TOPICS

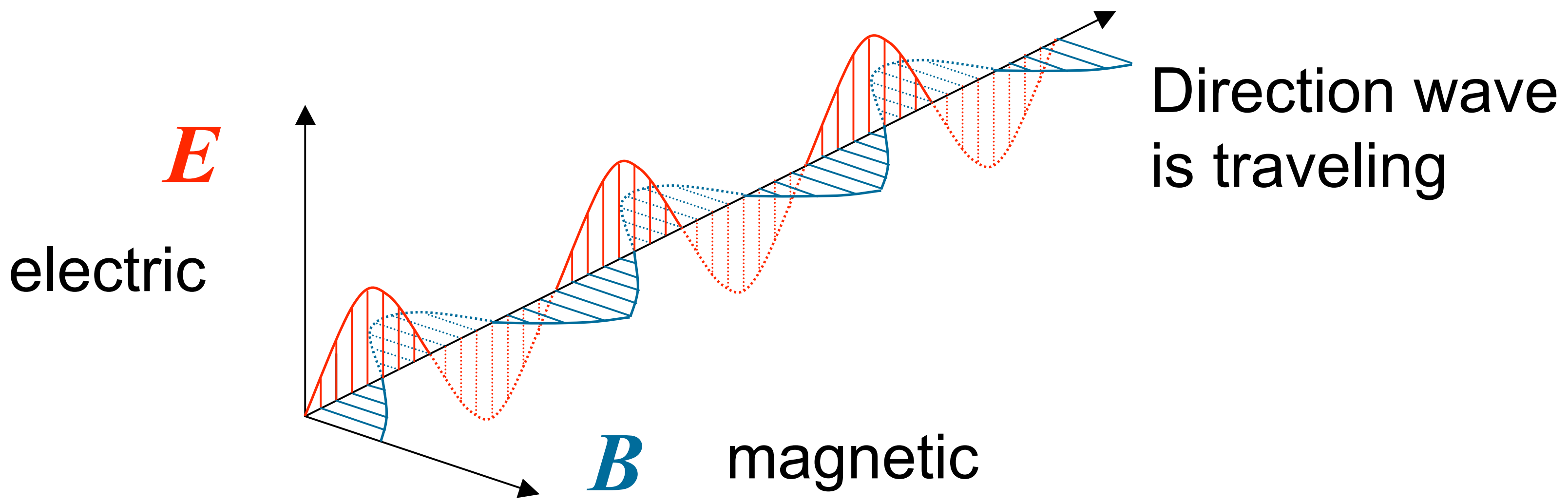
- Recap of PHYS110 *- 1 lecture*
- **Physical Optics** *- 4 lectures*
  - EM spectrum and colour
  - Light sources
  - Interference and diffraction
  - **Polarisation**
- Lens Aberrations *- 3 lectures*
  - Spherical aberrations
  - Coma, astigmatism, field curvature, distortion
  - Chromatic aberrations
- Instrumental Optics *- 4 lectures*
  - Telescope, microscope
  - Stops, eyepieces
  - Instruments for the anterior eye
  - Instruments for the posterior eye

Lecture 5: polarisation

- EM waves
- Polarising filters
- Polarisation in the air
- Polarisation by reflection
- Polarising sunglasses
- Randot/Titmus test

