizing axis, causing the remaining light to be plane polarized
- A second polarizer, called the analyzer, can be at different orientations to the polarizer
- If the polarizer and analyzer are perpendicular, the final intensity of light is near zero



MALUS' LAW

- When light is incident on a polarizer, the intensity of the light is reduced
- The intensity of a wave is directly proportional to the square of its amplitude

$$I \propto A^2$$

- Let's call E the vibrational distance of the electromagnetic field of a light ray

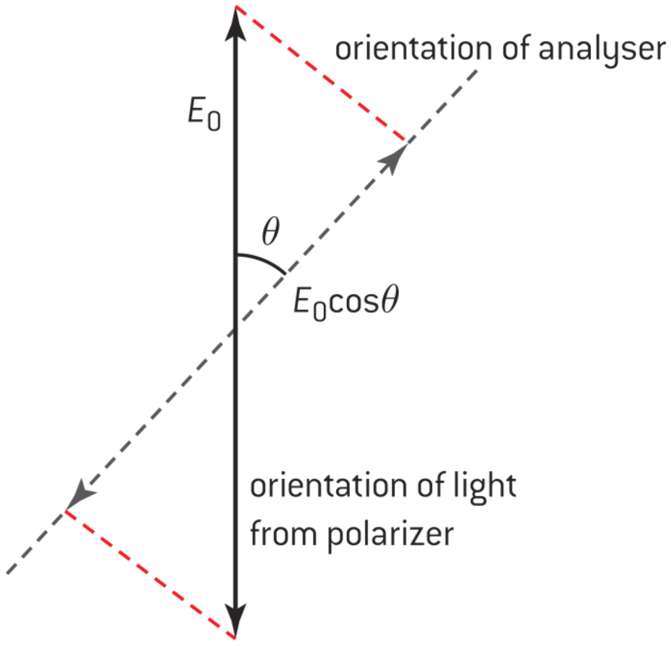
$$E = 2A$$
$$I \propto E^2$$

MALUS' LAW – CONT.

- When polarized light is incident on a polarizer (or analyzer), only the component of light that is parallel to the polarizing axis will get through

$$E = E_0 \cos\theta$$

  - E – final electric field vibrational distance
  - E_0 – initial electric field vibrational distance
  - θ – angle between incident light and polarizer



MALUS' LAW – CONT.

- Since $I \propto E^2$, we can write, for some constant k, that

$$I = kE^2$$

- Since $E = E_0 \cos\theta$

$$I = kE^2$$

$$I = k(E_0 \cos\theta)^2$$

$$I = \left(kE_0^2\right) \cos^2\theta$$

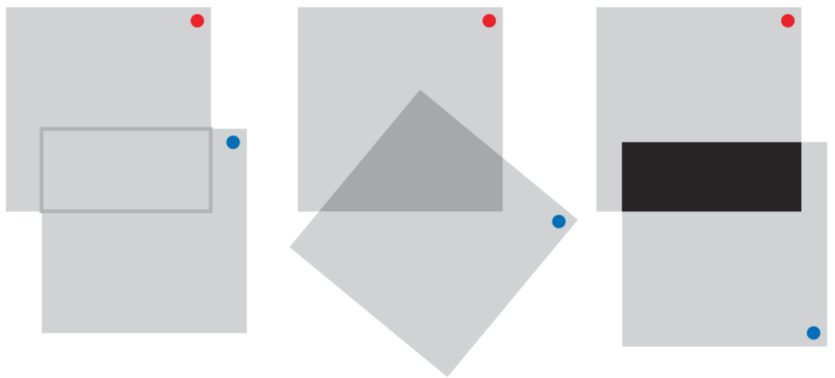
$$I = I_0 \cos^2\theta$$

MALUS' LAW – CONT.

