IGCSE PHYSICS 0625 · CHAPTER 8 NOTES · ~11 MIN READ

Light & the EM spectrum

Mirrors, refraction, total internal reflection, lenses, colour — and all seven families of electromagnetic waves with uses, dangers and a mnemonic.

Plane mirrors | Refraction & critical angle | Optical fibres | Dispersion | Converging lenses | Sight correction | Electromagnetic spectrum | Digital & analogue signals

RS by Riyaz Sir
mentorriyaz.in

No tag = **Core** (everyone) EXTENDED Extended only highlight = comes up again and again

Test yourself at the end

IN 30 SECONDS

- **Reflection:** angle of incidence = angle of reflection, both measured from the **normal**.
- **Refraction:** light bends towards the normal when it slows down (air → glass). EXT n = sin i ÷ sin r and n = 1 ÷ sin c.
- **Total internal reflection** happens inside a dense material when the angle is bigger than the **critical angle**.
- A converging lens makes a **real** image if the object is beyond F, and a **virtual, magnified** image if the object is inside F. EXT
- The EM spectrum, from long to short wavelength: **radio, microwave, infrared, visible, ultraviolet, X-ray, gamma**. All travel at 3.0 × 10^8 m/s in a vacuum.

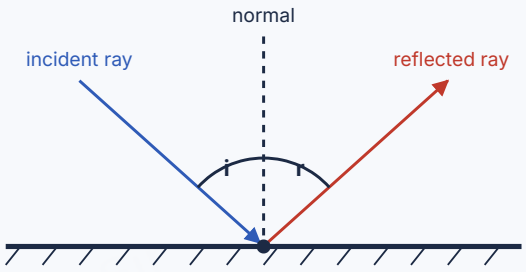
BY THE END YOU CAN

- Draw and use the law of reflection for a plane mirror and describe the image.
- Describe refraction, the critical angle and total internal reflection, and calculate n. EXT
- Describe dispersion and the colours of the spectrum.
- Draw ray diagrams for a converging lens and describe the image.
- List the EM waves in order with uses and dangers.

1 Reflection

Plane mirrors

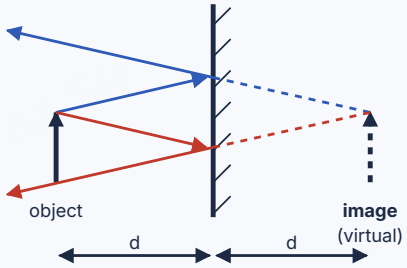
Normal — a line drawn at 90° to the surface at the point where the ray hits.



angle of incidence i = angle of reflection r
both angles are measured from the NORMAL

The law of reflection: angle of incidence (i) = angle of reflection (r). Both angles are measured from the normal, never from the mirror surface.

image: same size, upright, same distance behind the mirror



rays only APPEAR to come from the image (dotted lines)

The image in a plane mirror: same size as the object, upright, the same distance behind the mirror as the object is in front, and virtual.

- A **virtual** image cannot be shown on a screen, because the rays only seem to come from it (dotted lines). The image is also laterally inverted (left and right swapped).

WORKED EXAMPLE

A ray hits a plane mirror making an angle of 30° with the mirror surface. Find the angle of incidence and the angle between the incident and reflected rays.

1. The normal is at 90° to the surface, so i = 90° − 30° = **60°**
2. r = i = 60°
3. **angle between incident and reflected rays = 60° + 60° = 120°**

WORKED EXAMPLE

EXT **A person stands 2.0 m in front of a plane mirror. How far is the person from their image?**

1. The image is 2.0 m behind the mirror
2. **distance from the person = 2.0 + 2.0 = 4.0 m**

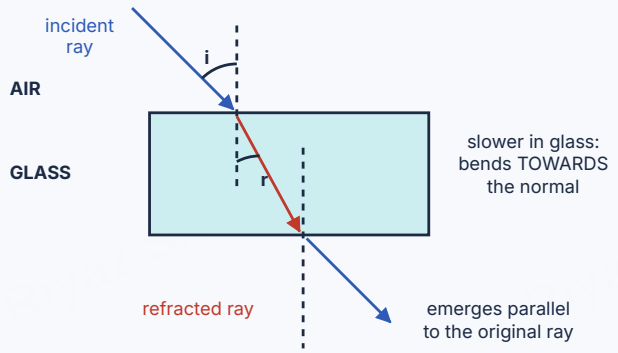
COMMON MISTAKE

Measuring the angle of incidence from the mirror instead of from the normal.

