

light bends at every boundary it crosses, and geometrical optics is just bookkeeping for exactly how much

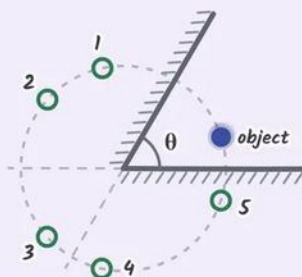
Light, and the four laws behind ray optics

- light: an electromagnetic wave that also carries energy as photons, a dual nature
- each picture explains its own set: ray optics for mirrors, lenses, prisms
- wave optics: interference, diffraction. particle nature: photoelectric effect
- four laws: straight lines in a homogeneous, isotropic medium; crossing rays don't disturb each other
- reflection: angle of incidence = angle of reflection. refraction: Snell's law
- straight travel, reflection, refraction all follow from Fermat's least time; ray independence is a separate assumption

Multiple images between two inclined mirrors



- for two plane mirrors at angle θ , let $n = \frac{360^\circ}{\theta}$
- n even: number of images $N = n - 1$, whatever the object's position between them
- n odd, object on the bisector: $N = n - 1$
- n odd, object off the bisector: $N = n$
- n not a whole number: N is the integer part of n
- all the images lie on one circle through the object, centred where the mirrors meet



mirrors at 60° : $360^\circ/\theta$ is even, so $N = n - 1$, five images, each an image of an image

Cartesian sign convention

- distances from the pole, incident light drawn left to right
- along the incident light positive, against it negative
- heights above the principal axis positive, below negative
- a real object sits left of the pole: u is always negative

Spherical mirrors

focal length, radius of curvature $f = \frac{R}{2}$

mirror formula $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$

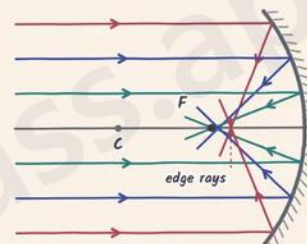
lateral magnification $m = -\frac{v}{u}$

focal power, in dioptre $P = \frac{1}{f}$

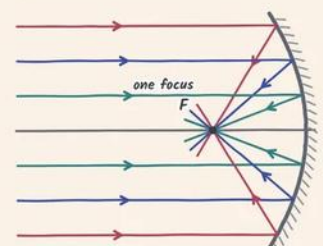
convex mirror's f is positive, concave's is negative

Spherical aberration

- $f = R/2$ and one sharp focus: paraxial rays only
- outer rays focus nearer the pole: a blur, the circle of least confusion
- a parabolic mirror has none: parallel rays meet at one focus
- so searchlights, torches, headlights, reflecting telescopes use parabolic mirrors



spherical mirror: rays near the axis cross it at F , the edge rays (pink) nearer the mirror, so a point blurs



parabolic mirror: every ray parallel to the axis passes through the one focus F