- **Malus' Law:** when totally plane-polarized light (from a polarizer) is incident on an analyzer, the intensity I of the light transmitted by the analyzer is directly proportional to the square of the cosine of angle between the transmission axes of the analyzer and the polarizer.

$$\boldsymbol{I = I_0 \cos^2 \theta}$$

  - I – intensity of transmitted light
  - I_0 – intensity of incident light
  - θ – the angle between the plane-polarized light and the analyzer

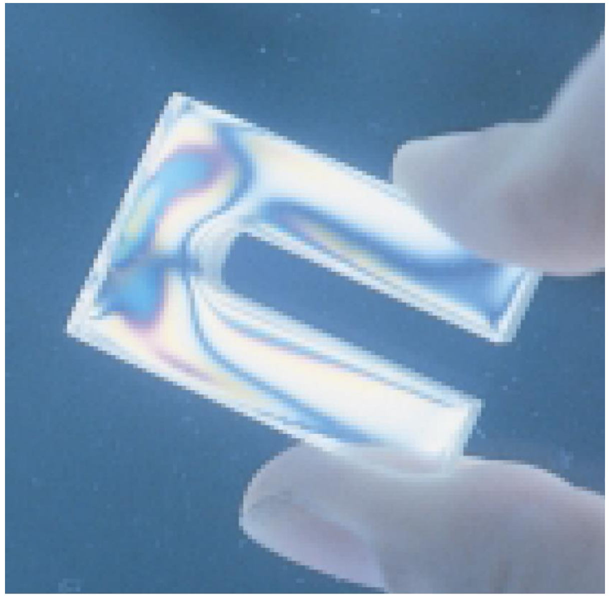


POLAROIDS

- **Polaroid:** a plastic, light-polarizing material
- The invention of the polaroid made it possible to apply this concept into new technologies
- It could also be used to determine polarization of light in nature

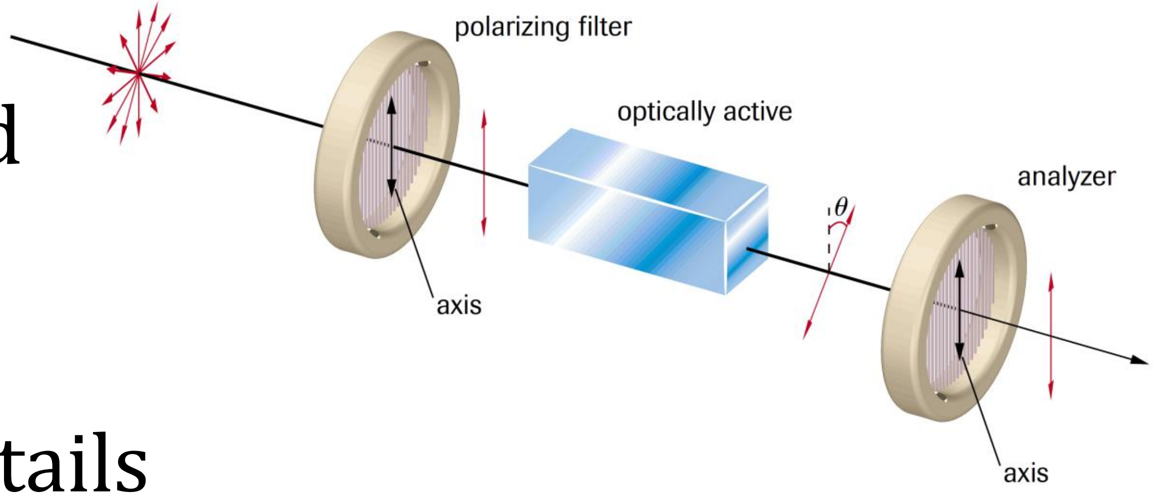
PHOTOELASTICITY

- **Photoelasticity:** the property of a material that, when analyzed, reveals the material's stress distributions
- Materials that are doubly refractive under stress can be analyzed using polarizing filters
- This is especially useful to determine stress points for a material used in infrastructure



OPTICAL ACTIVITY

- **Optical Activity:** property of a substance whereby a transparent material rotates the plane of polarization of transmitted light
- Since the degree to which the plane of polarization is rotated depends on the type and concentration of a substance, a polarizer and analyzer can be used to determine these details



SUMMARY – POLARIZATION OF LIGHT

- Polarization of light can be achieved in the following ways: double refraction, reflection, scattering, and a polarizing filter.
- Polarization provided the proof that light is a transverse wave.
- Polaroid can be used to detect the presence of polarized light and the orientation of the plane of polarization.
- Scattering occurs when light from the Sun passes through our atmosphere and encounters small particles that scatter the light.
- Polarizing filters have many uses, including glare reduction, stress analysis, and photography.
- The optical activity of certain materials can be used to help identify some substances.

PRACTICE

Readings

- Section 10.1 (pg 494)

Questions

- pg 498 #1-3