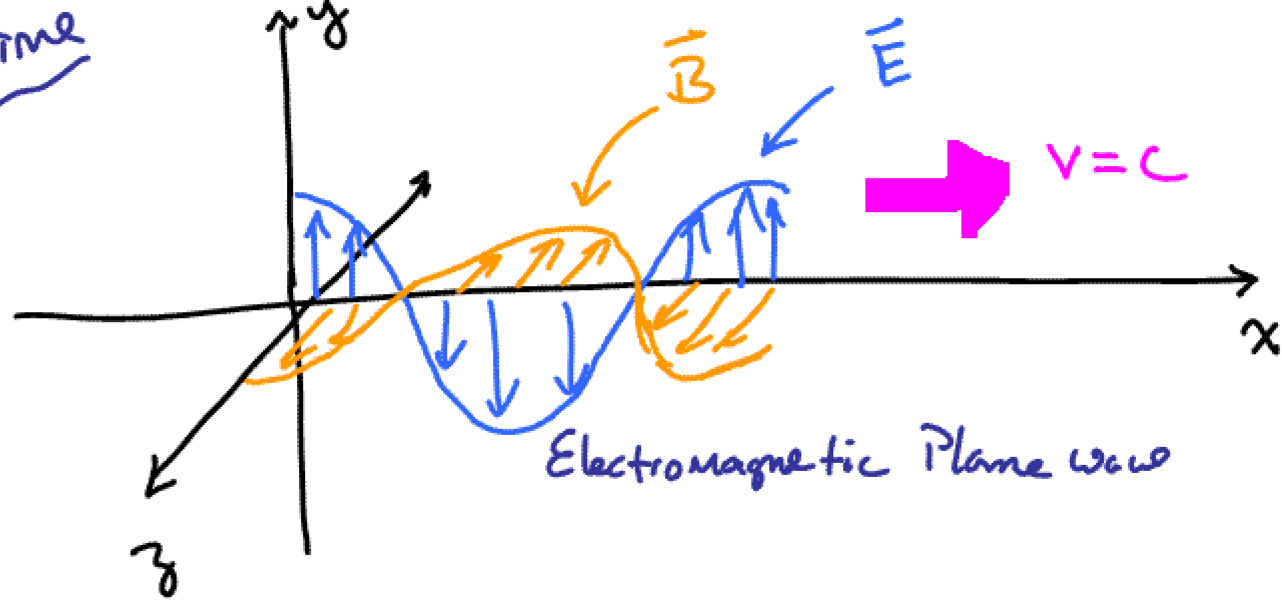
Physics 142 - November 29, 2007

- Presentation
  - Dec. 4 — Transistor; Planetary Magnetic fields
  - Dec. 6 — Elect. Musical Instr.; Laser
  - Dec. 11 — Wireless; Superconductivity
  - Dec. 13 — Particle Detectors; Electromagnetism in Medicine and/or Chem

Last Time



Direction of $\left\{ \begin{array}{l} \text{propagation} \\ \text{Energy flow} \end{array} \right\}$ given by $\hat{E} \times \hat{B}$

Energy flow

$$\vec{S} = \frac{\vec{E} \times \vec{B}}{\mu_0}$$ Poynting vector

$|\vec{S}| \equiv$ Intensity $\equiv$ Energy Flux $\equiv$ Watts/m^2

Area density of Power ~ Brightness

$$|E| = c|B|$$

$$\langle S \rangle = \frac{E_0^2}{2\mu_0 c} = \frac{c B_0^2}{2\mu_0} = \frac{E_0 B_0}{2\mu_0}$$

Momentum of EM wave

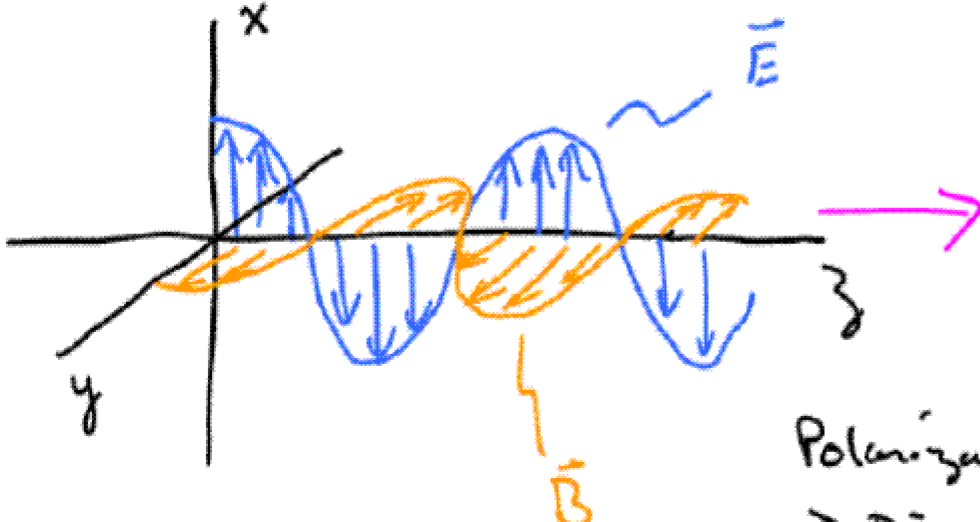
$$P = \frac{U}{c}$$

Radiation Pressure of EM wave

on "black" surface $= S/c$ $\qquad \langle \text{Pressure} \rangle = \frac{\langle S \rangle}{c}$

on Perfectly reflecting Surface $= \frac{2S}{c}$ $\qquad \langle \text{Press} \rangle = \frac{2\langle S \rangle}{c}$

Polarization of Electromagnetic waves

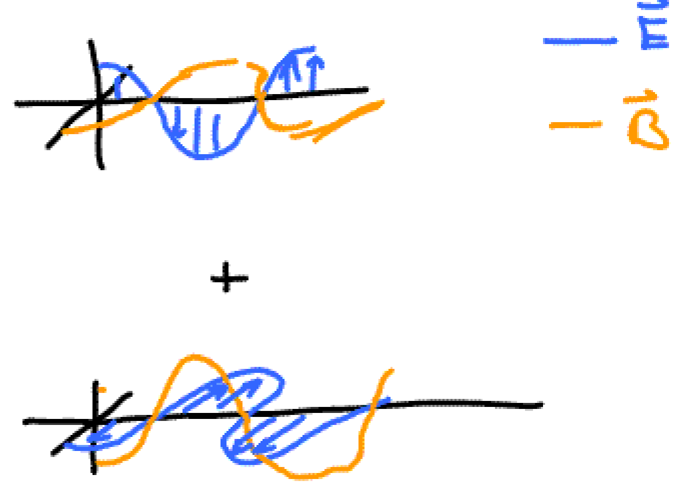


Polarization
→ Dir. of $\vec{E}$ vector

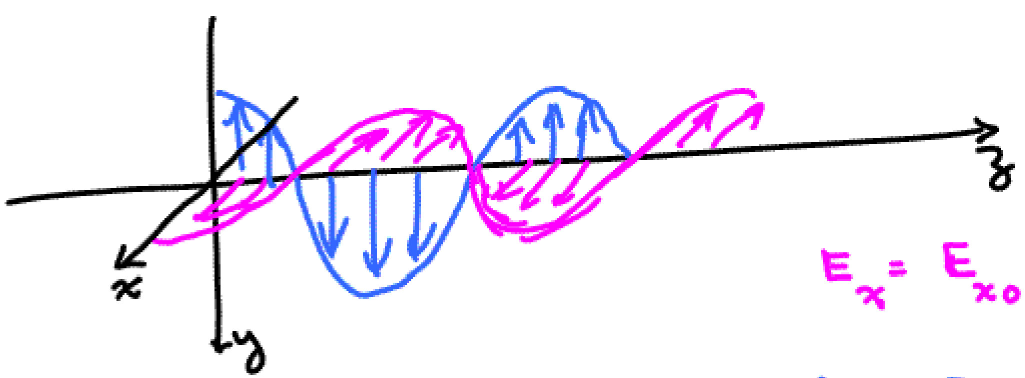
$\vec{E}$ ~~orinted~~ oriented along x axis

wave is polarized along x-axis

General Soln =



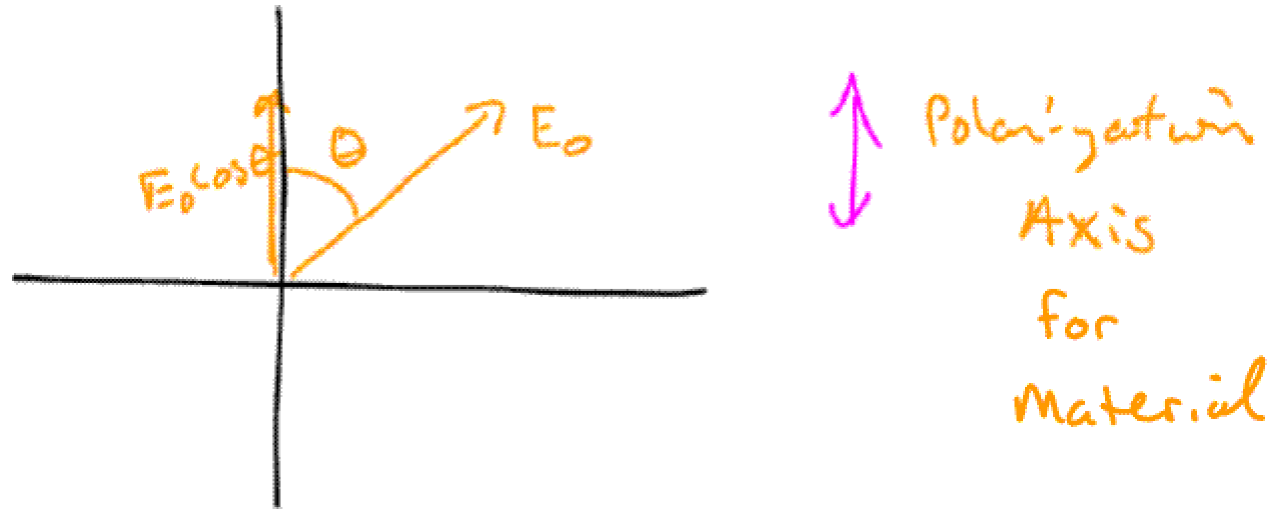
go to Basis where we draw just $\vec{E}$ for each of the possible orthogonal solns



