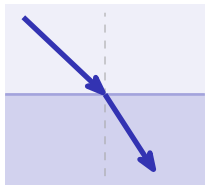
Geometric Optics

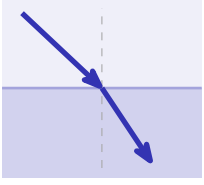
AP Physics 2 ▪ Unit 13

AP Physics 2



What we will cover

1. Reflection
2. Images formed by mirrors
3. Refraction and Snell's law
4. Images formed by lenses

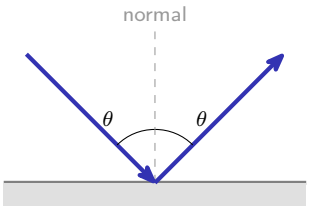


1 Reflection

Reflection

Model light as a **ray** 光线. The **law of reflection** 反射定律: the angle of incidence equals the angle of reflection (from the normal).

- **specular** 镜面反射 – smooth surface, a clear image
- **diffuse** 漫反射 – rough surface, scattered rays



2 Mirrors

Images formed by mirrors

Mirror equation

$$\frac{1}{s_o} + \frac{1}{s_i} = \frac{1}{f}, \quad m = -\frac{s_i}{s_o}$$

- **real** 实像 ($s_i > 0$): can be projected on a screen
- **virtual** 虚像 ($s_i < 0$): only appears behind the mirror
- $m < 0$ inverted; $|m| > 1$ enlarged

Worked example

Object $30\,\mathrm{cm}$, concave $f = 10\,\mathrm{cm}$:

$$\tfrac{1}{30} + \tfrac{1}{s_i} = \tfrac{1}{10} \Rightarrow s_i = 15\,\mathrm{cm}$$

$$m = -\tfrac{15}{30} = -0.5$$

Real, inverted, half size.

Mirrors, and the number that bends light

Concave mirror	A **concave mirror** curves inward and converges light: a real inverted image beyond the focal point, a virtual upright one inside it.
Convex mirror	A **convex mirror** curves outward and diverges light – always a virtual, upright, reduced image, which is why it is used for a wide view.
The equation	$\frac{1}{s_o} + \frac{1}{s_i} = \frac{1}{f}$, with $f = R/2$ and a sign convention that decides real from virtual.
Index of refraction	The **index of refraction** $n = c/v$ says how much slower light travels in the material – and Snell's law $n_1 \sin\theta_1 = n_2 \sin\theta_2$ follows from it.

Draw two principal rays. The intersection is the image; whether the rays actually meet there decides real against virtual.

3 Refraction

Refraction and Snell's law

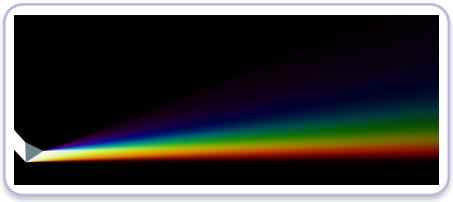
Crossing into a new medium, light changes speed and bends:

Snell's law

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

index 折射率 $n = c/v$; higher n bends light more.

Past the **critical angle** 临界角 ($\sin\theta_c = n_2/n_1$): **total internal reflection** 全内反射 – fibre optics.



Refraction bends light at boundaries

4 Lenses

Images formed by lenses

A **converging lens** 会聚透镜 (convex) bends parallel rays to a focus; a **diverging lens** 发散透镜 spreads them.

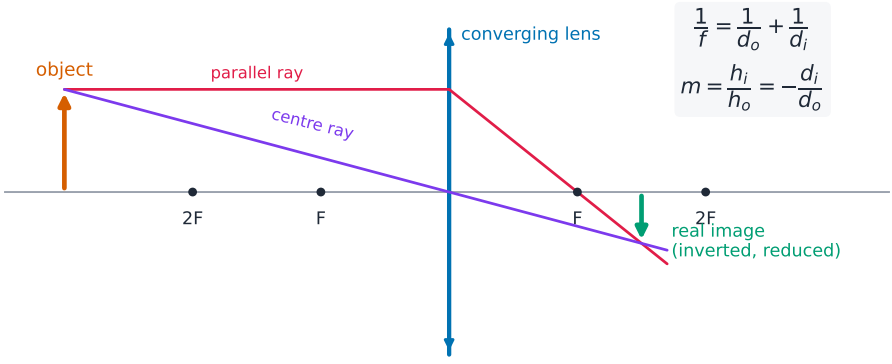
Thin-lens equation

$$\frac{1}{s_o} + \frac{1}{s_i} = \frac{1}{f}$$

Same form as the mirror equation; a camera and the eye cast a real image.

