PHYS210: Optics for Orthoptics II

- Prerequisite:
  - PHYS110 Optics for Orthoptics 1
- Your teacher: Kurt Rinnert
  - Oliver Lodge, 220 on 2nd floor, through the red door, first on the left , tel 42137, email kurt.rinnert@cern.ch
- Organization:

  12 lectures of 1 hour

  6 tutorials of 1 hour

  5 practical assignments of 3 hours
- Assessment:

  30% lab reports

  70% written exam

Schedule

- Lectures and tutorials:
  - Wednesday mornings 9-11 am, Rotblat theatre
  - Week 1-12
  - 3-week spring break between week 10 and 11
- Practical assignments:
  - Chadwick building, lab T9
  - Week 3, 5, 7, 9, 10
  - Group 1: Monday morning 10:00-13:00
    - 5/2, 19/2, 5/3, 19/3, 26/3
  - Group 2: Friday afternoon 14:00-17:00
    - 9/2, 23/2, 9/3, 23/3, 30/3

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

Recommended books:

"Clinical Optics"

A.R. Elkington, H.J. Frank, M.J. Greaney

Blackwell Science, Oxford

Third Edition (1999) ISBN 0632049898

"Physics for Ophthalmologists"

Edited by D.J. Coster. Churchill Livingstone.

First Edition. ISBN 0443049351

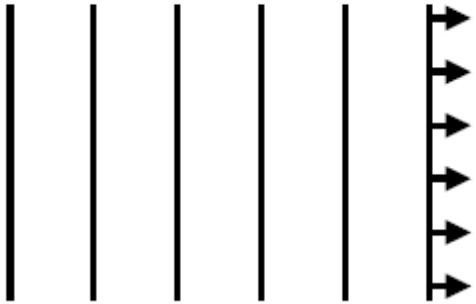
Lecture 1: recap of PHYS110

- Last year's lectures from Dr N. McCauley
  - Mirrors
  - **Refraction**
  - **Prisms**
  - **Lenses**
  - Squint
  - Thick lenses
  - **The Eye**

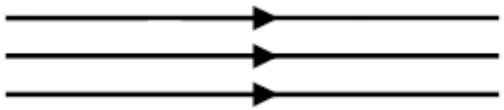
Representation of light

Different ways to represent light

as waves



as wave fronts



as light rays

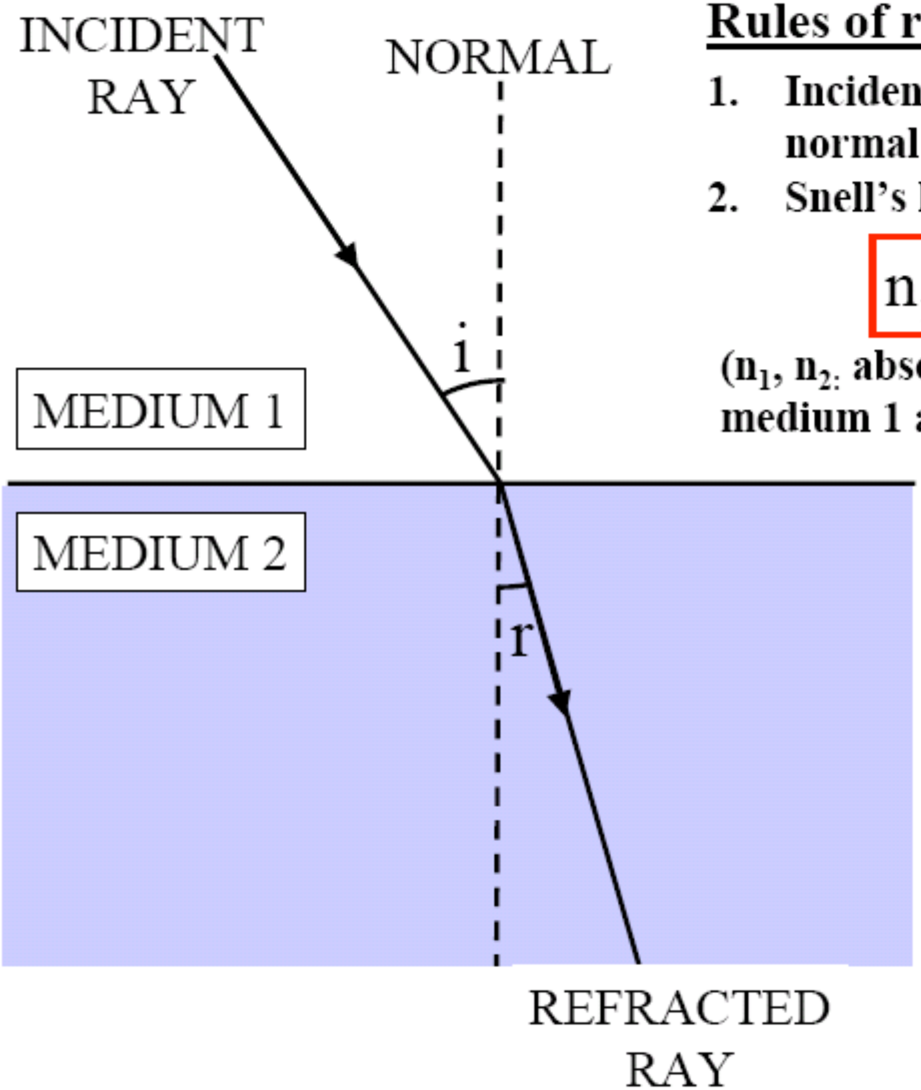
Which one to use?

Wave optics: interference (E&F, p5), diffraction, …

Wave optics: interference, diffraction, refraction, …

Geometric optics: reflection, refraction, image formation, …

Snell's law



<u>Rules of refraction:</u>

1. **Incident and refracted ray and the normal are in the same plane.**
2. **Snell's law**

$$n_1 \sin i = n_2 \sin r$$

(n_1, $n_{2:}$ absolute refractive index of medium 1 and 2)

OPTICS for ORTHOPTICS 3. Refraction > 3.1 Refraction; Total Internal Reflection 56

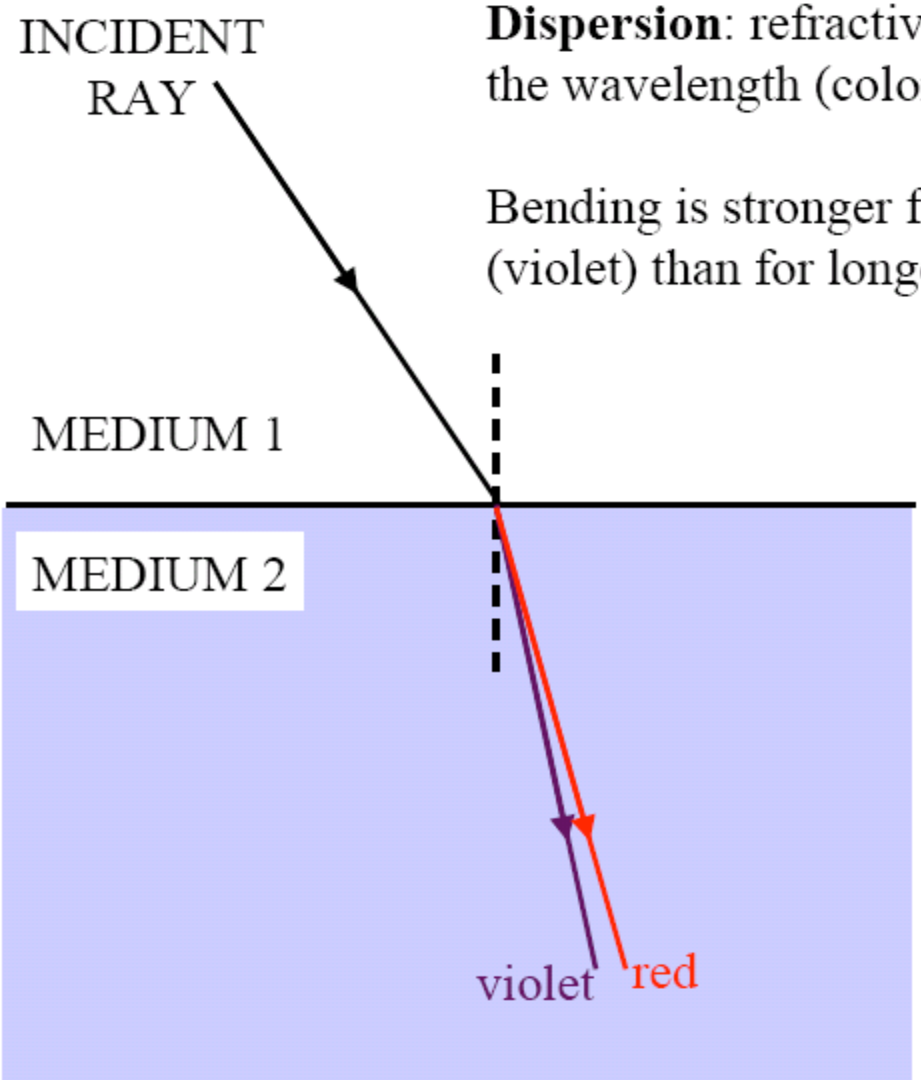
common materials:

air:	$n = 1.0003 \approx 1.0$
water:	$n = 1.33$
glass:	$n = 1.5$ to 1.8
diamond:	$n = 2.4$

Dispersion

Dispersion: refractive index depends slightly on the wavelength (color)

Bending is stronger for shorter wavelengths (violet) than for longer wavelengths (red)!