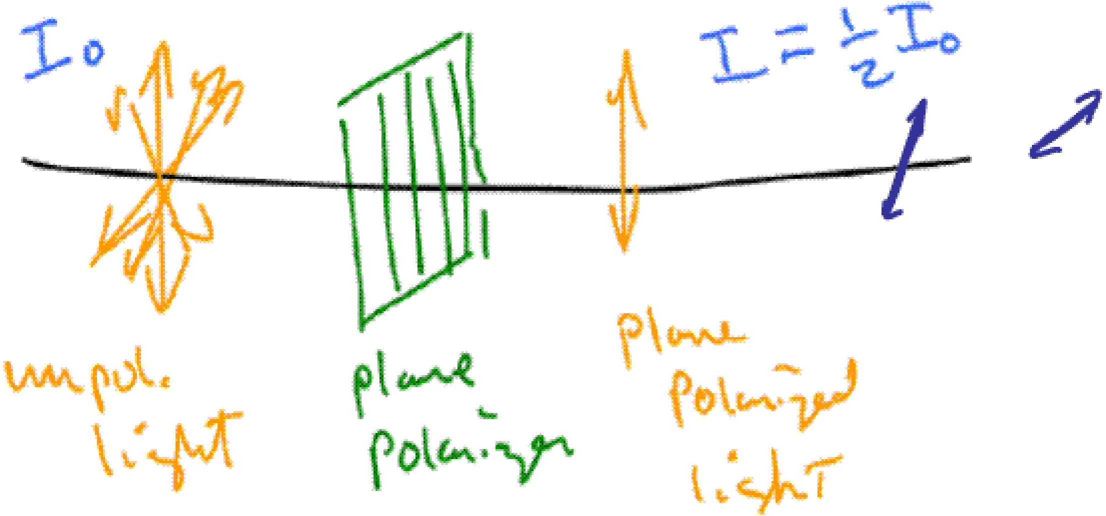
$$E_x = E_{x0} \sin(kx - \omega t)$$

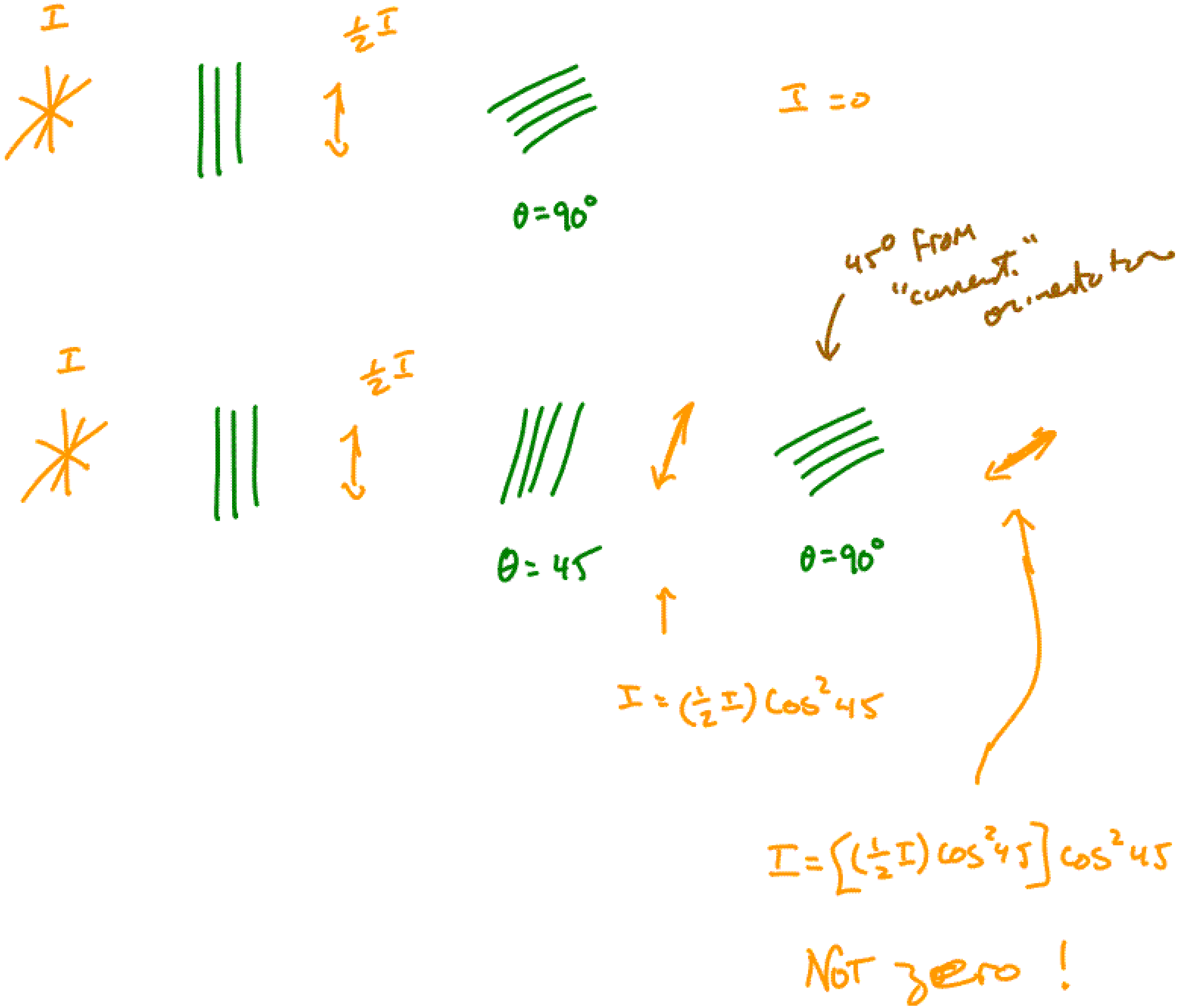
$$E_y = E_{y0} \sin(kx - \omega t + \varphi)$$

Amplitudes + phases may differ to give different types of Polarization

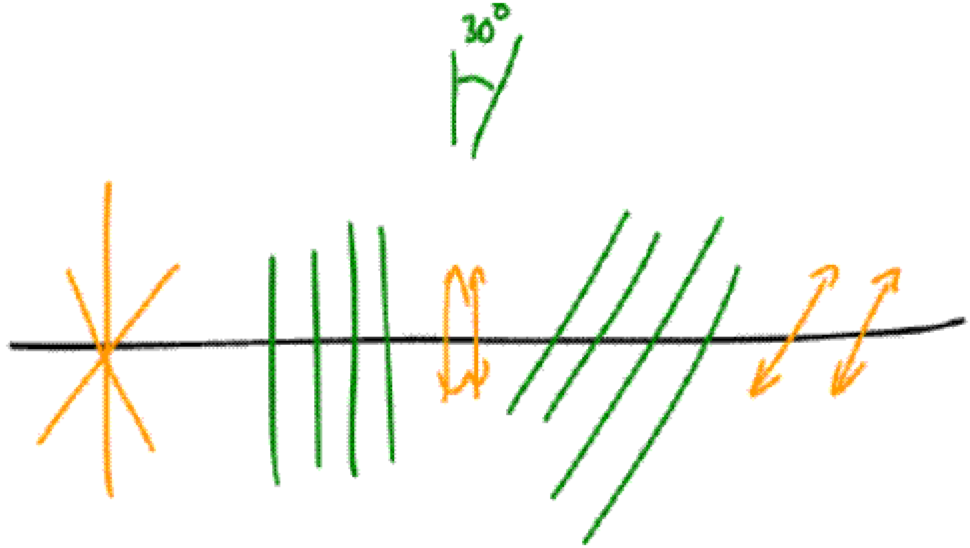


$$I_{New} \sim E_0^2 \cos^2\theta \sim I_{init} \cos^2\theta$$





I
½I
θ=90°
I =0
45° from "current" orientation
I
½I
θ= 45
θ=90°
I = (½I) cos²45
I = [(½I) cos²45] cos²45
Not zero !