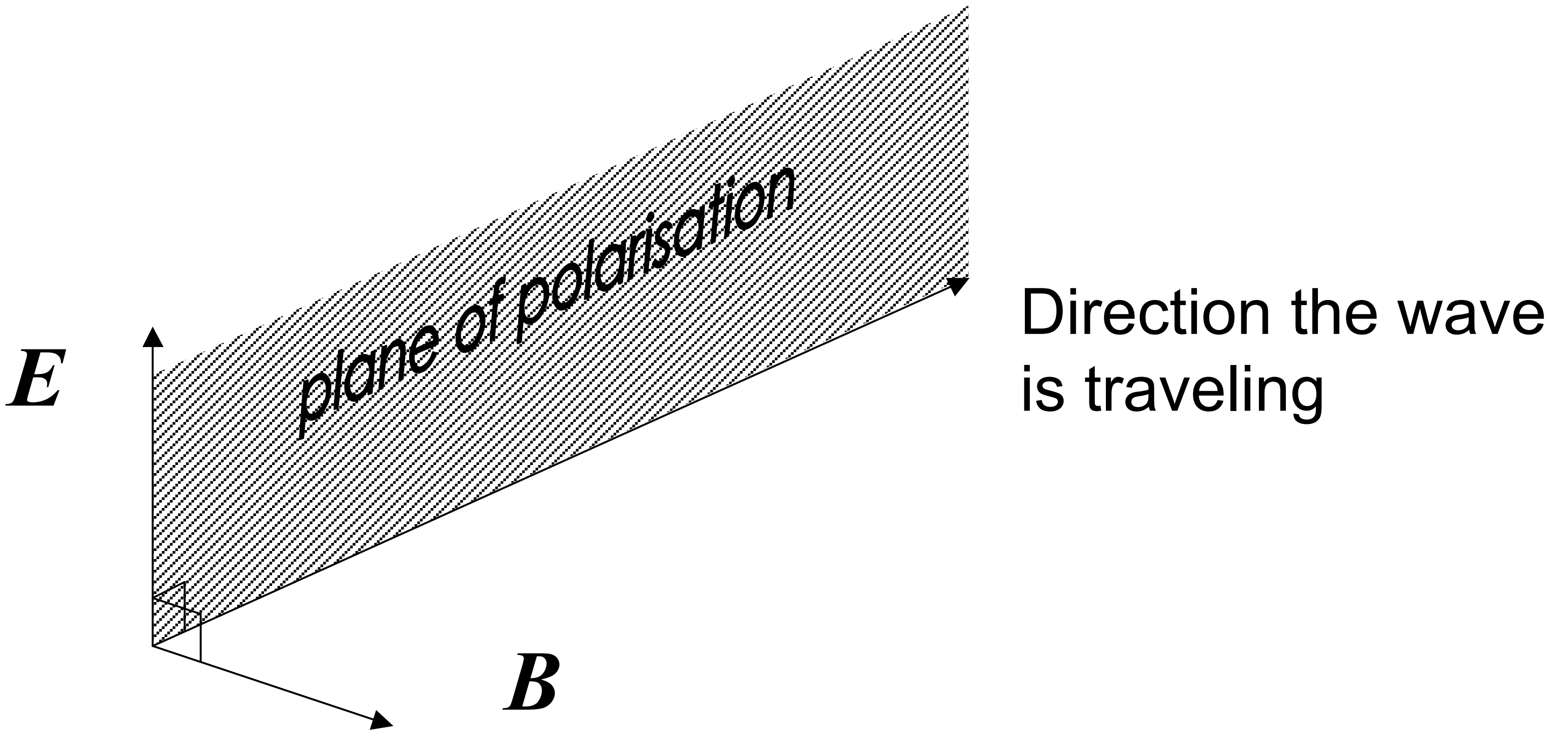
EM waves

- Light is a **transverse** wave - like waves on a string, or ripples on the surface of water
- The associated electric and magnetic fields, ***E*** and ***B*** are at right angles to the direction the wave is travelling and to each other



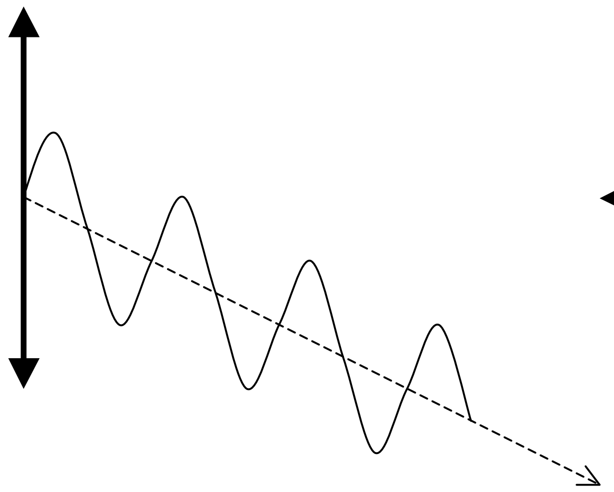
Plane of polarisation

- The plane of polarisation is the plane containing the electric field ***E*** and the direction of the wave



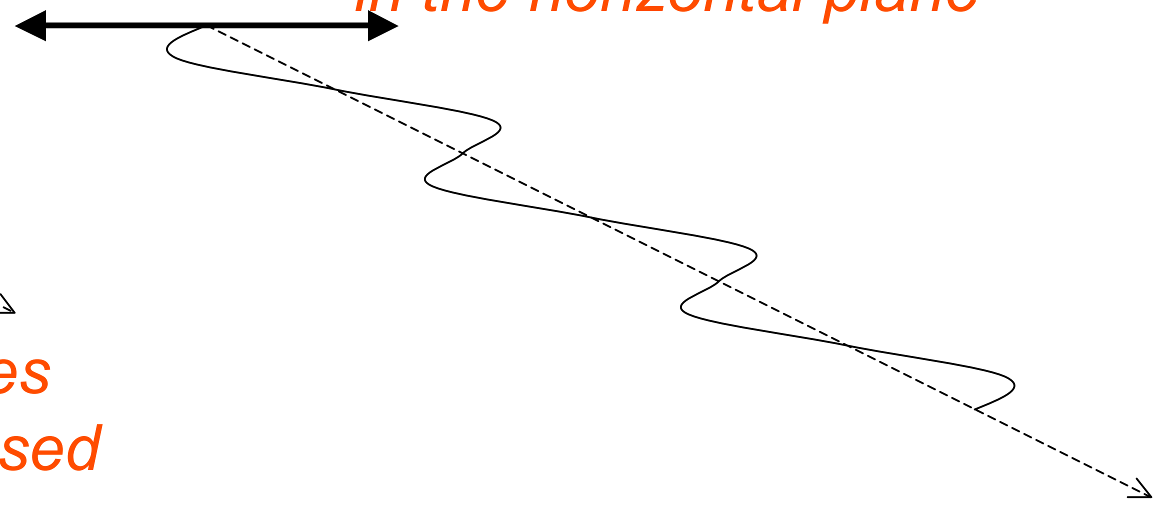
Production of radio waves

- Radio waves are produced by electric currents in an aerial
- The waves are polarised in the same direction as the aerial.