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Critical angle

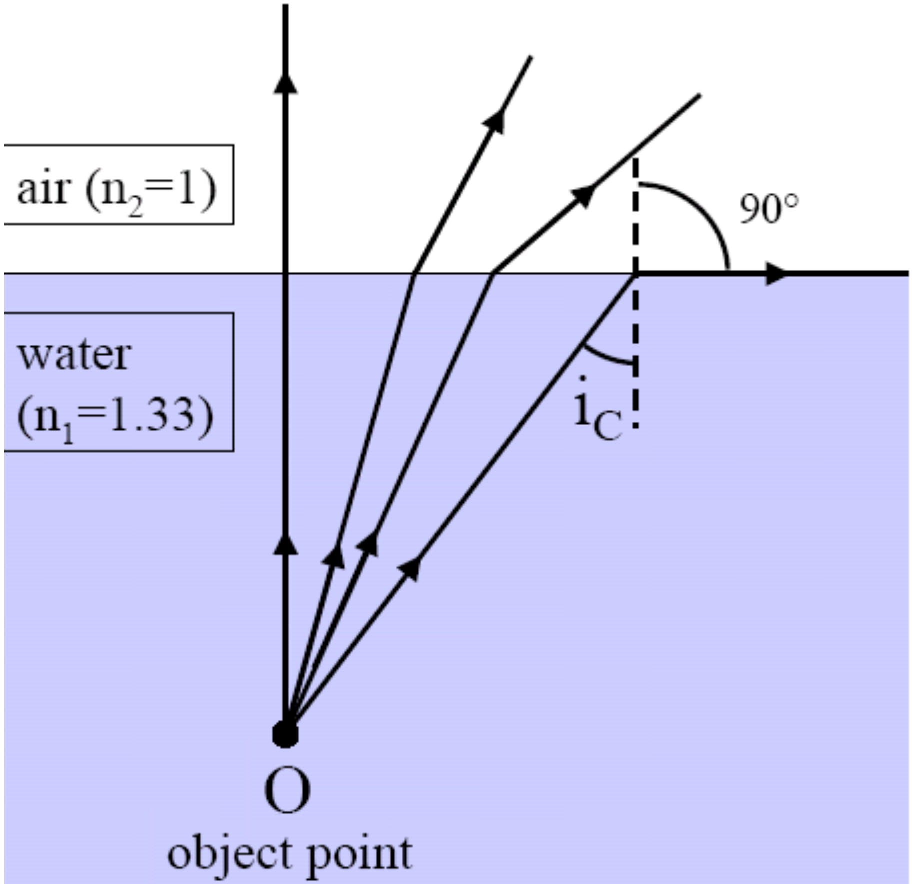
Critical angle: refracted ray parallel to surface ($r = 90°$)

$$n_1 \sin i = n_2 \sin r$$

$$n_1 \sin i_C = n_2 \sin 90°$$

$$n_1 \sin i_C = n_2$$

$$\sin i_C = \frac{n_2}{n_1}$$



For water:

$$\sin i_C = \frac{n_2}{n_1} = \frac{n_{air}}{n_{water}} = \frac{1}{\mu_{water}}$$

$$\mu_{water} = 1.33$$

$$\sin i_C = \frac{1}{1.33} = 0.75$$

$$i_C \approx 49°$$

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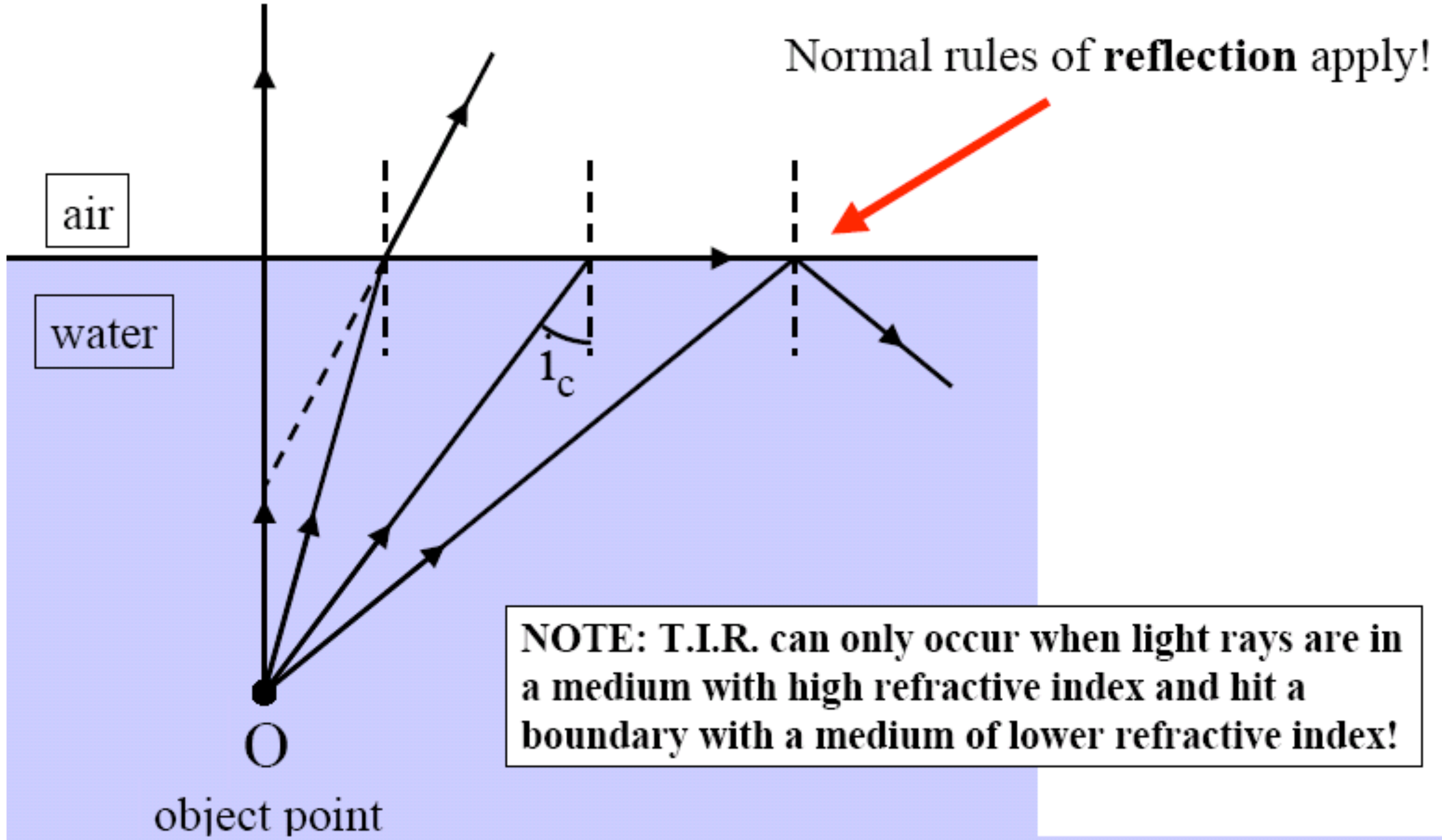
Total Internal Reflection

Beyond the critical angle there cannot be refraction:

Total Internal Reflection (T.I.R.)