I_0 $\frac{1}{2}I_0$ $I = \frac{1}{2}I_0\cos^2 30$

EM waves + Laws of optics

Light in a Material

$$c = \frac{1}{\sqrt{\epsilon_0\mu_0}} \rightarrow v = \frac{1}{\sqrt{\epsilon\mu}}$$

$v < c$

$$\frac{c}{v} \equiv n \equiv \text{index of refraction}$$

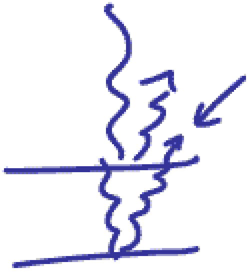
vacuum

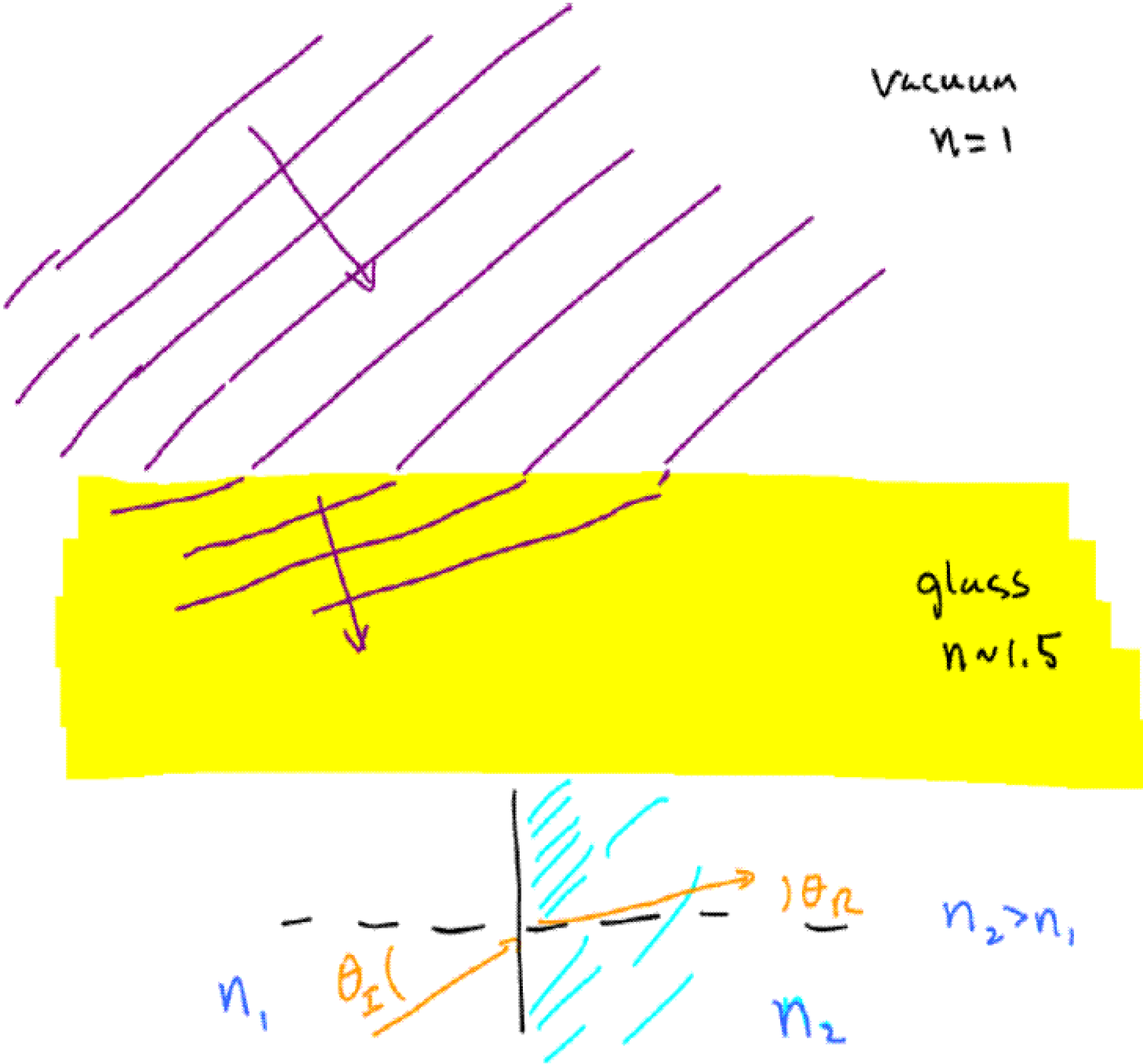
$$\lambda_0 \nu = c \qquad \lambda \nu = v$$

$$\lambda \nu = \frac{c}{n}$$

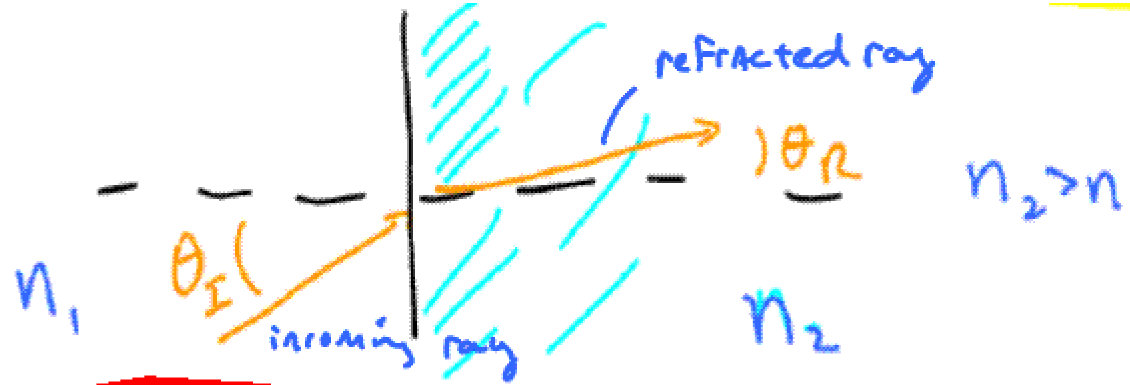
$$\lambda n = \frac{c}{\nu} = \lambda_0$$

in Material — in vacuum



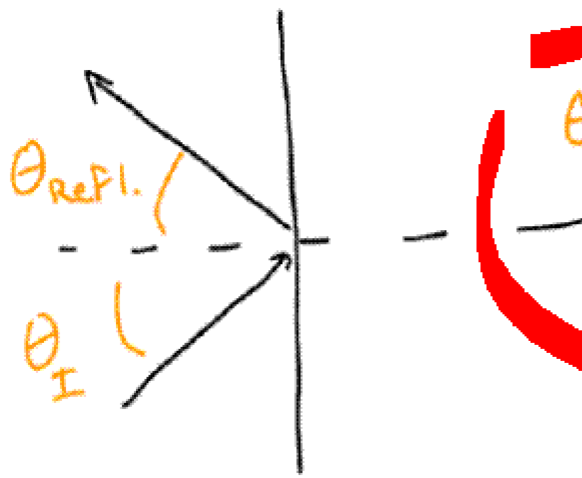


vacuum
n=1
glass
n~1.5
θ_I
θ_R
n_2>n_1
n_1
n_2



Snell's law $n_1 \sin\theta_I = n_2 \sin\theta_R$

Refraction



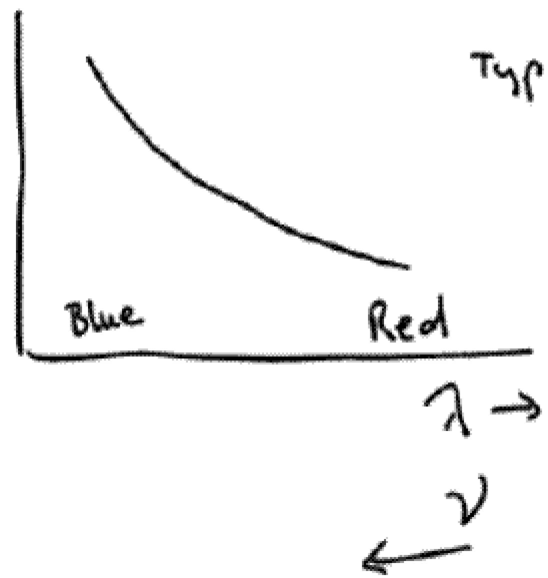
$\theta_I = \theta_{Refl}$

Law of Reflection

Dispersion

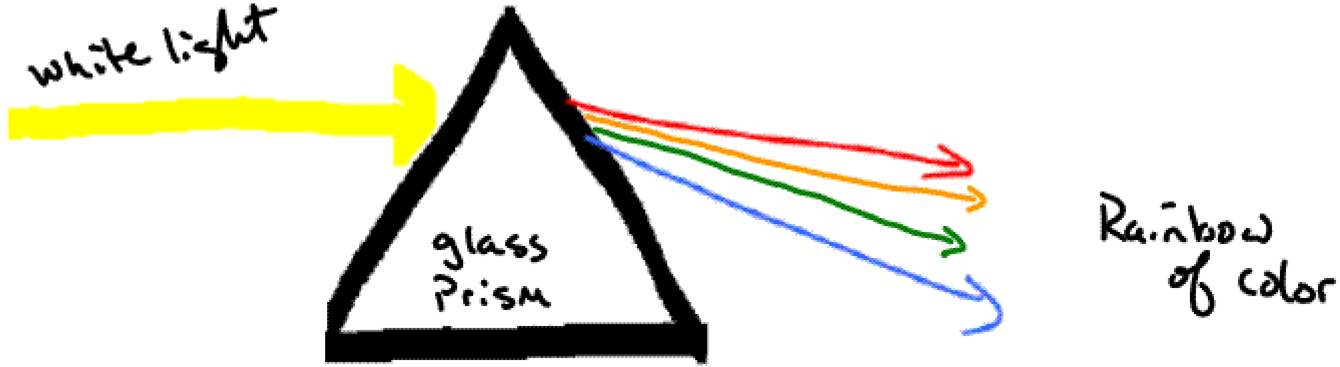
n depends on λ (ν)