A vertical aerial makes waves that are polarised in the vertical plane

A horizontal aerial makes waves that are polarised in the horizontal plane



Light waves

- Light waves are produced by electric currents within atoms
- In most light sources, atoms are oriented randomly and the produced light is unpolarised

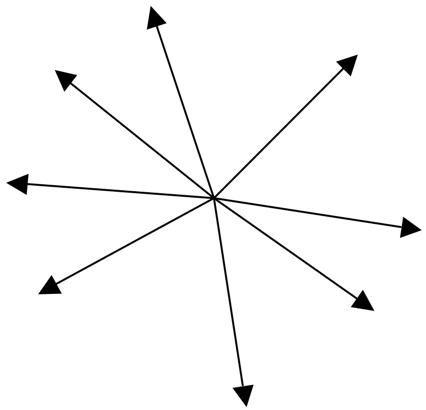
Polarised vs unpolarised

- Observed along the direction the wave is travelling,

A polarised wave looks like this:

E has a definite direction and oscillates up and down

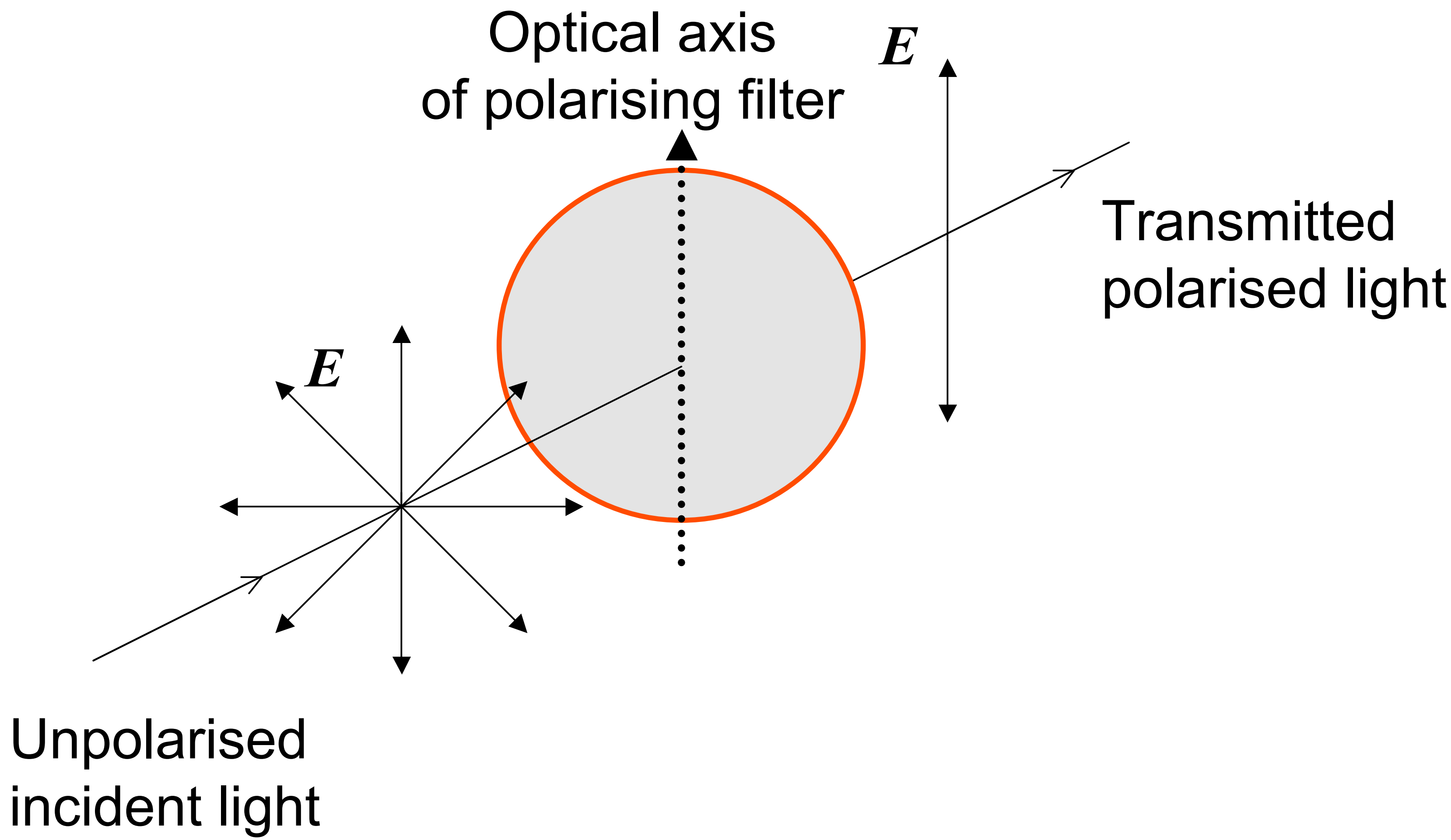
An unpolarised wave looks like this:



Direction of ***E*** changes randomly with time

Production of polarized light

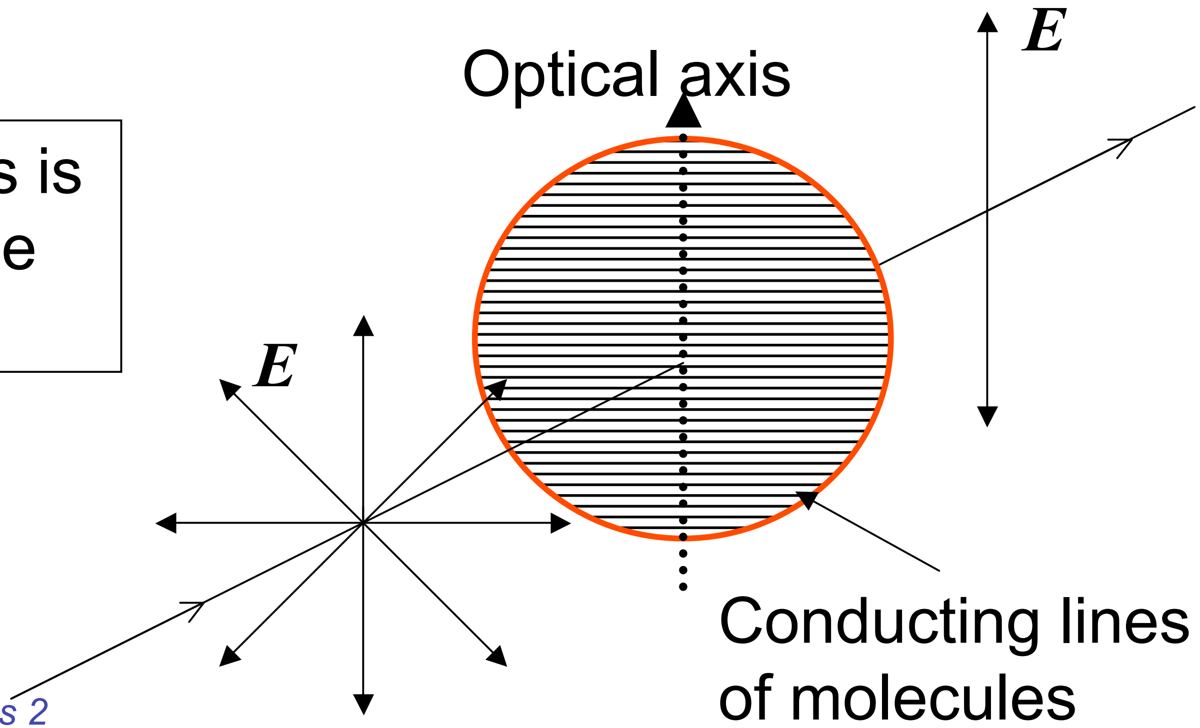
- This is most easily done by placing a polarising filter in front of an unpolarised light source



Polarising filters

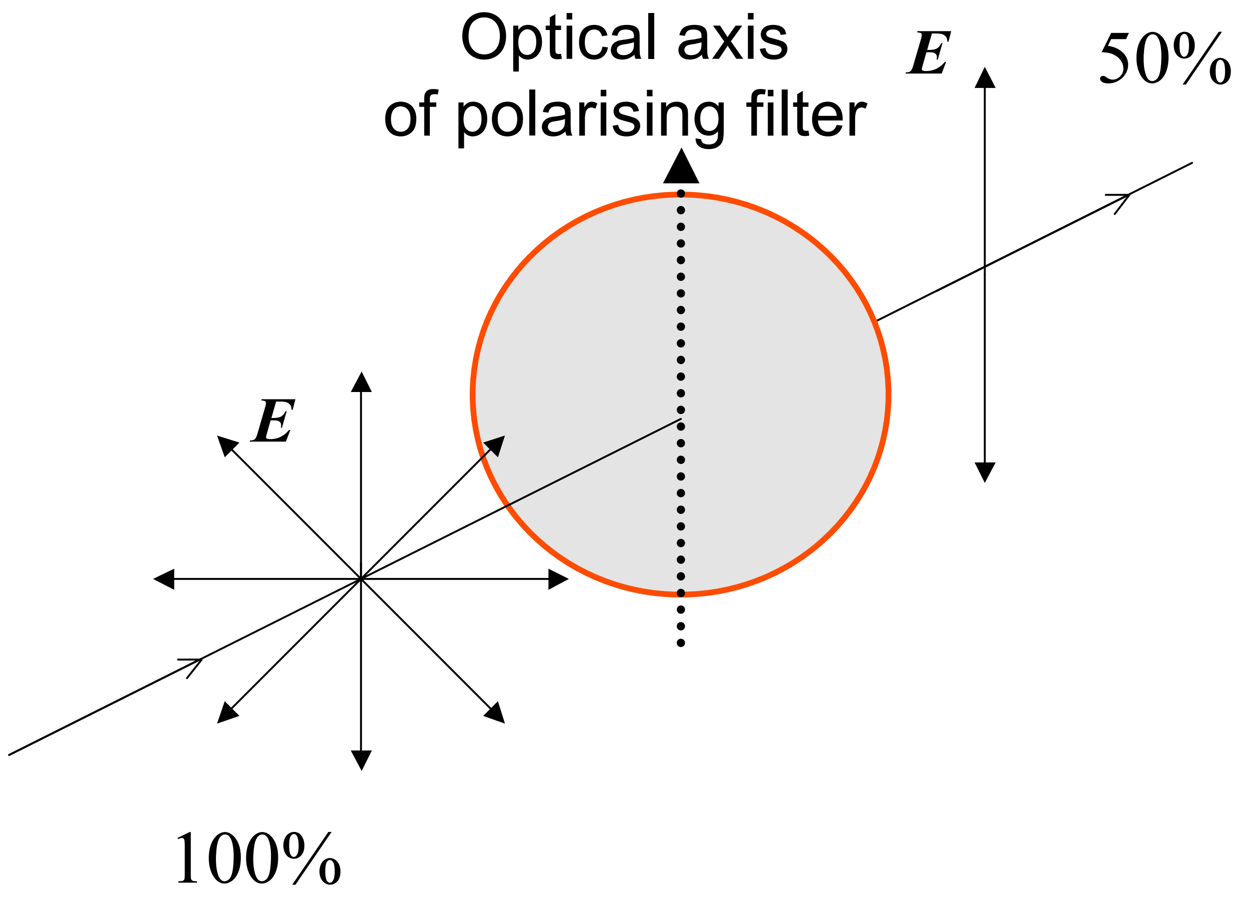
- A polarising filter has conducting lines of molecules
- Electric fields along these lines generate electric currents and are absorbed
- Only the component perpendicular to the conducting lines is transmitted