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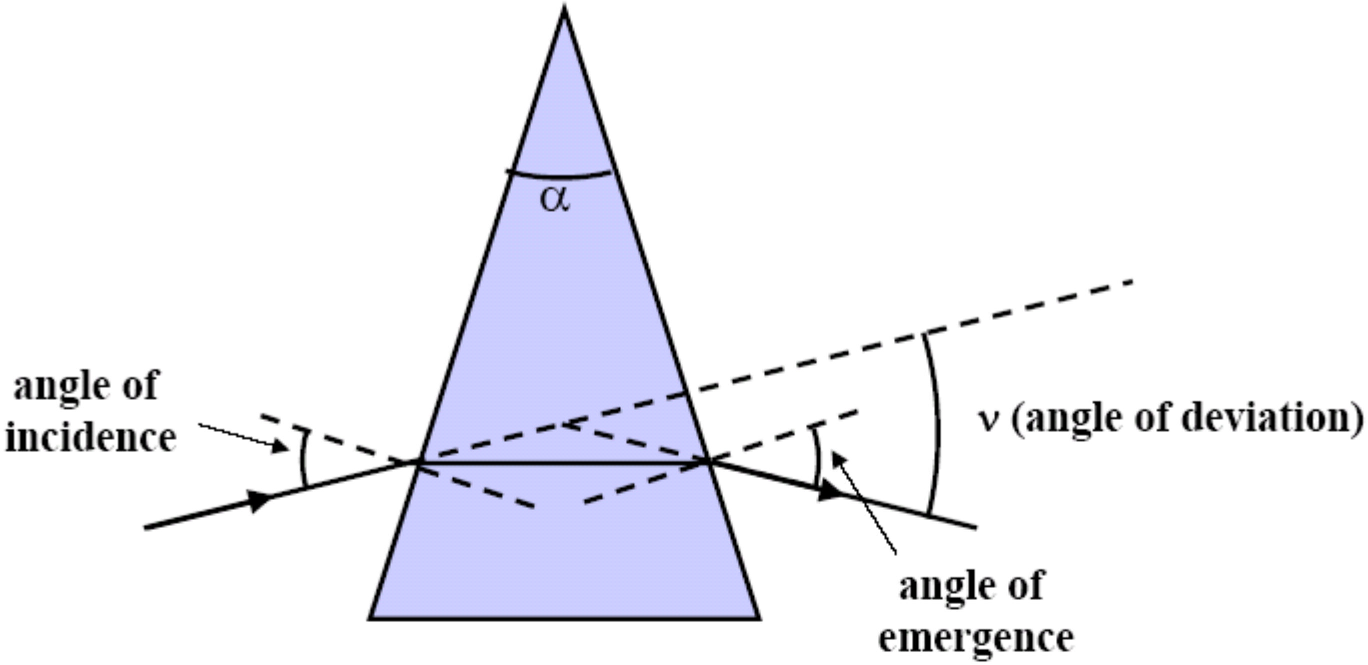
Prisms

Position of minimum deviation



Smallest angle of deviation occurs in the above case, where the ray passes symmetrically through the prism.
i.e Angle on incidence is equal to angle of emergence.

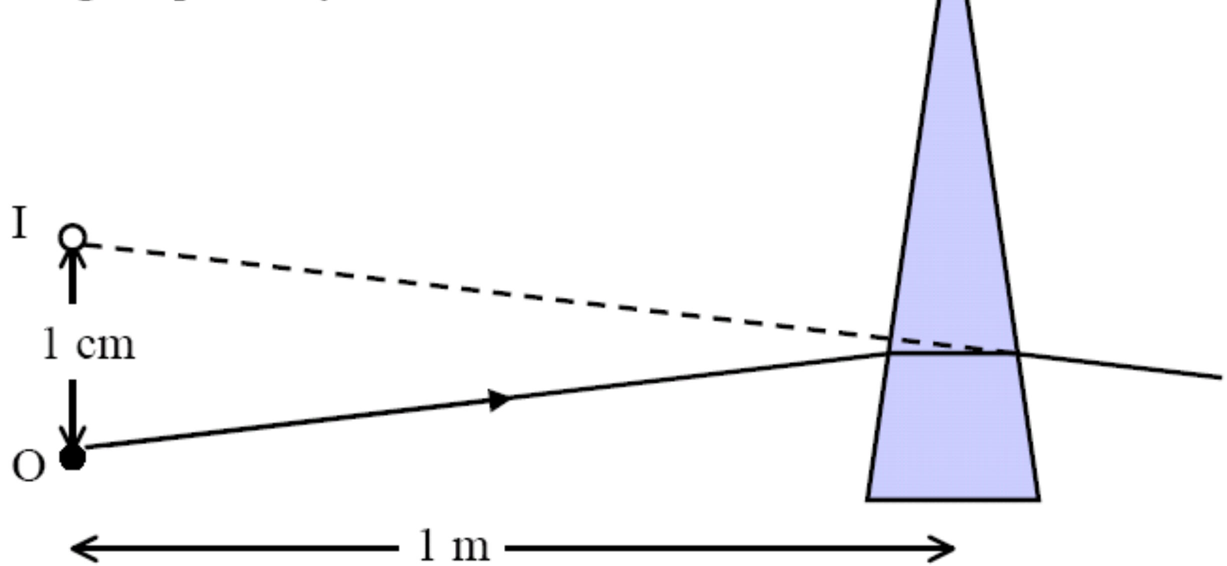
Angle of minimum deviation(D): $D \approx (n-1)\,\alpha$ (for a thin prism)

Prism strength

The refractive strength or power of a prism.

The refractive strength is often given in __prism dioptres__.

If a prism has a strength of 1 prism dioptre power (P = 1$^{\Delta}$), then the image of an object 1 metre from the prism will have an image displaced by 1 cm.



So a displacement of 3 cm at ½ a metre would give a dioptre of P = 6$^{\Delta}$

OPTICS for ORTHOPTICS 3. Refraction > 3.2 Refraction through prisms 79

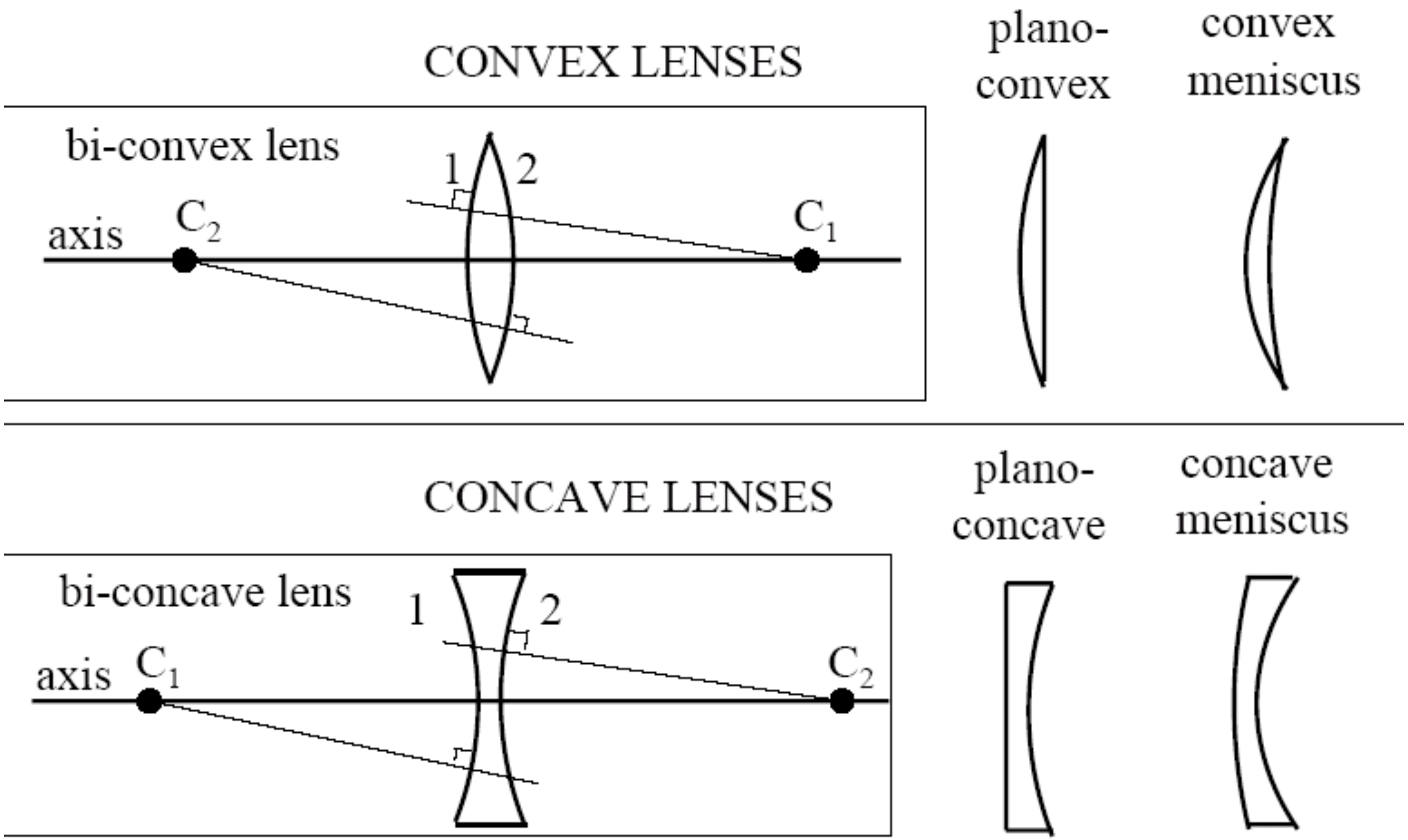
prism strength P is directly related to angle of minimum deviation D :