$\frac{c}{v} = n$



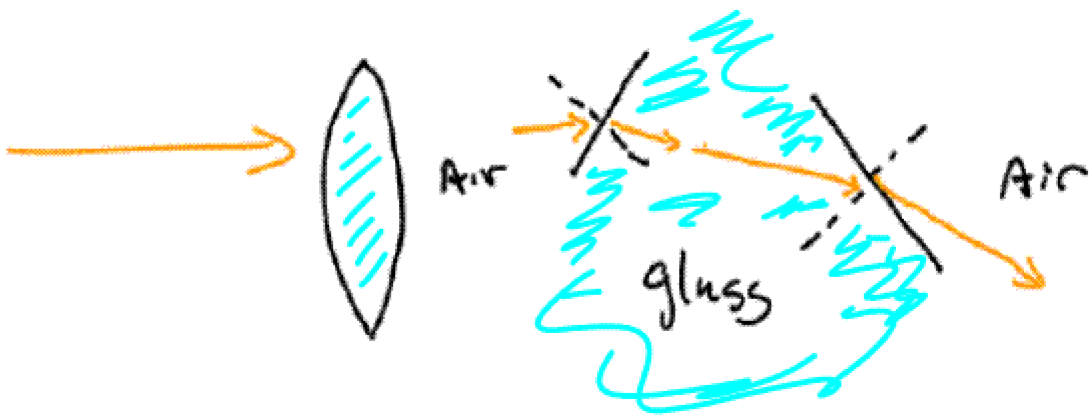
Typically $n(\text{red}) < n(\text{blue})$

red light typically faster

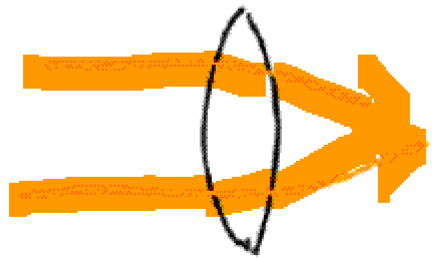


because $n_{red} < n_{blue}$

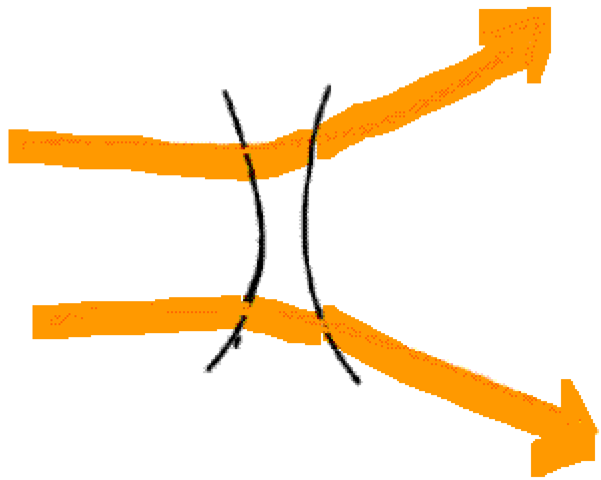
red bent less



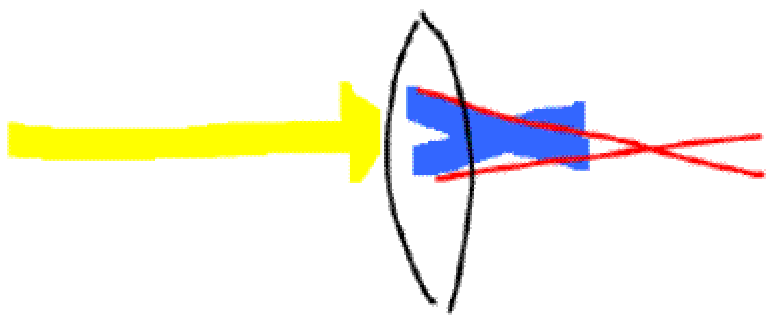
operation of a thin convex lens



Converging lens (convex)

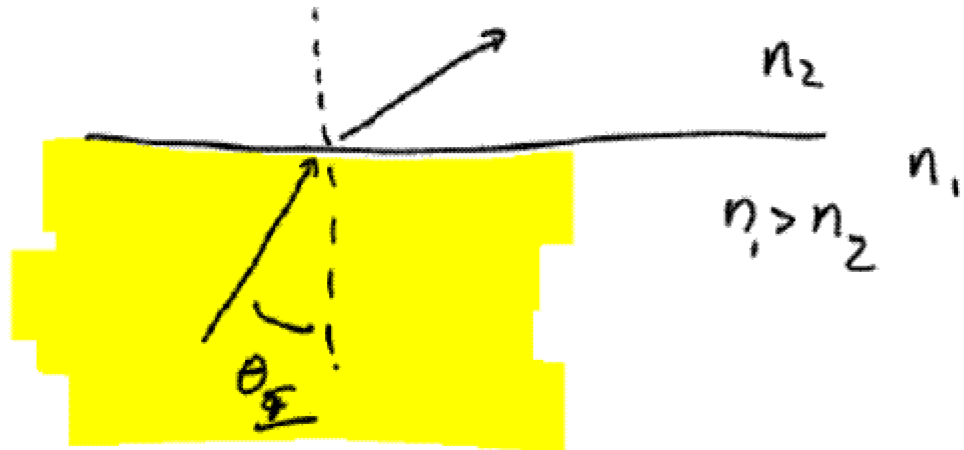


Diverging lens (concave)