NB: the optical axis is perpendicular to the conducting lines!



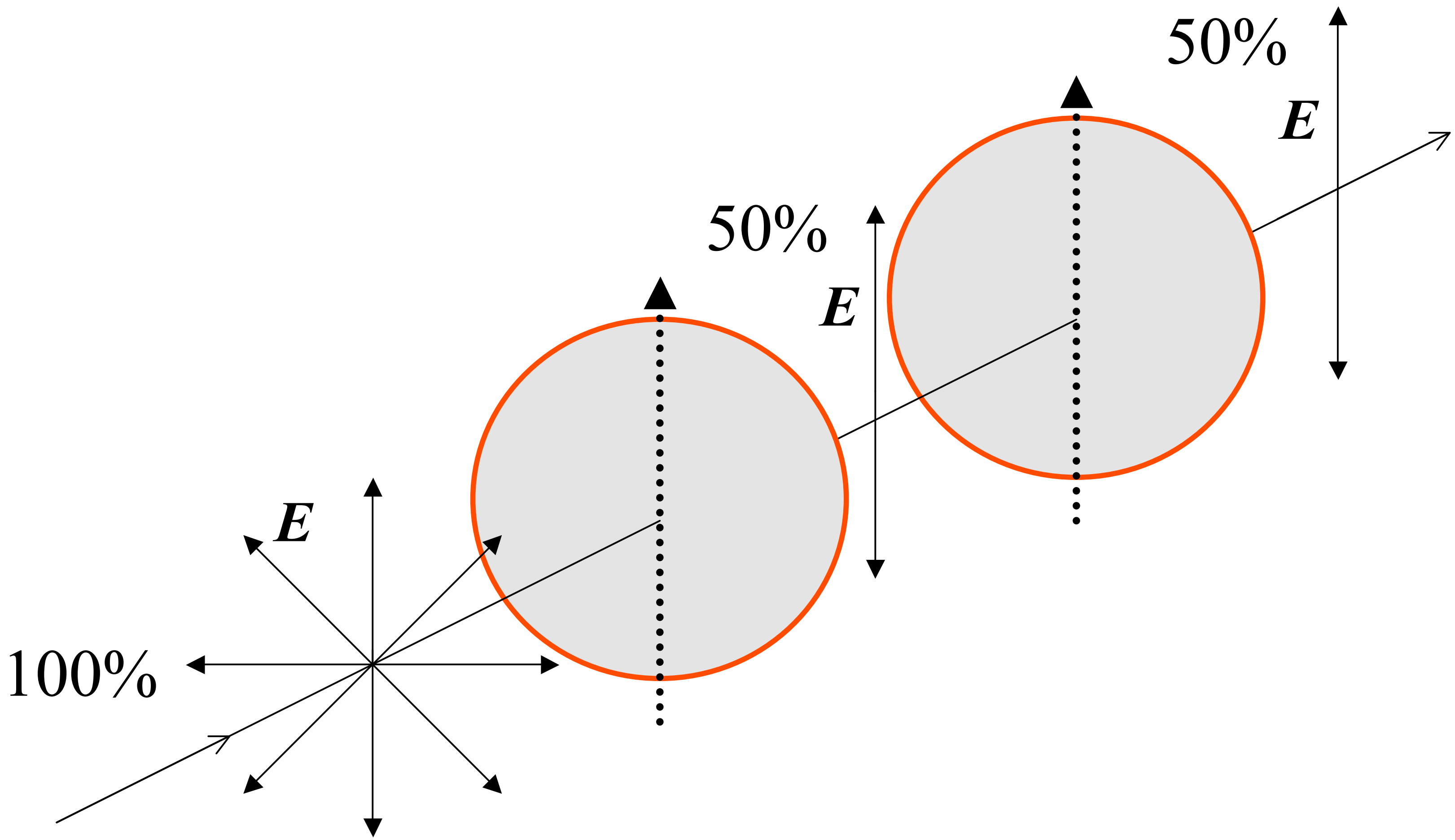
Transmitted intensity

- A polarising filter absorbs **half** the intensity of unpolarised light