$$P = 100\tan(D)$$

Lens types

Spherical lenses

(two surfaces, each of which has a centre-of-curvature associated with it.)



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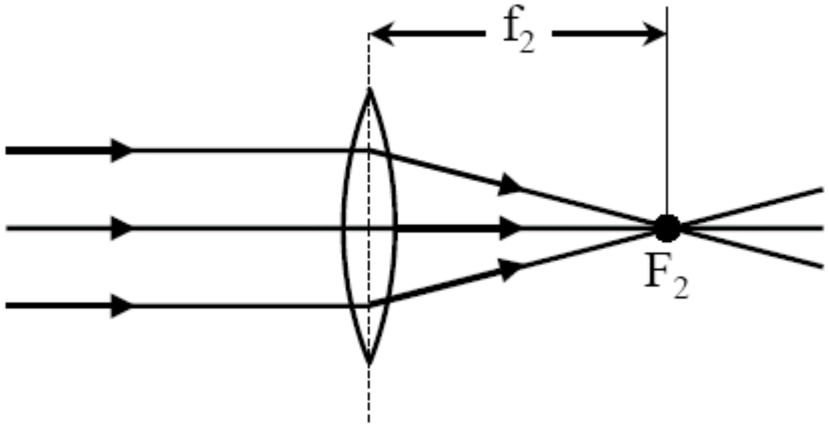
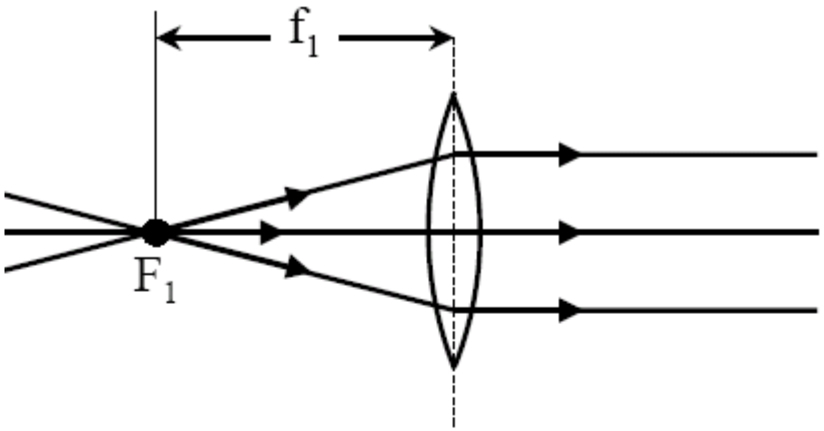
Focal points of convex lens

Lenses have two focal points. (example convex lens)



Parallel rays focused in F_2

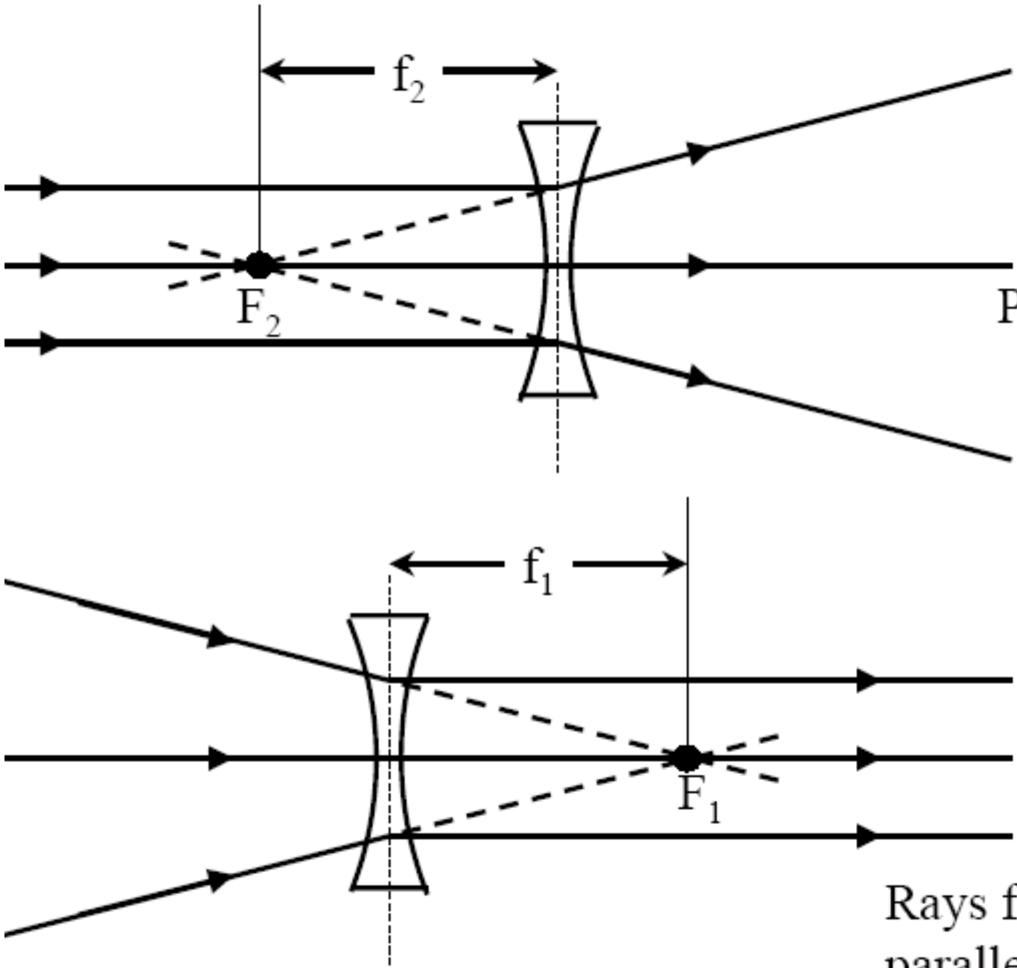


Rays from F_1 deflected into parallel rays.

In general focal length f_1 is equal to focal length f_2 (but opposite sign).
(not if medium on one side is different from that on the other side. E.g. contact lens.)

Focal points of concave lens

Similar for concave lenses



Parallel rays focused in F_2

Rays from F_1 deflected into parallel rays.

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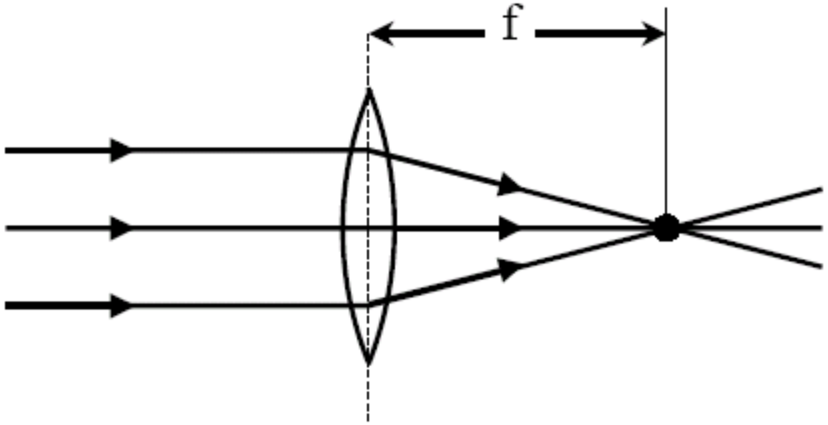
Vergence power

The vergence power (F) is related to the focal length (f):



$$F\text{ (in dioptres)} = \frac{1}{f\text{ (in metres)}}$$ (always using f_2!)