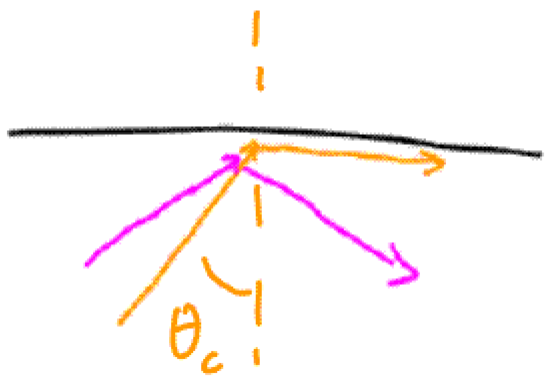


common abberation

Chromatic dispersion



$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

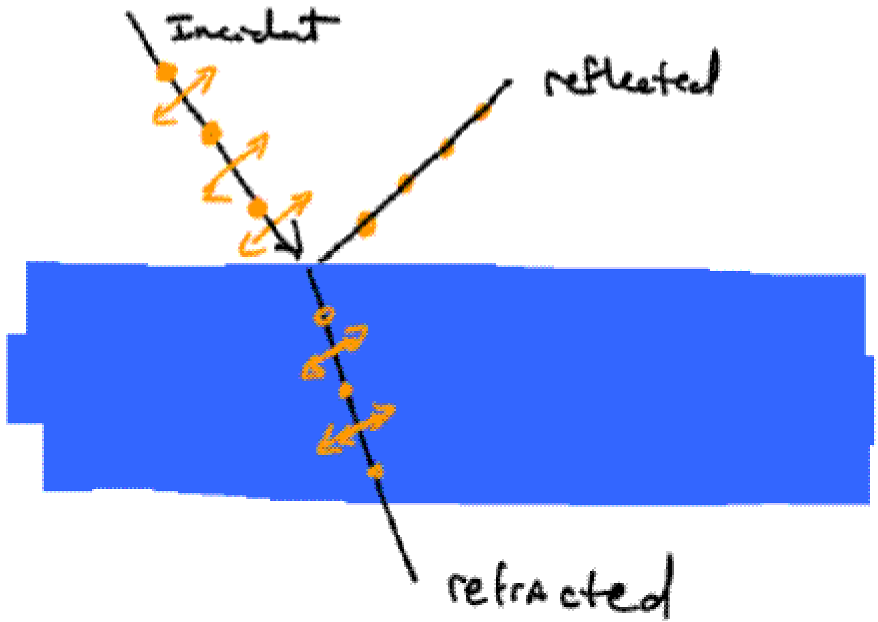


$$n_1 \sin\theta_c = n_2 \sin 90$$

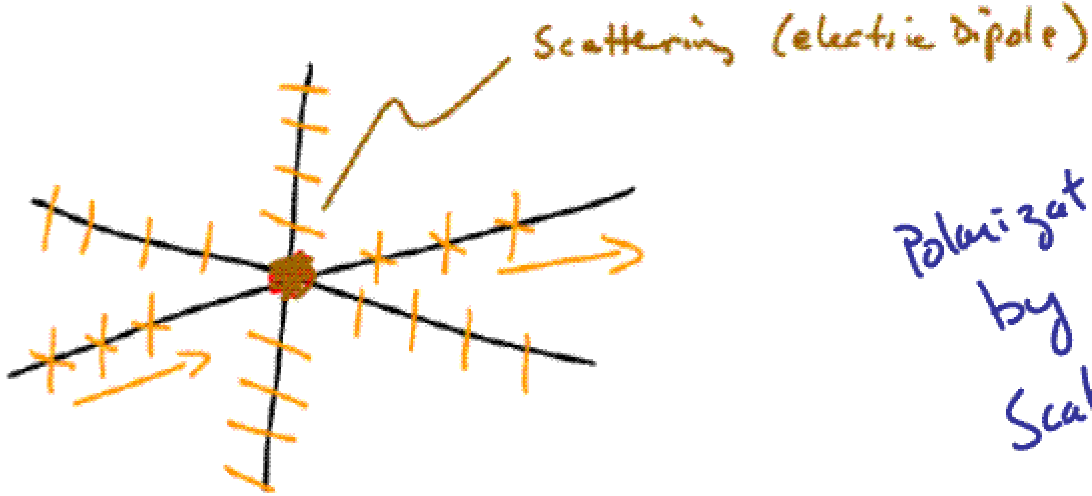
θ_c = critical Angle

If $\theta_I > \theta_c$ Total internal reflection

Polarization by Reflection



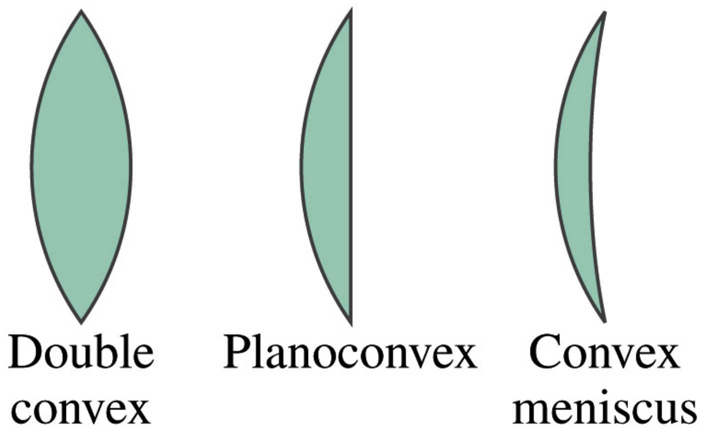
Polarization by Scattering



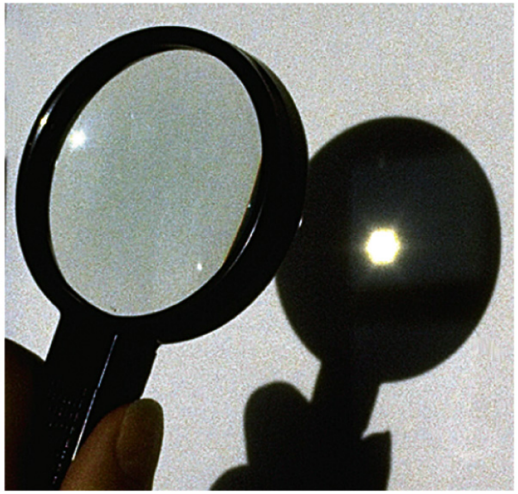
Thin lenses and optical instruments

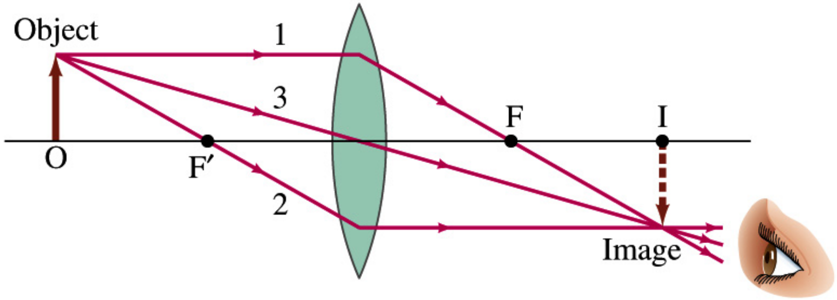
http://cvs.anu.edu.au

http://www.ebiomedia.com

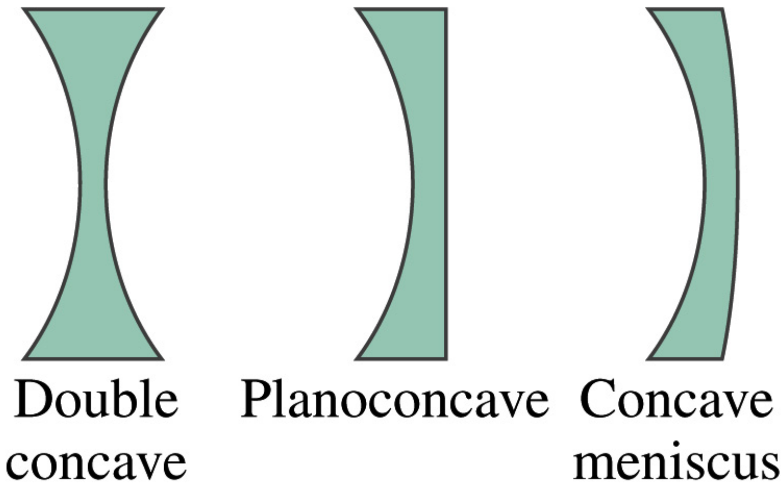


(a) Converging lenses

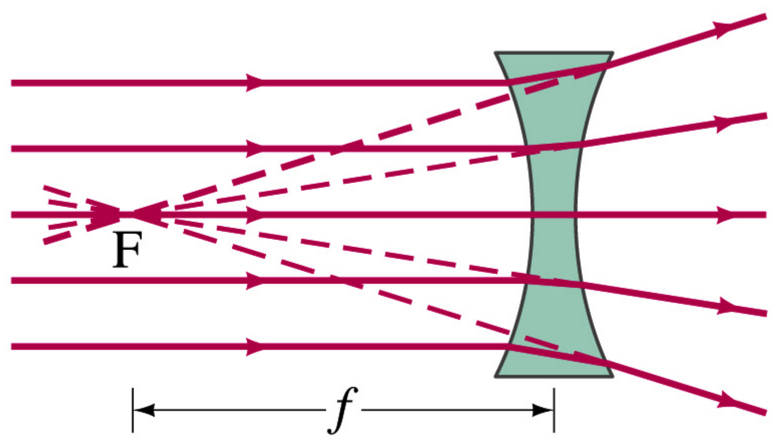


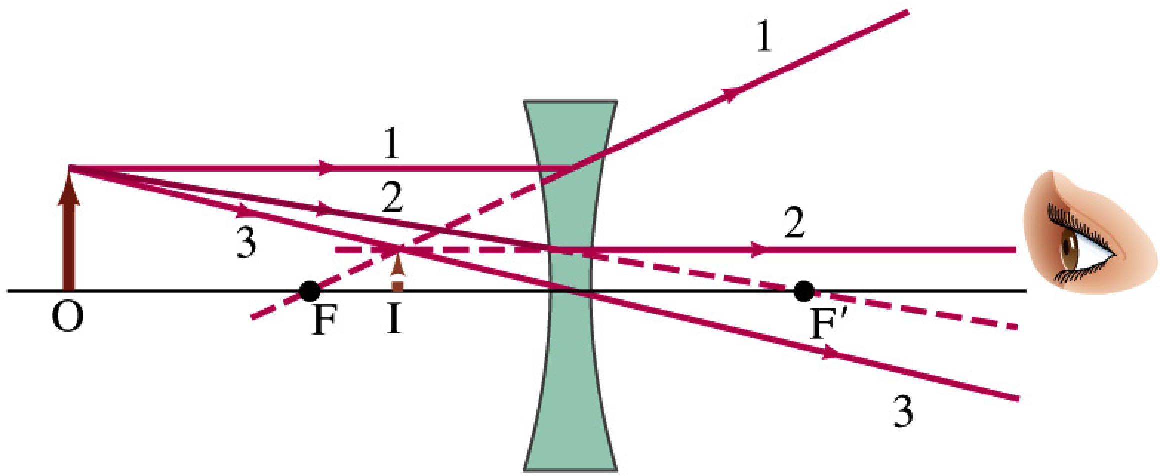


(c) Ray 3 passes straight through the center of the lens (assumed very thin).