2 Refraction

Refraction of light

Refraction — the change in direction of light when it passes from one transparent material to another, caused by a change in speed.



Air to glass: light slows down and bends TOWARDS the normal. Glass to air: it speeds up and bends AWAY. Through a parallel-sided block the ray comes out parallel to the one that went in.

- A ray going into a denser material (air → glass or water) slows down and bends **towards the normal**. A ray leaving bends **away** from it. A ray along the normal (90° to the surface) goes straight through without bending.
- EXT The **refractive index** n of a material shows how much it slows light: n = (speed in vacuum) ÷ (speed in the material). Glass has n ≈ 1.5.

EXT $$n = \frac{\sin i}{\sin r}$$

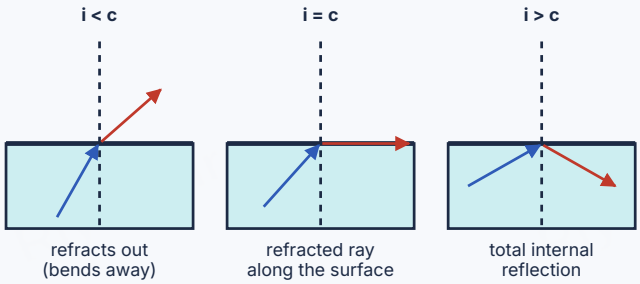
i = angle in air, r = angle in the material (both from the normal)

WORKED EXAMPLE

EXT **A ray enters glass at i = 45° and refracts at r = 28°. Find n.**

1. n = sin i ÷ sin r = sin 45° ÷ sin 28°
2. = 0.707 ÷ 0.469
3. **= 1.5**

Critical angle and total internal reflection



c = critical angle: only light going from a denser to a less dense medium

As the angle inside glass increases, the refracted ray bends towards the surface. At the critical angle c it runs along the surface. Beyond c all the light is reflected.

Critical angle (c) — the angle of incidence inside a dense material for which the refracted ray travels along the boundary (an angle of refraction of 90°).

- **Total internal reflection** happens only if (1) light travels from a **denser** to a **less dense** material and (2) the angle of incidence is **greater than the critical angle**.
- Below c, some light refracts out and a little is reflected. This partial reflection is called **internal reflection**.

EXT $$n = \frac{1}{\sin c}$$

or sin c = 1 ÷ n

WORKED EXAMPLE

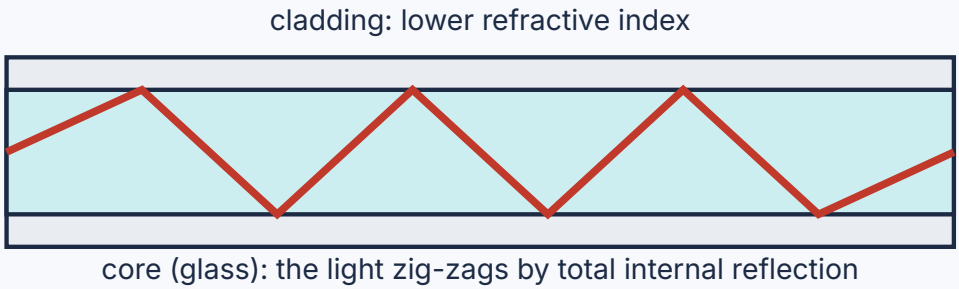
EXT **Glass has n = 1.5. Find the critical angle.**

1. sin c = 1 ÷ n = 1 ÷ 1.5 = 0.667
2. **c = 42°**

- Uses: bicycle reflectors and prisms in binoculars and periscopes.

Optical fibres

EXTENDED



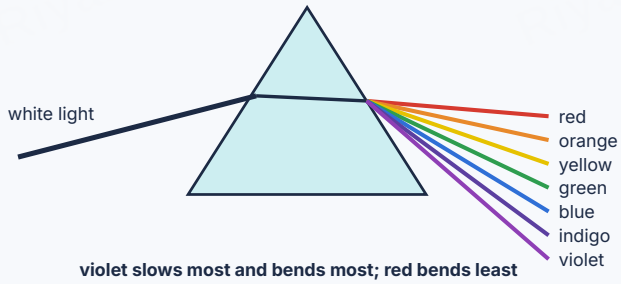
used for: endoscopes · broadband & phone signals · very little energy lost

Light zig-zags along the glass core by total internal reflection. The outer cladding has a lower refractive index.