The shorter the focal length the more powerful the lens!

E.g. a convex lens with f = +5 cm has power: $F = \frac{1}{f} = \frac{1}{+0.05} = +20\text{ D}$

or a concave lens with a f = -20 cm has power: $F = \frac{1}{f} = \frac{1}{-0.20} = -5\text{ D}$

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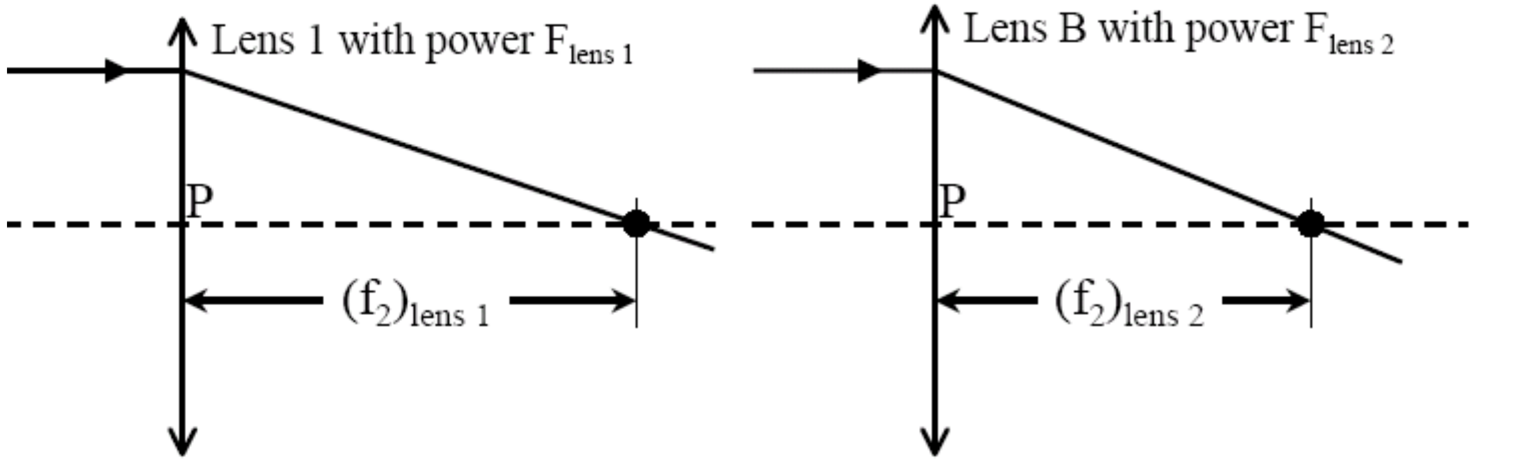
Combining lenses

<u>Combination of lenses:</u>



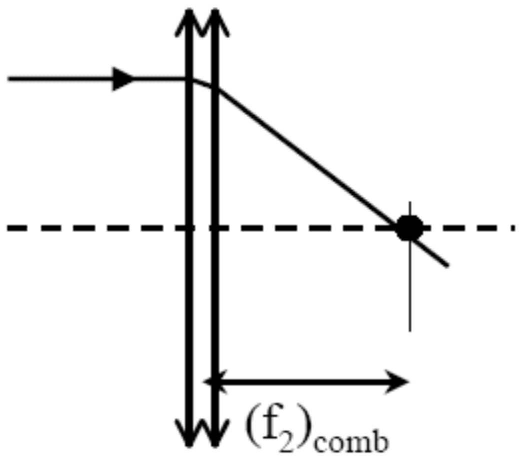
Remember: $F_{lens} = F_{surface\ 1} + F_{surface\ 2}$

For two **<u>thin</u>** lenses placed **<u>close</u>** together:

$$F_{combined\ lenses} = F_{lens\ 1} + F_{lens\ 2}$$

or

$$\frac{1}{(f_2)_{combined}} = \frac{1}{(f_2)_{lens\ 1}} + \frac{1}{(f_2)_{lens\ 2}}$$



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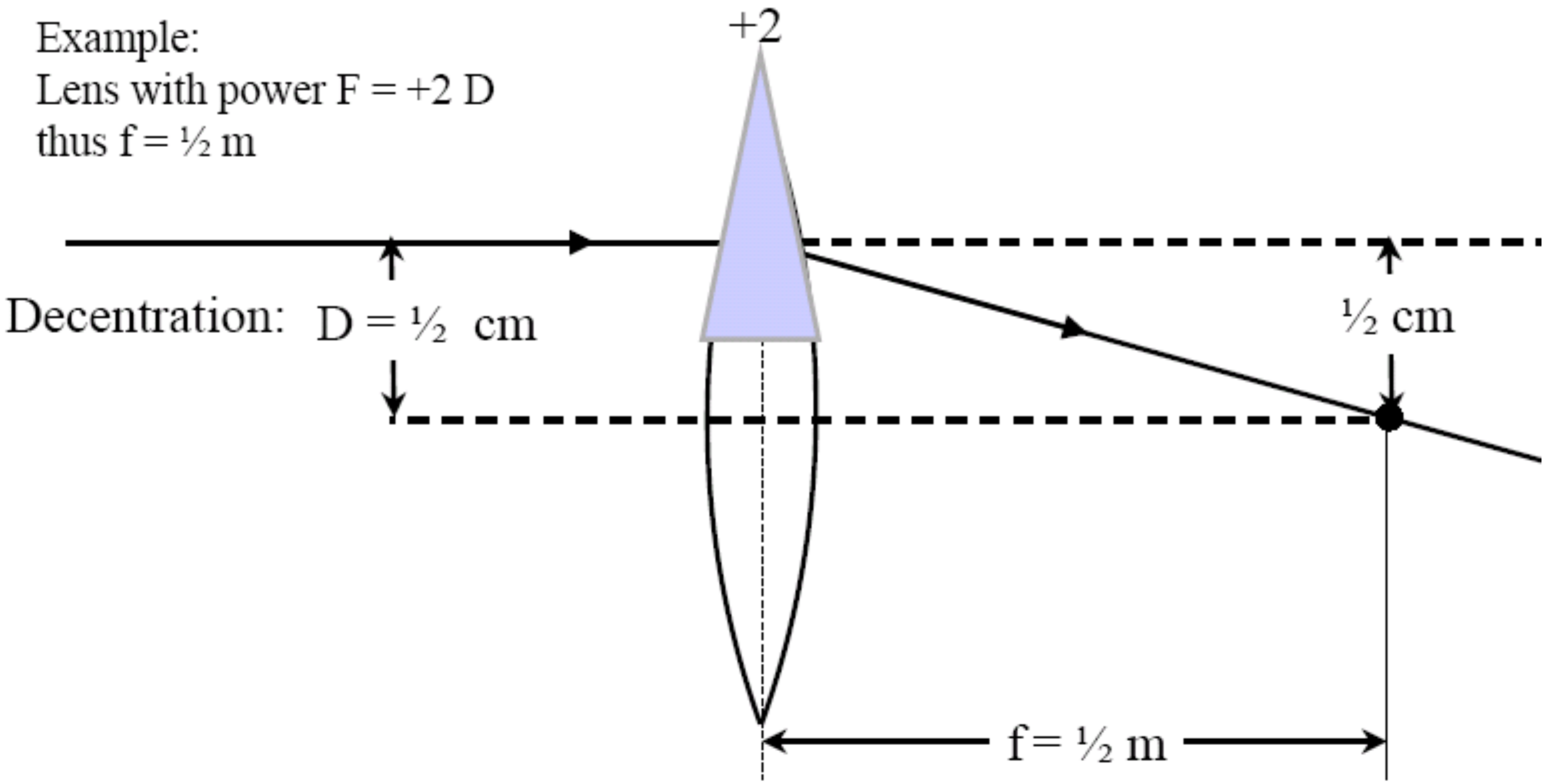
Prentice rule