(b) Diverging lenses





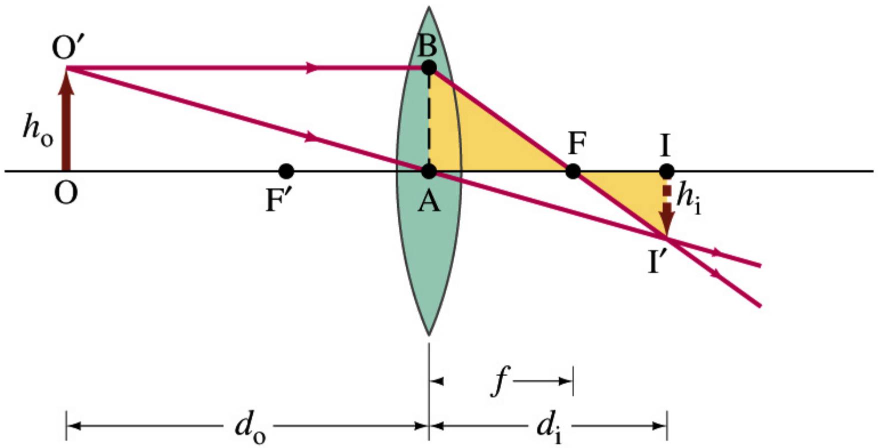
1
1
2
2
3
3
O
F
I
F′

Power of lens measured in diopters

$$P = \frac{1}{f}$$

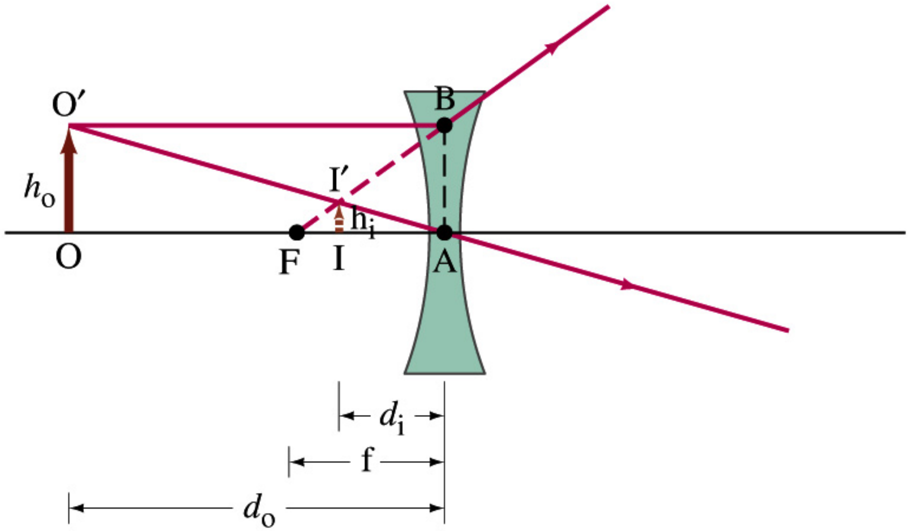
where f is focal length in meters

Power is positive for converging lenses
and negative for diverging lenses



Magnification:

$$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

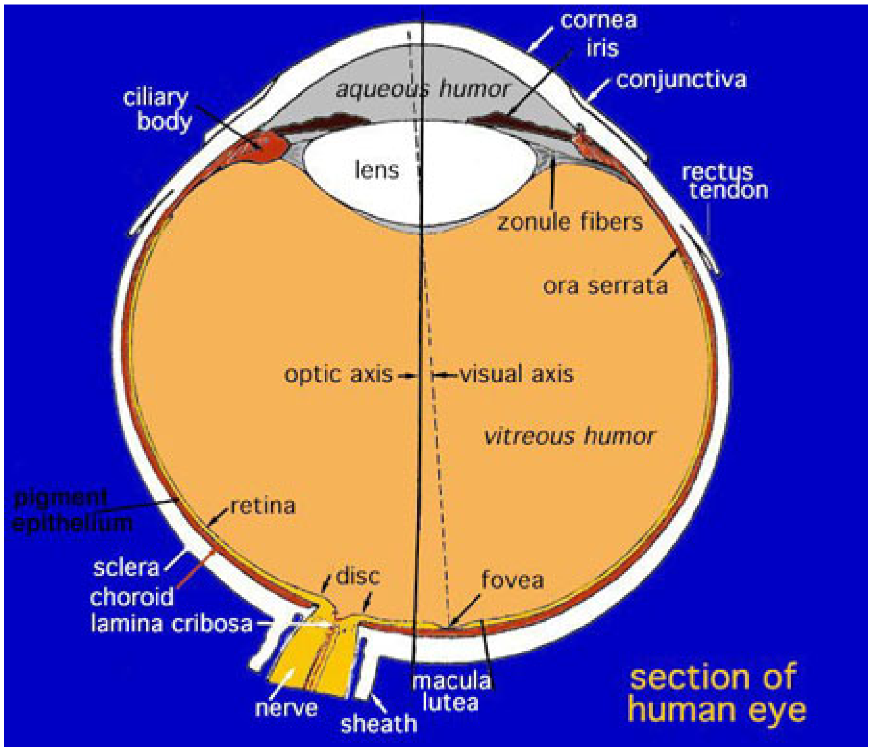


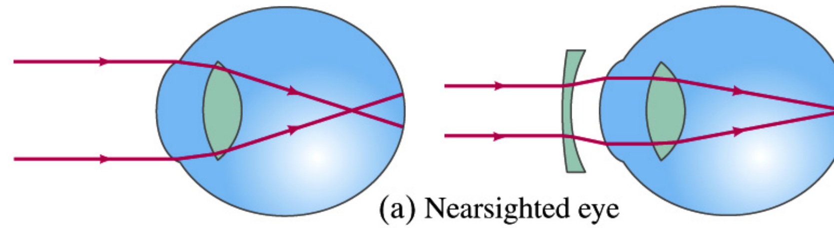
Lens equation:

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

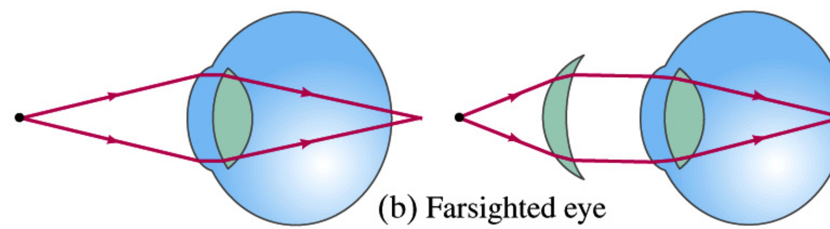
Convention from Giancoli p. 841:

- **Focal length is + for converging lens and - for diverging lens**
- **Object distance is + if on the side of the lens from which the light is coming (usual, unless in multi-lens system)**
- **Image distance is + if on the opposite side of the lens from where the light is coming, if on same side, image distance is –**
- **Image distance is + for real images and – for virtual images**
- **Height of image is + if image is upright and – if image is inverted. Height of object is always taken to be +.**