- Used for **broadband, cable TV and phone signals** (infrared or light pulses carry the data) and **endoscopes** that look inside the body. Almost no energy is lost, so signals travel a long way.

3 Colour

Dispersion



violet slows most and bends most; red bends least
(this is why white light splits into a spectrum)

White light is a mixture of colours. In glass violet slows most, so it bends most; red bends least. A prism splits white light into a spectrum.

- **Dispersion** is the splitting of white light into its colours.
- Order: **red, orange, yellow, green, blue, indigo, violet**. Red has the **longest wavelength and lowest frequency**; violet has the **shortest wavelength and highest frequency**.
- EXT **Monochromatic** light has a single frequency, so it is only one colour.

EXAM TIP

In a vacuum all colours travel at the same speed. They are only separated because they travel at different speeds in glass.

4 Lenses

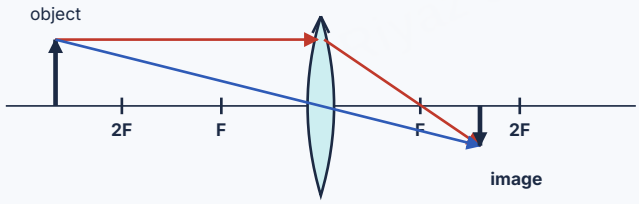
Converging lens ray diagrams

Principal axis — the line through the centre of the lens at right angles to it.

Principal focus (F) — the point where rays parallel to the axis meet after a converging lens.

Focal length — the distance from the centre of the lens to F.

- A **converging (convex)** lens bends parallel rays so that they meet at F. A **diverging (concave)** lens spreads them out.
- Draw a ray diagram using two rays: **(1)** a ray parallel to the axis, which refracts through F; **(2)** a ray through the centre of the lens, which goes straight on. The image is where they cross.



object beyond 2F → image between F and 2F: real, inverted, diminished

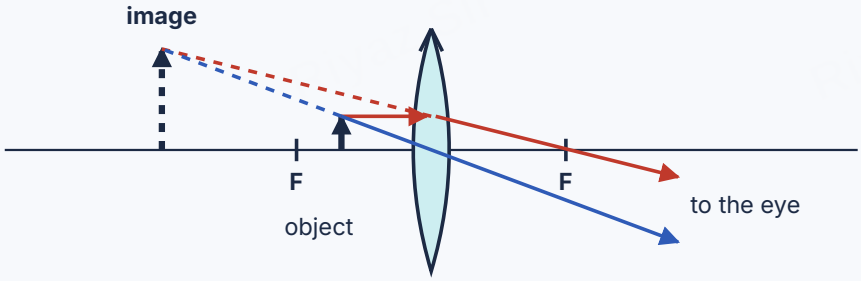
Object beyond 2F: the image is between F and 2F, real, inverted and smaller.

Object position	Image
beyond 2F	between F and 2F; real, inverted, smaller
at 2F	at 2F; real, inverted, same size
between F and 2F	beyond 2F; real, inverted, bigger
inside F	virtual, upright, magnified EXT

- A **real** image can be projected onto a screen. A **virtual** image cannot.

Magnifying glass and sight correction

EXTENDED



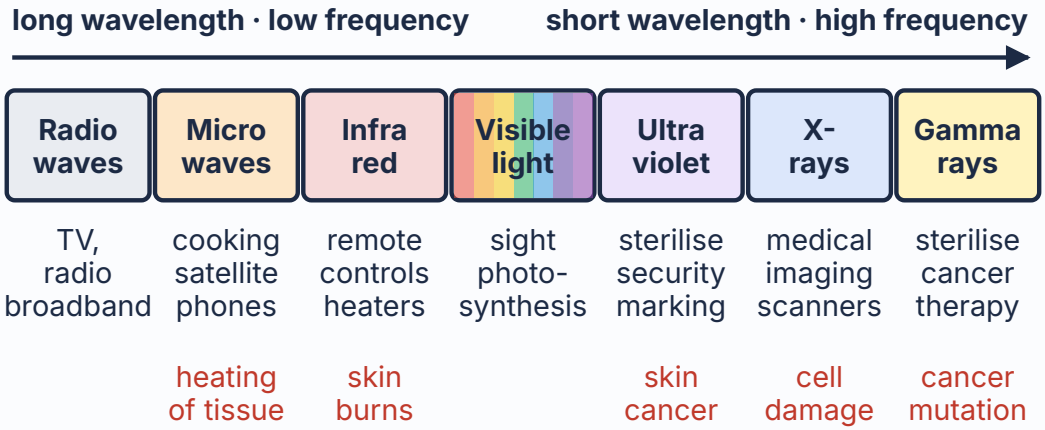
object INSIDE F → virtual, upright, magnified image
(a magnifying glass)

An object inside F gives an upright, magnified, virtual image. The lens is used as a magnifying glass.