Prismatic effect of lenses. **(the relation between prism power and lens power)**

Example:
Lens with power F = +2 D
thus f = ½ m



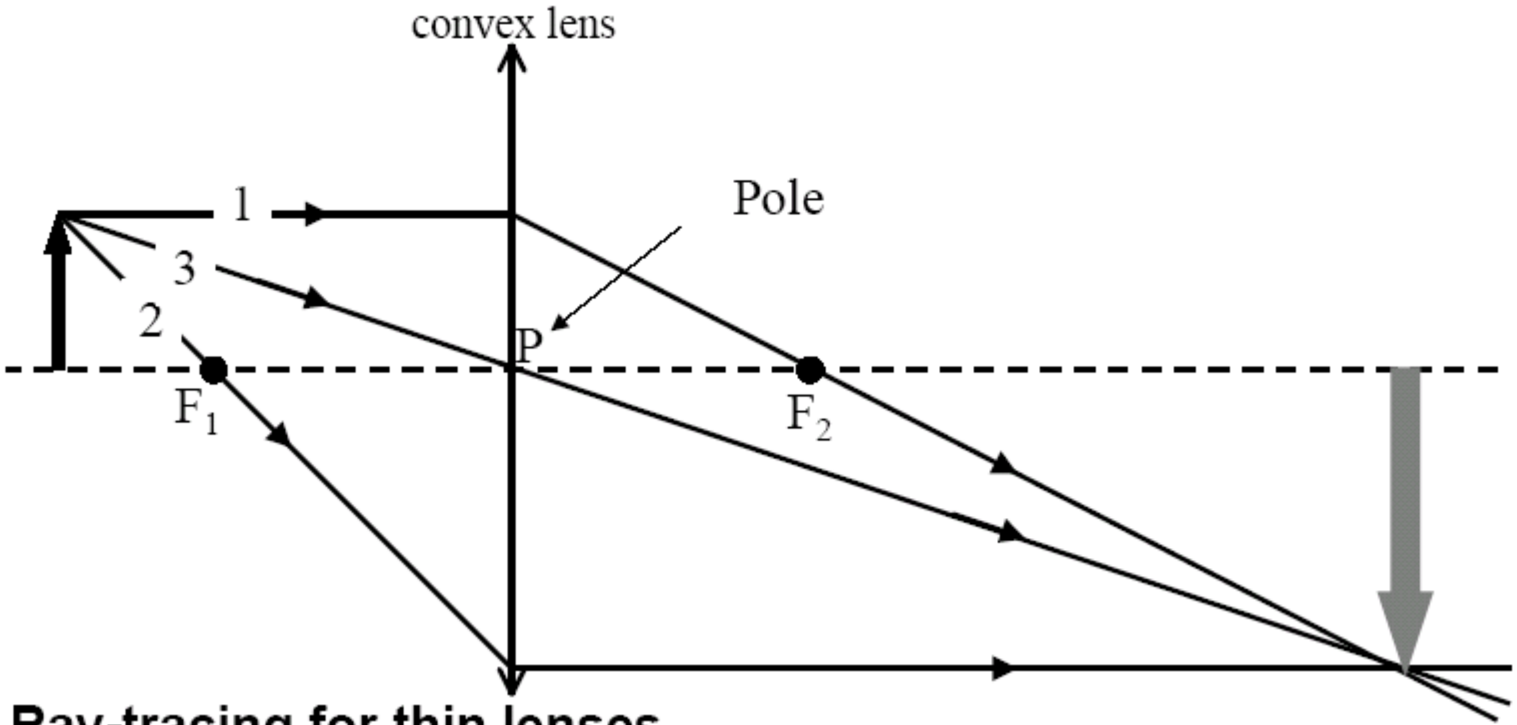
A prism with power $P = 1^{\Delta}$ would bend the ray in the same manner!

<u>Prentice rule:</u> $P = F \times D$

Lens with power F offset from its centre by D causes same bending as a prism with P=F×D.

Image formation

Image formation by a lens:



Ray-tracing for thin lenses

Once again at least two rays are needed to find the image position.

Ray 1: Rays parallel to the axis are deflected to pass through F_2.

Ray 2: Rays passing through F_1 emerge from the lens parallel to the axis.

Ray 3: Rays through the pole (P) of the lens are not deflected.

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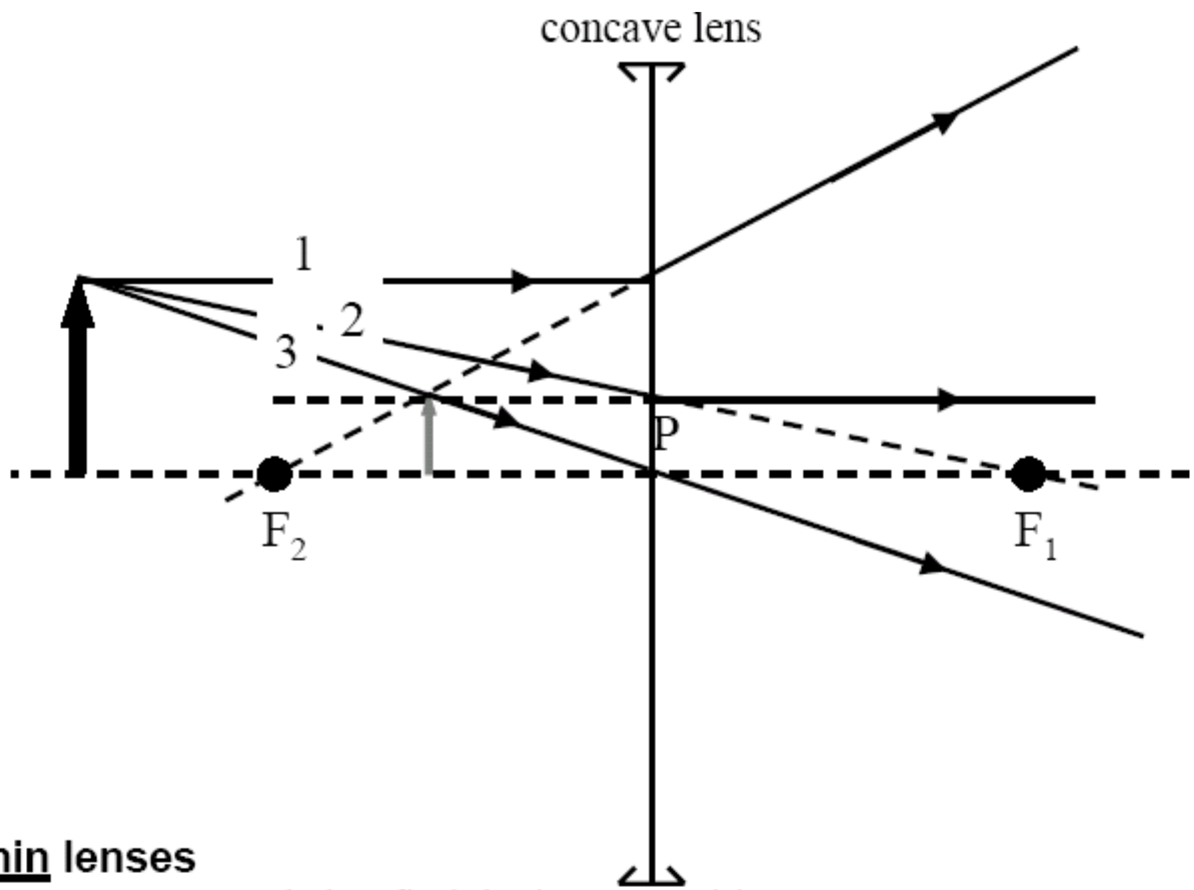
Virtual image



Ray-tracing for thin lenses

Once again at least two rays are needed to find the image position.

Ray 1: Rays parallel to the axis are deviated to pass through F_2.

Ray 2: Rays passing through F_1 emerge from the lens parallel to the axis.

Ray 3: Rays through the pole (P) of the lens are not deviated.

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The lens equation

As for spherical mirrors there are two important equations for thin lenses

To find the **image position** we us the lens equation:

$$\frac{1}{f_2} = \frac{1}{v} - \frac{1}{u}$$

(Notice the minus sign that was not there for spherical mirrors.)