Lenses form real and virtual images

Images Formed by Lenses, continued

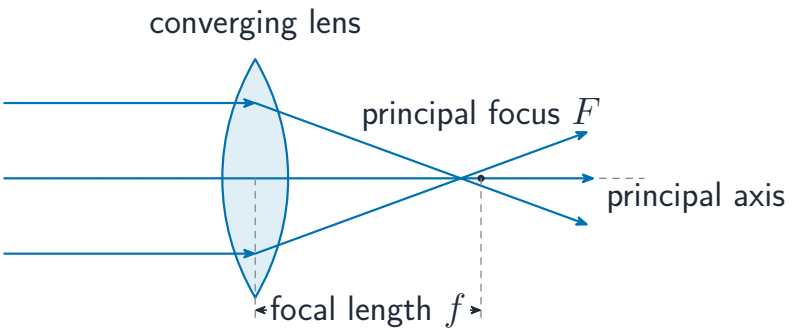


$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

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

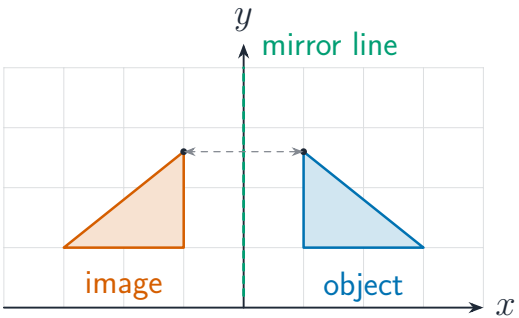
Two rays locate the image: parallel-then-focus, and straight through the centre

Images Formed by Lenses, continued (2)



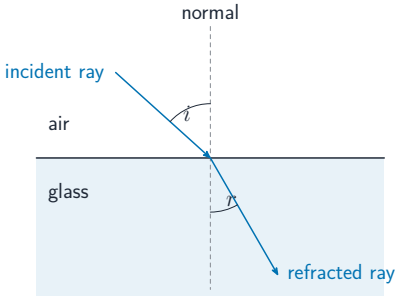
A converging lens brings parallel rays to its principal focus

Reflection, continued



The law of reflection: the angle of incidence equals the angle of reflection

Refraction



Light refracts, bending towards the normal as it enters glass

Exam tips

- Measure all angles from the **normal**, not the surface.
- Light entering a **denser** medium (larger n) bends **toward** the normal; use Snell's law $n_1 \sin\theta_1 = n_2 \sin\theta_2$.
- Total internal reflection happens only going into a **less** dense medium, beyond the critical angle ($\sin\theta_c = 1/n$).
- For mirrors and lenses use $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$ and $m = -d_i/d_o$: a **positive** d_i is a real image, negative is virtual.
- $n = c/v$, so a bigger index means a slower speed of light in the material.

5 Recap

Unit 13 – key takeaways

1 Reflection

angle in $=$ angle out from the normal

2 Mirrors

$1/s_o + 1/s_i = 1/f$; $m = -s_i/s_o$

3 Refraction

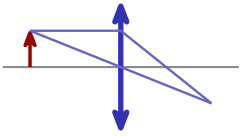
$n_1 \sin\theta_1 = n_2 \sin\theta_2$; TIR past the critical angle

4 Lenses

same thin-lens equation; converging casts a real image

Check yourself

1. A ray hits a mirror at 25° to the normal – at what angle does it leave?
2. A negative magnification means the image is…?
3. Light enters a denser medium – does it bend toward or away from the normal?
4. What effect makes fibre-optic cables work?



Answers **1.** 25° **2.** inverted **3.** toward the normal **4.** total internal reflection