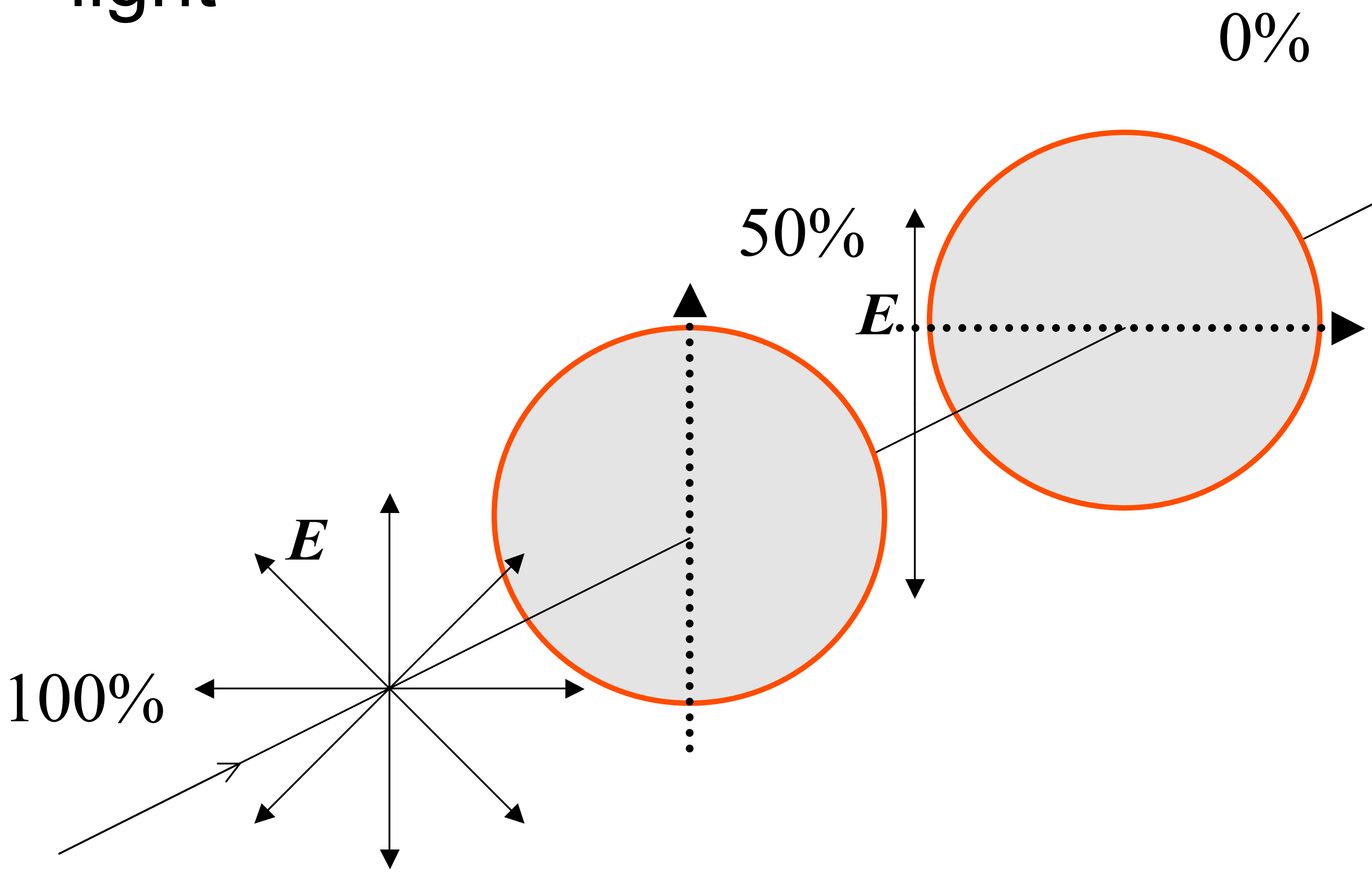
Combining polarising filters

- A second polarising filter with the same optical axis as the first does not absorb additional light