To find the **image size** we use the magnification formula:

$$m = \frac{\text{image size}}{\text{object size}} = \frac{v}{u}$$

(Here the minus sign that was there for spherical mirrors has gone.)

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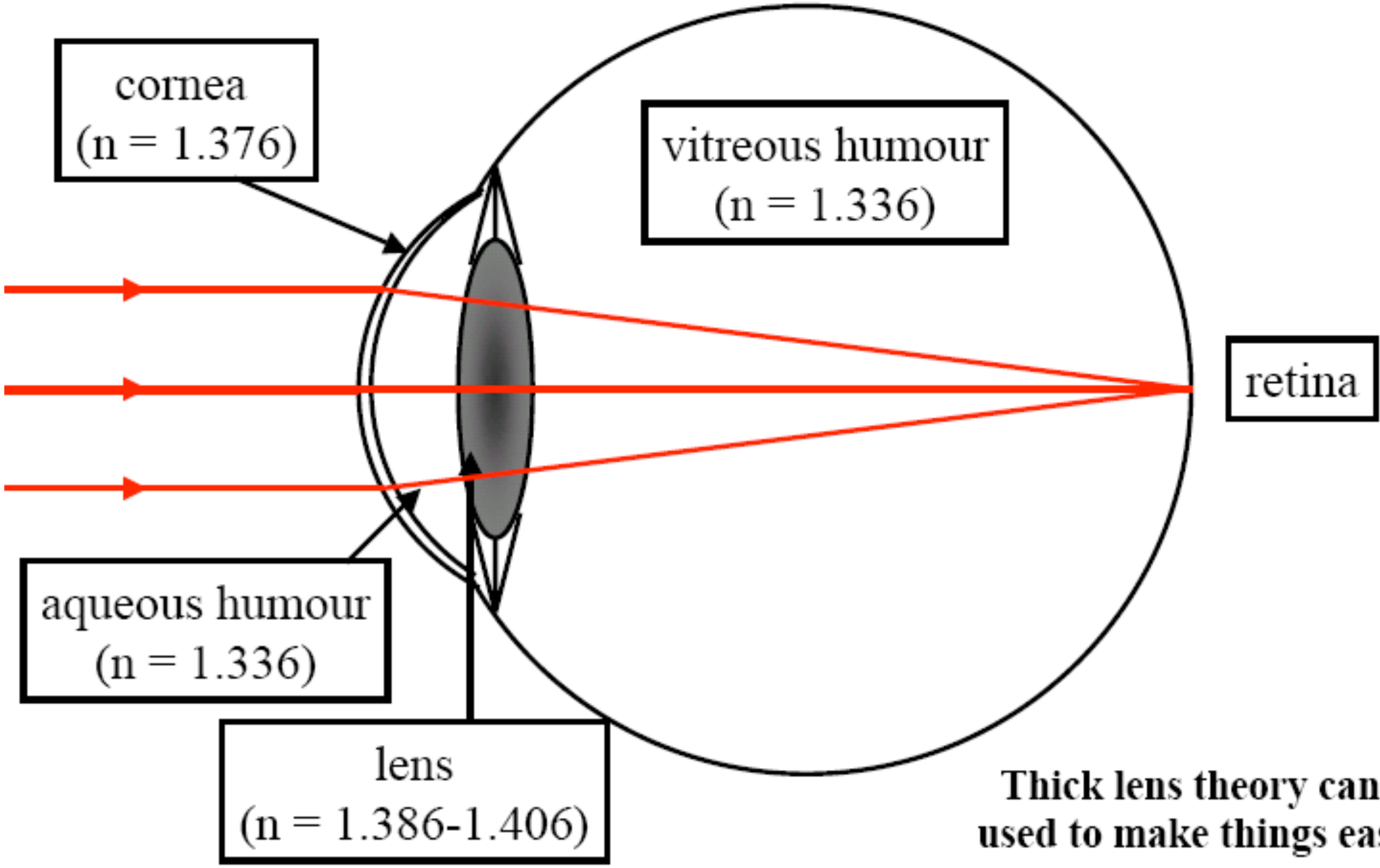
The eye

The eye: complex refracting system.

Most of the refractive power from the surface of the cornea



Thick lens theory can be used to make things easier!

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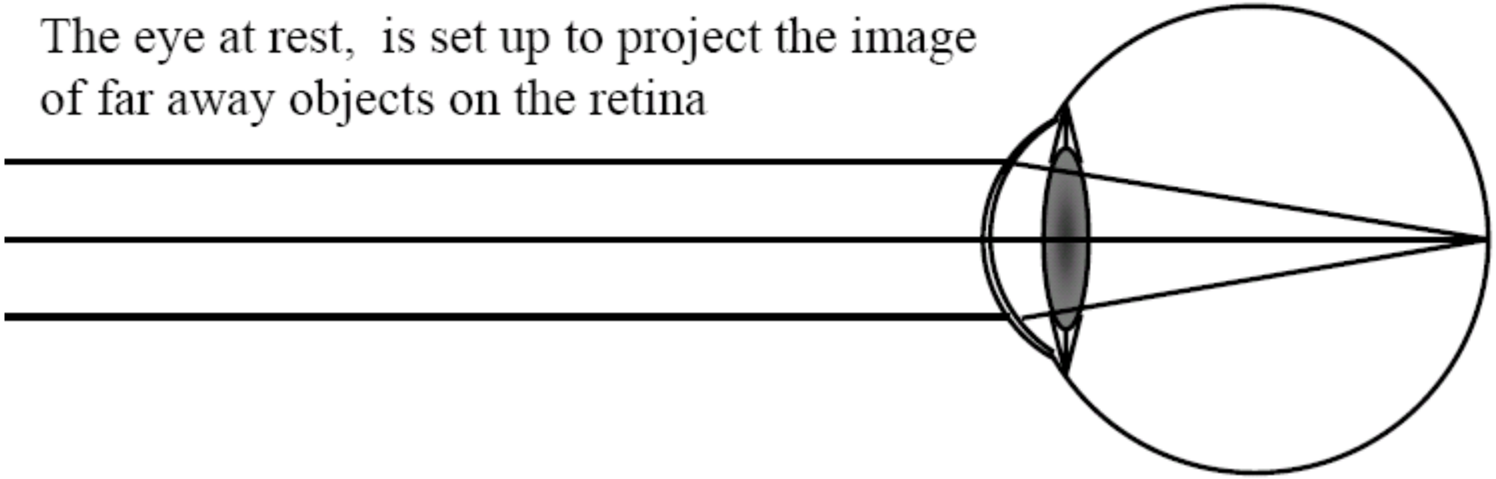
Accommodation

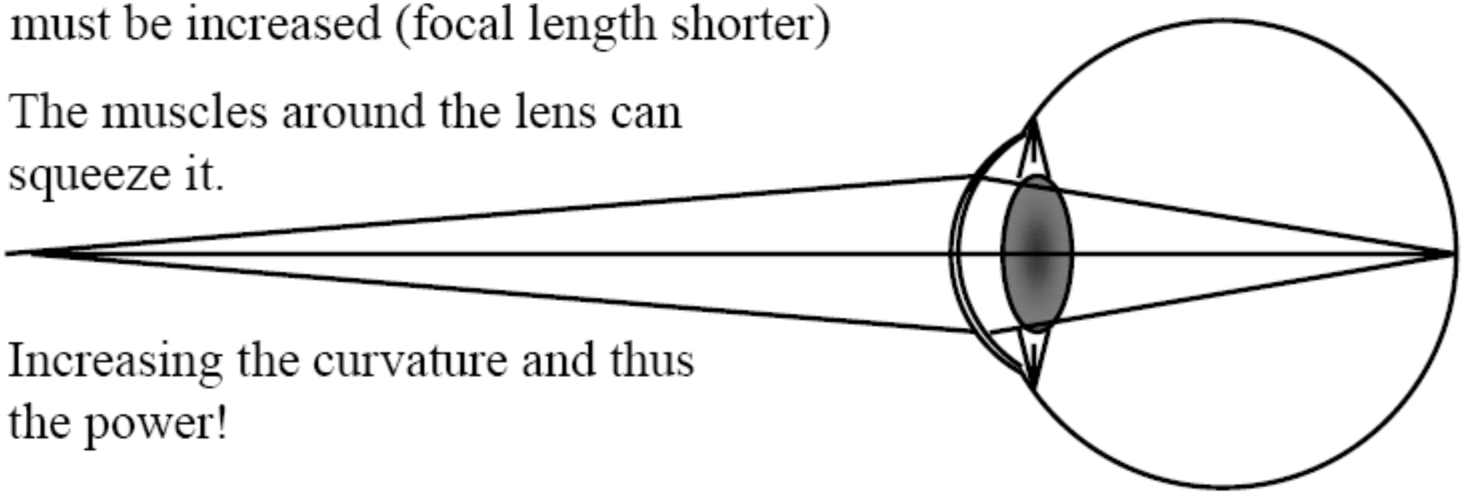
Accommodation

The eye at rest, is set up to project the image of far away objects on the retina



To look at nearer object (light rays must be bent more) the lens power must be increased (focal length shorter)

The muscles around the lens can squeeze it.