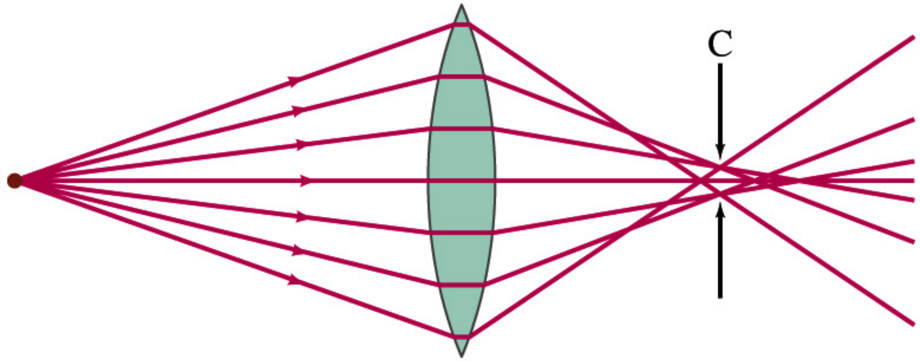


(a) Nearsighted eye

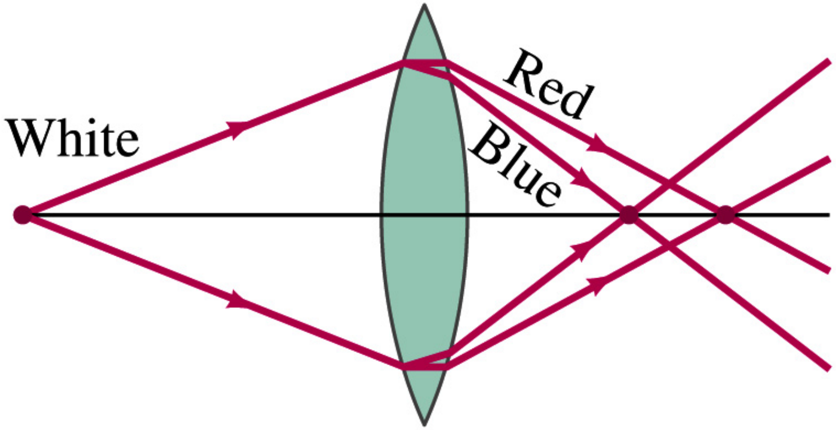


(b) Farsighted eye

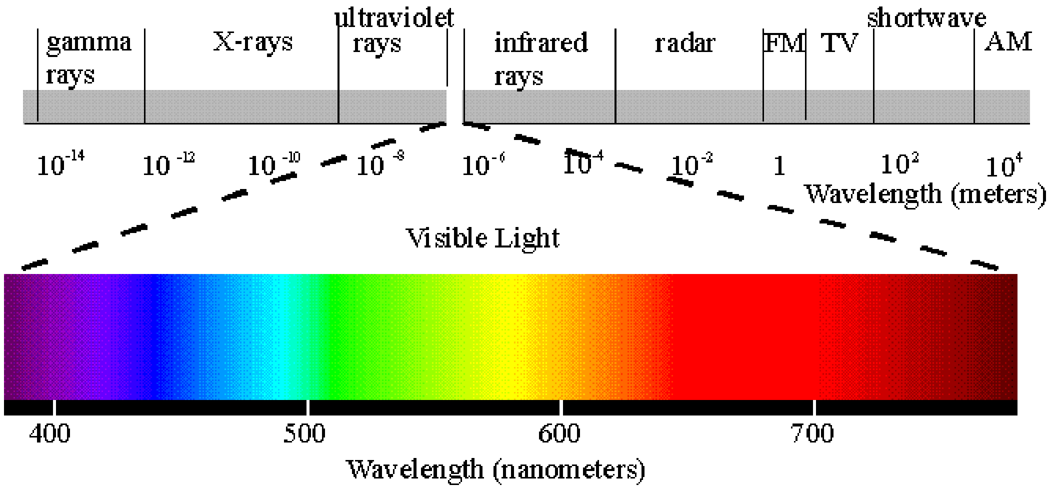
Aberrations



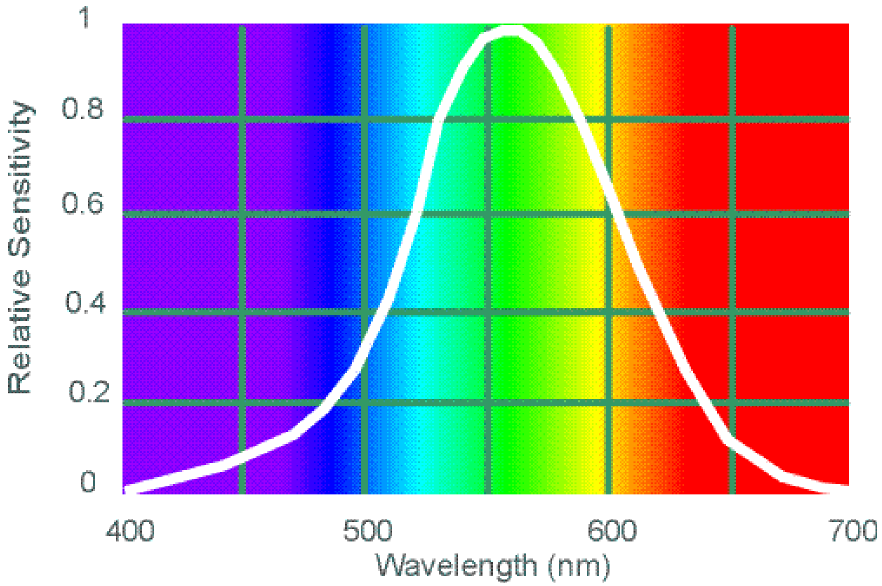
Spherical aberration

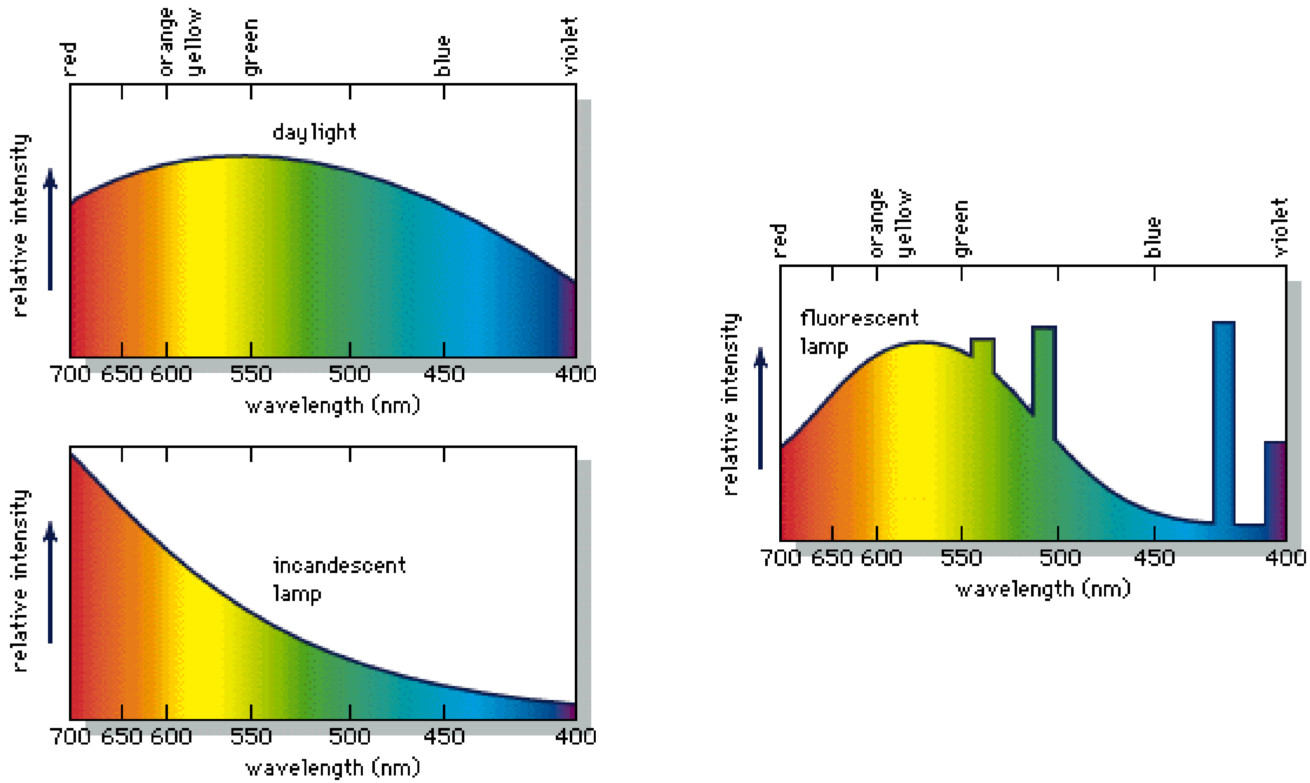


Chromatic aberration

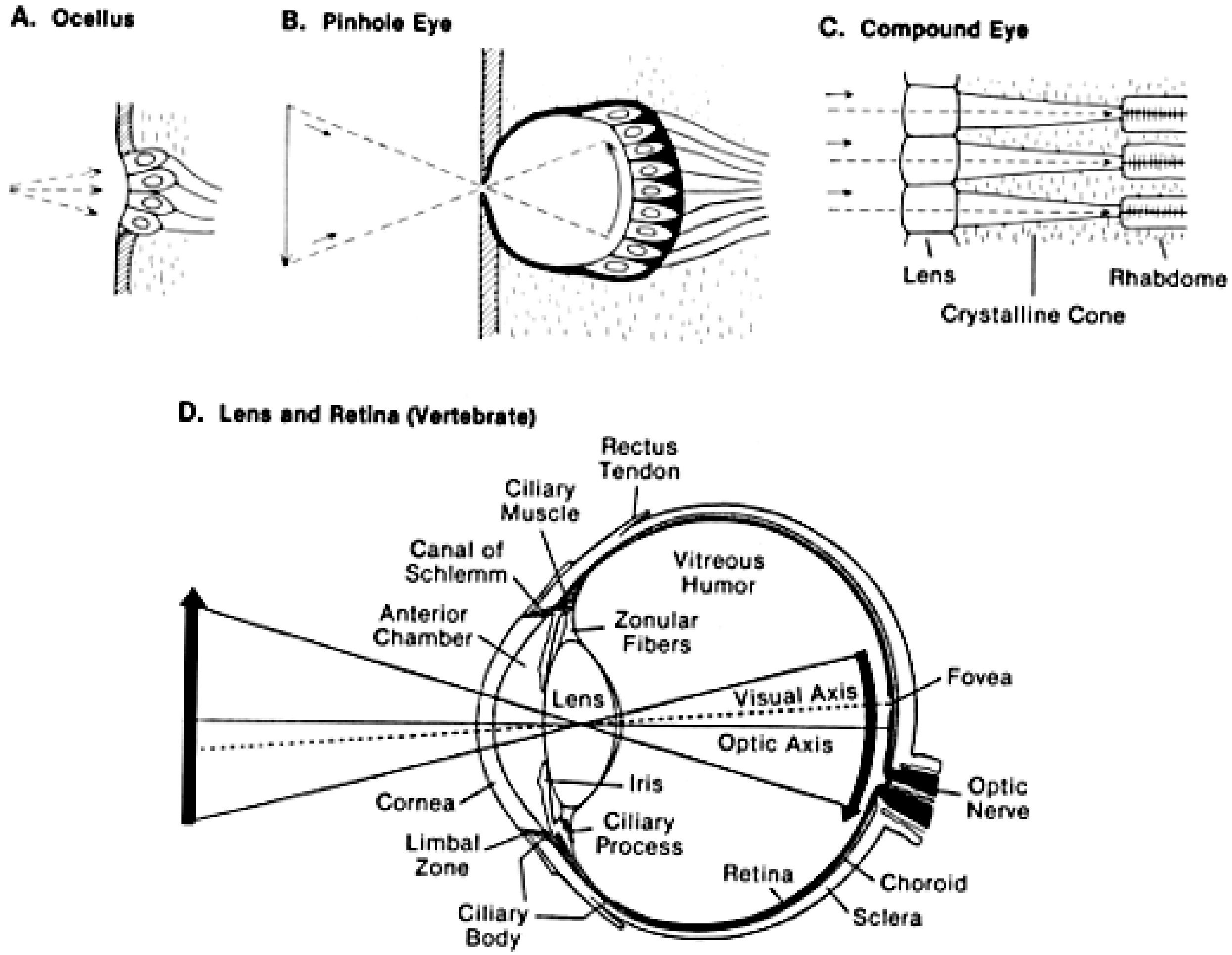


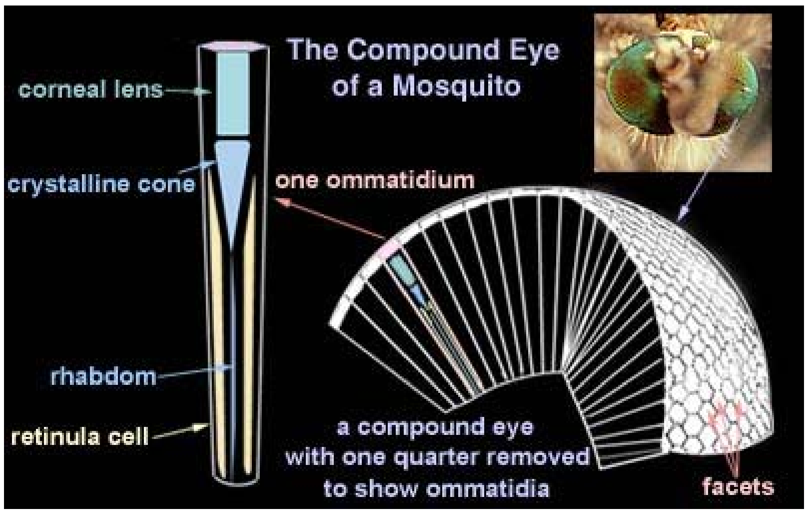
The electromagnetic spectrum
from "The Joy of Visual Perception: A Web Book"
http://www.yorku.ca/eye/

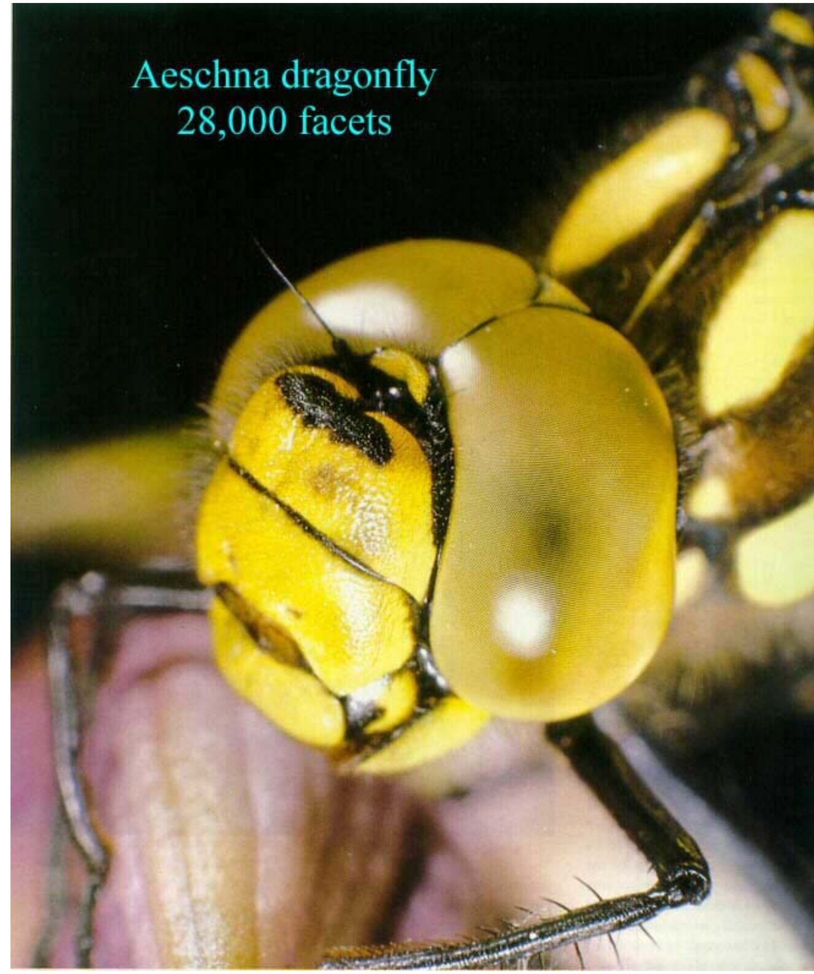



red
orange
yellow
green
blue
violet
daylight
relative intensity
700 650 600 550 500 450 400
wavelength (nm)
incandescent
lamp
fluorescent
lamp

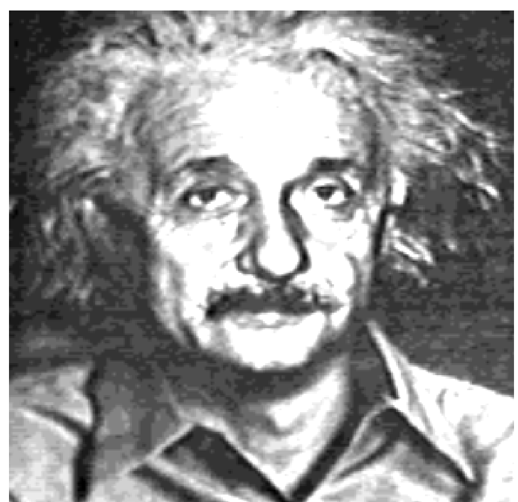
Types of eyes in the animal kingdom




The Compound Eye
of a Mosquito