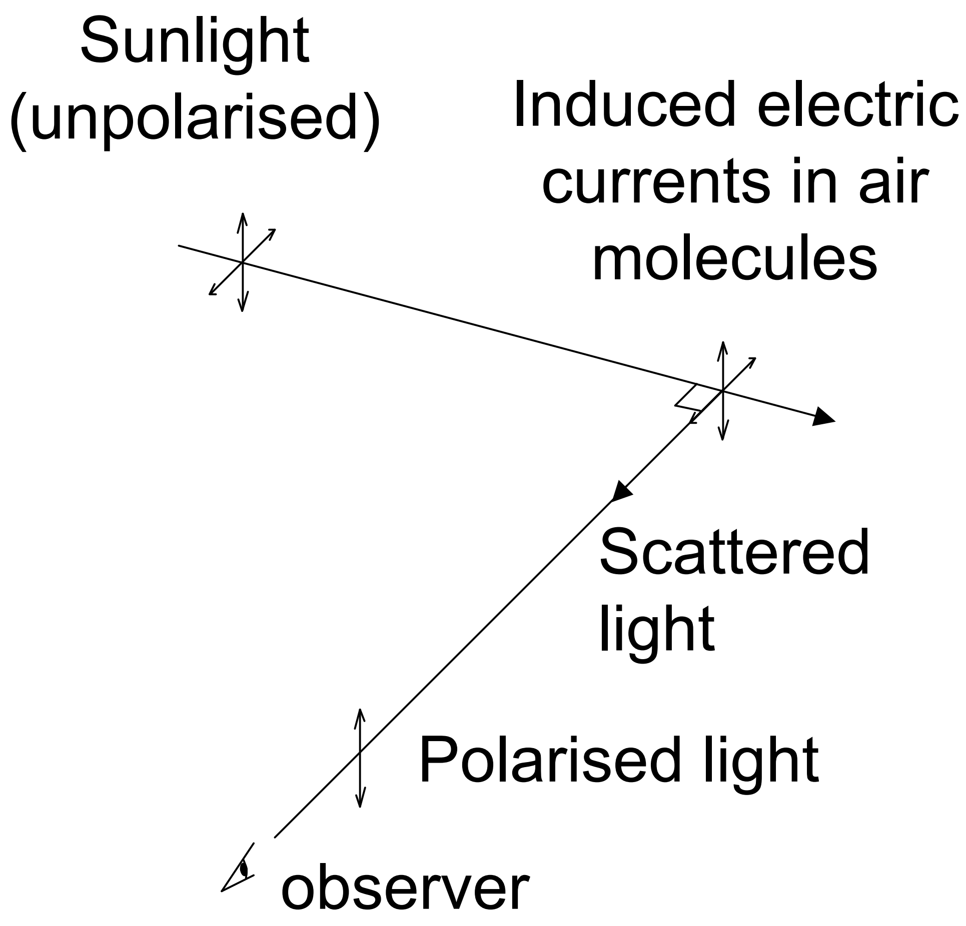
Combining polarising filters

- A second polarising filter with an optical axis perpendicular to the first absorbs all remaining light



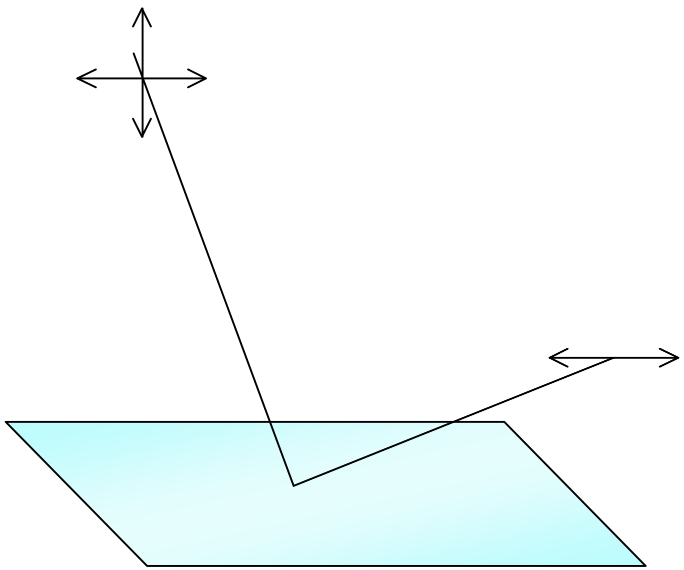
Polarisation by scattering in air

- Sunlight induces electric current oscillations in air molecules
- The scattered light at right angles to the incident light direction is polarised because oscillations along the observation direction cannot produce transverse scattered light



Polarisation by reflection

- Light reflected off non-metallic surfaces (e.g. water, glass) is partly polarised with ***E*** parallel to the surface