Increasing the curvature and thus the power!

Near/far point

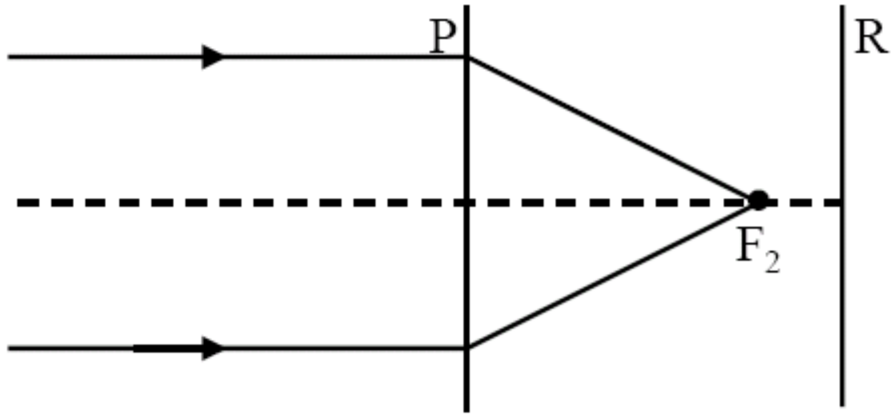
Far-point: point from where object are focussed on the retina when the eye is at rest (far-away or infinity for a normally functioning eye.

Near-point: closest point to the eye from where an object can be brought to focus (seen sharply) when full accommodation is used.

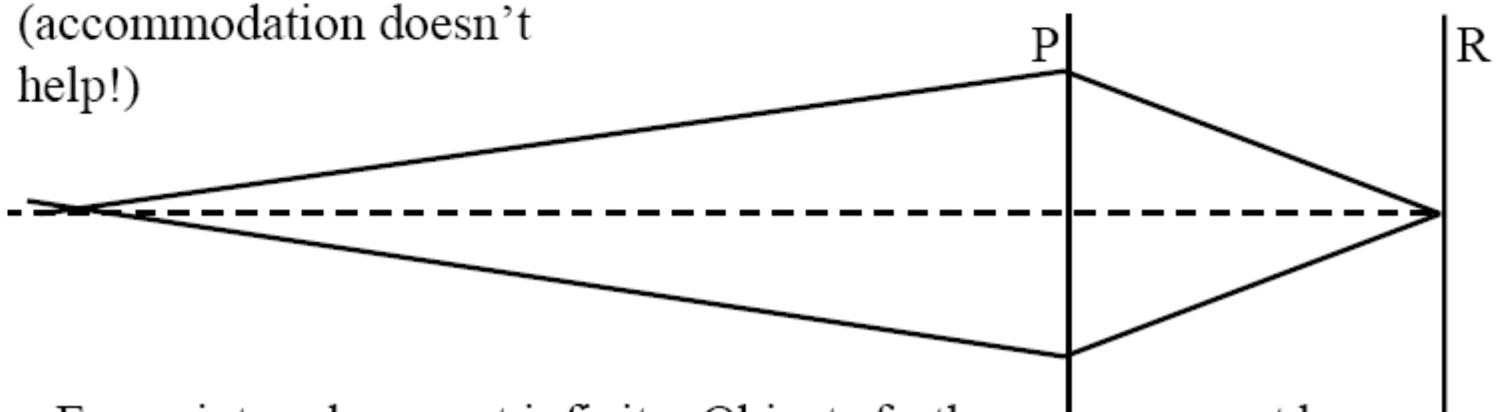
Anything between the near point and the far point can be brought to a focus on the retina.
(the distance between the two is called the **range of accommodation**)

Myopia

Myopia (near-sightedness)
Lens power of the eye is too strong (or the eye itself too long)



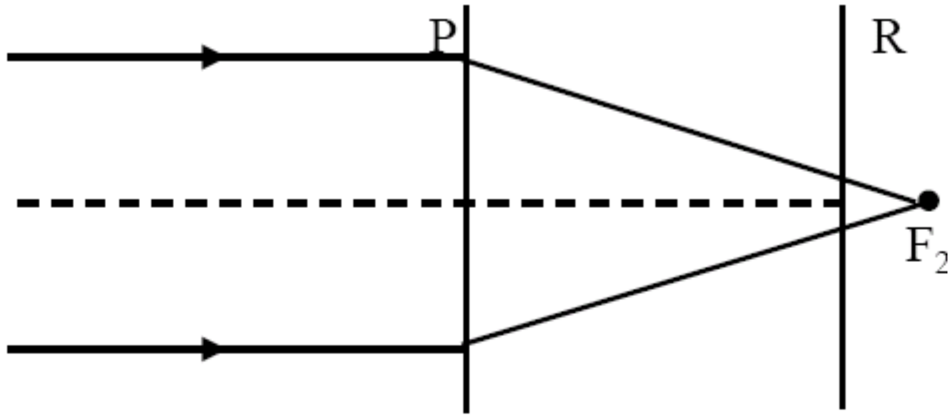
Light from far away object focussed in front of retina. i.e. focal point in front of retina)
(accommodation doesn't help!)



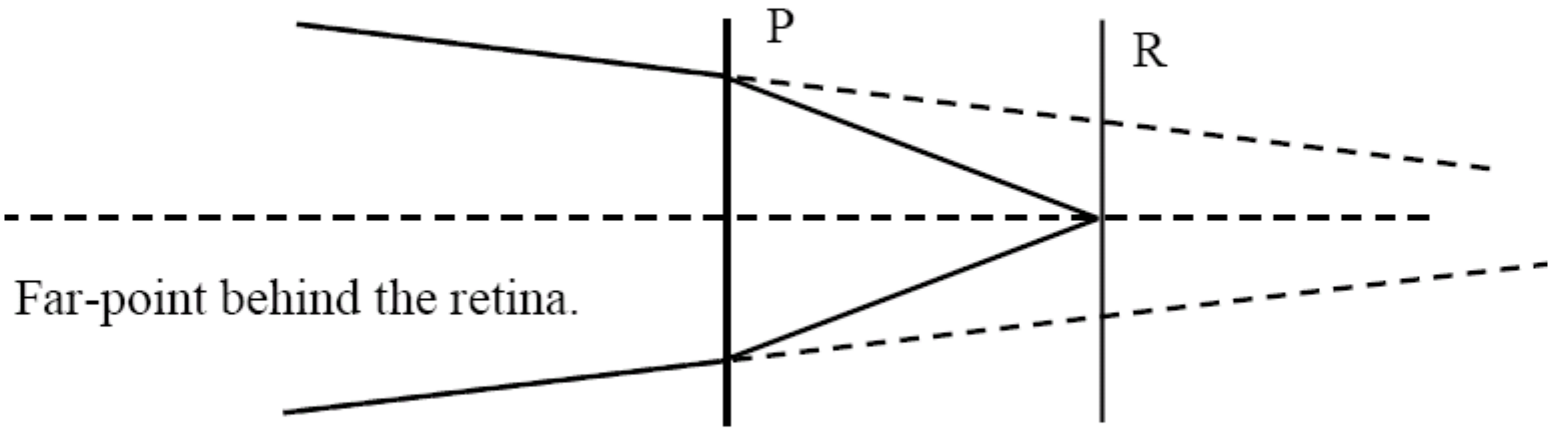
Far-point no longer at infinity. Objects further away cannot be seen sharp.

Hypermetropia

Hypermetropia (far-sightedness)
Lens power of the eye is too weak (or the eye itself too short)



Light from far away object focussed behind retina.
(need accommodation to focus!)



Far-point behind the retina.