corneal lens
crystalline cone
one ommatidium
rhabdom
retinula cell
a compound eye
with one quarter removed
to show ommatidia
facets


Aeschna dragonfly
28,000 facets

A bee’s eye view



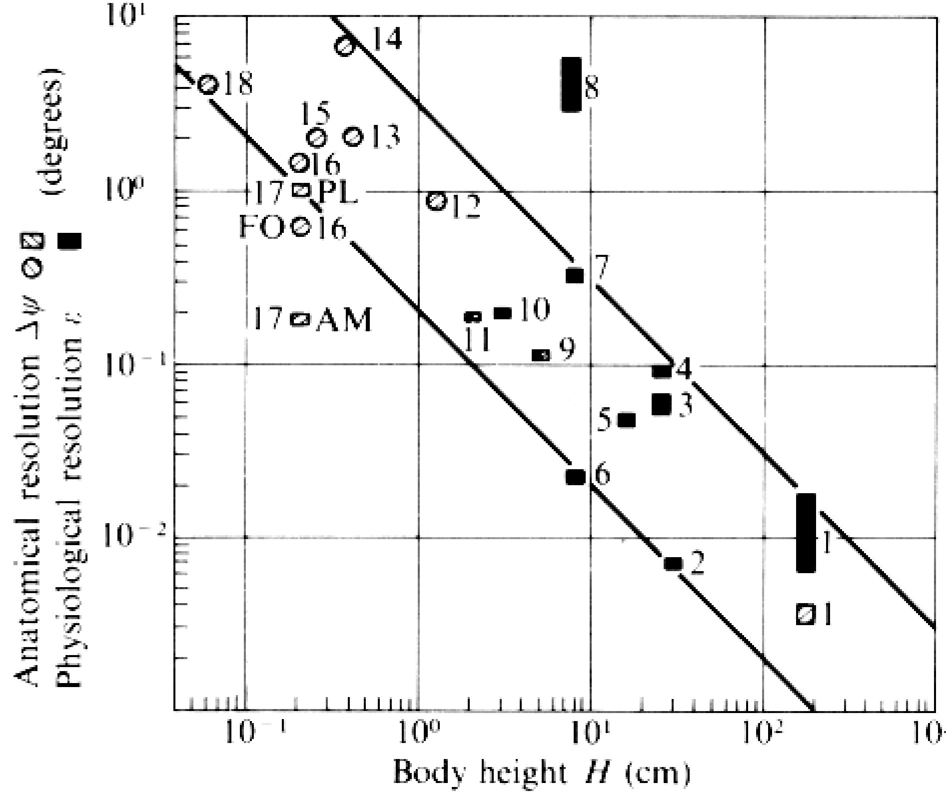


Fig. 2.9. Resolution of the eyes of various animals measured physiologically and deduced from anatomical criteria compared to body height: (1) man; (2) peregrine falcon; (3) hen; (4) cat; (5) pigeon; (6) chaffinch; (7) rat; (8) bat (*Myotis*); (9) frog; (10) lizard; (11) minnow; (12) dragonfly (*Aeschna*); (13) bee (Apis); (14) *Chlorophanus*; (15) housefly (*Musca*); (16) hover fly (*Syrrita*), frontal region FO; (17) jumping spider (*Methaphidippus*), anteromedian eye AM, postero-lateral eye PL; (18) fruit fly, *Drosophila*. (From Kirschfeld 1976.)

Anableps - minnow