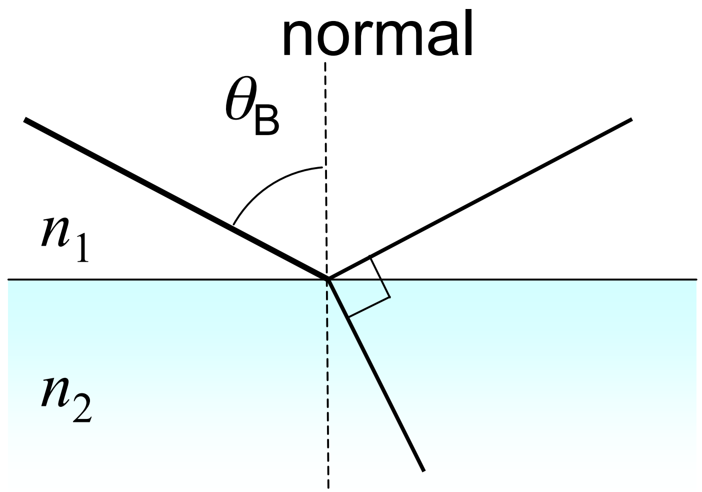


Brewster angle

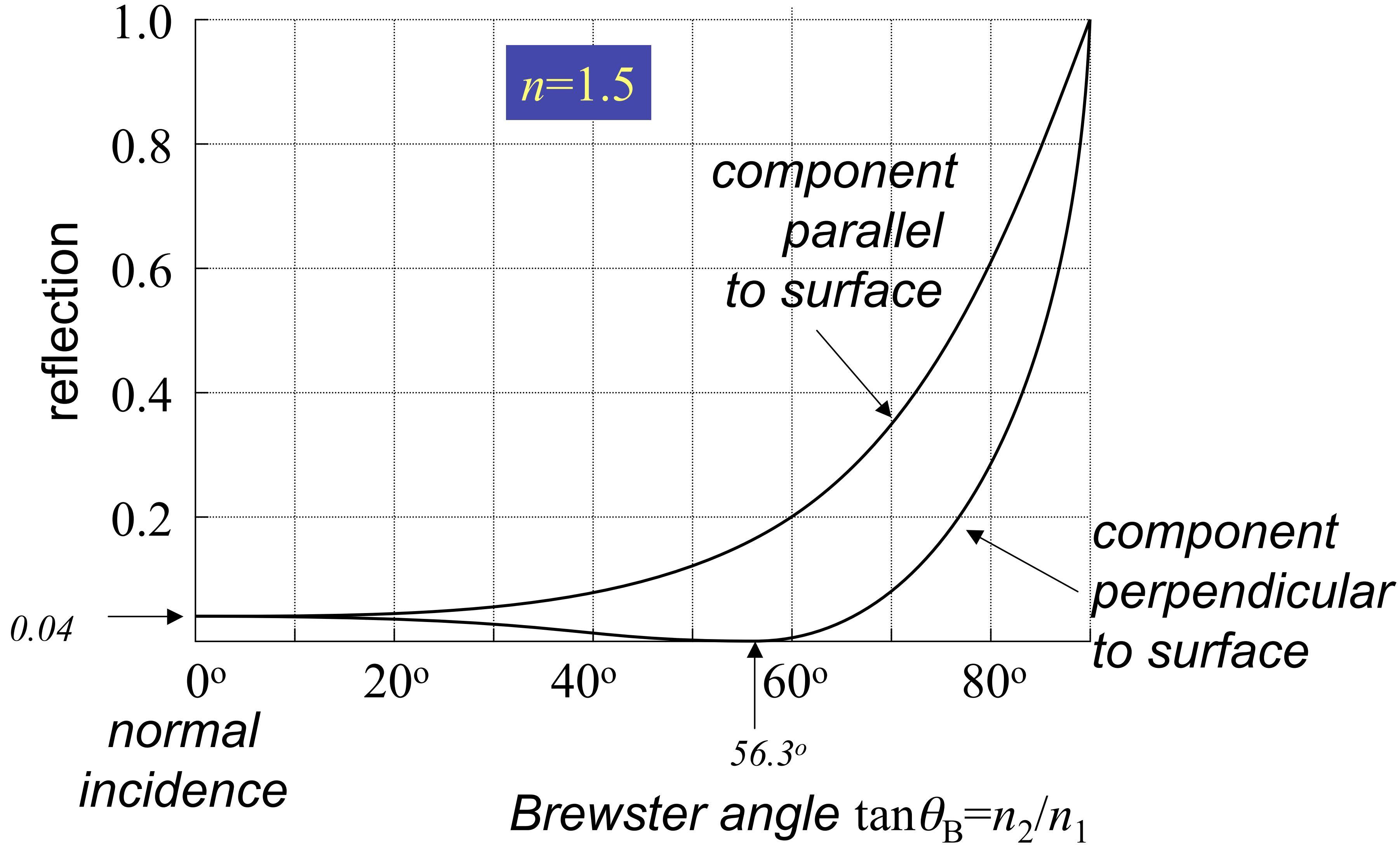
- The amount of polarisation depends on the incidence angle
- At the Brewster angle of incidence the reflection is fully polarised
- At the Brewster angle of incidence, the reflected and refracted light are at right angles
- The Brewster angle is calculated as $\tan\theta_B = n_2/n_1$

for air, $n_1=1.0$:

n_2	θ_B
1.3	52°
1.4	54°
1.5	56°



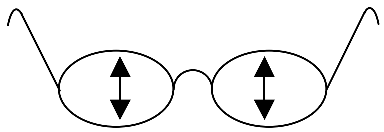
Reflection off non-metallic surfaces



$$R = \left(\frac{n_2 - n_1}{n_2 + n_1}\right)^2 = \left(\frac{0.5}{2.5}\right)^2 = 0.04$$

Polarising sun-glasses

- Some sunglasses are made with a polarising filter
- The optical axis is vertical



- This reduces the reflection from horizontal surfaces (e.g. water on the road)

Randot and Titmus tests

- The left and right eye see slightly different images: close objects are displaced more between the left and right eye than far objects. This allows depth perception.
- One way to simulate this is overlaying two images with different polarisations and watching them through polarizing glasses
- If the optical axis differs by 90^o between the two filters, the left eye sees a different image than the right eye
- This is used to test stereoscopic vision in the Randot and Titmus tests