Sight problem	Cause	Corrected with
short sight: far objects blurred	light focuses in front of the retina	diverging lens
long sight: near objects blurred	light focuses behind the retina	converging lens

5 The electromagnetic spectrum

Seven families of waves



black = uses · red = dangers

all are transverse waves that travel at 3 × 10^8 m/s in a vacuum

All EM waves are transverse and travel at 3.0 × 10^8 m/s in a vacuum, about the same in air. They differ in wavelength and frequency.

MEMORY TRICK

Raging Martians Invaded Venus Using X-ray Guns — **R**adio, **M**icrowave, **I**nfrared, **V**isible, **U**ltraviolet, **X**-ray, **G**amma (long wavelength to short).

Wave	Uses	Danger of too much
radio	TV, radio, Bluetooth EXT	—
microwaves	cooking, satellite signals, mobile phones EXT, wifi EXT	heating of body cells inside the body
infrared	remote controls, heaters, thermal cameras, burglar alarms	skin burns
visible	seeing, photography, photosynthesis	very bright light damages the eye
ultraviolet	sterilising water, security marks, sun beds	skin cancer and eye damage
X-rays	medical images, airport security	damage to cells, cancer
gamma rays	sterilising food and instruments, treating cancer	damage to cells, cancer

- **Satellite communication** uses microwaves, which pass through the atmosphere. Both low-orbit and geostationary satellites are used (see the space chapter).

WORKED EXAMPLE

EXT **Sunlight takes how long to reach the Earth? (distance 1.5×10^{11} m, speed of light 3.0×10^{8} m/s)**

1. t = distance ÷ speed = $1.5 \times 10^{11} \div 3.0 \times 10^{8}$
2. = 500 s
3. **= 8.3 minutes**

Digital and analogue signals

EXTENDED

- An **analogue** signal varies continuously. A **digital** signal has only two values (on and off, or 1 and 0).
- Sound, pictures and data can be sent as either. A digital signal can be **cleaned up** (regenerated) as it travels, so it keeps a high quality over long distances. It can also carry more information and works with computers.

6 Test yourself

Test yourself — cover the answers first

QUICK CHECK

1. State the law of reflection.
2. Give two properties of the image in a plane mirror.
3. Which colour of light bends the most in a prism?
4. Name the EM waves used for (a) cooking, (b) sterilising food.
5. Which EM waves have the highest frequency?
6. What two conditions are needed for total internal reflection?

EXAM-STYLE

7. EXT Light goes from air into glass with i = 40°. The refractive index of the glass is 1.5. Find the angle of refraction.
8. EXT The refractive index of water is 1.33. Find the critical angle.
9. Describe the image formed by a converging lens (f = 10 cm) when an object is 30 cm from the lens. [3]
10. EXT Explain how an optical fibre carries a signal. [3]
11. State two differences between light waves and sound waves. [2]

Show answers

1. The angle of incidence equals the angle of reflection (both from the normal).
2. virtual, upright, same size as the object, same distance behind the mirror
3. violet
4. (a) microwaves (b) gamma rays
5. gamma rays
6. Light goes from a denser to a less dense material, and the angle of incidence is greater than the critical angle.
7. sin r = sin i ÷ n = sin 40° ÷ 1.5 = 0.6428 ÷ 1.5 = 0.4285
   r = 25°
8. sin c = 1 ÷ 1.33 = 0.752
   c = 49°
9. The object is beyond 2F (20 cm)
   so the image is between F and 2F
   it is real, inverted and smaller
10. Light enters the glass core
    and hits the core–cladding boundary at an angle bigger than the critical angle
    so it is totally internally reflected again and again along the fibre
11. Light is transverse, sound is longitudinal
    light can travel through a vacuum, sound cannot (or: light travels much faster)

Stuck on a question?

Send it to me on WhatsApp. I read every message.

Want regular help? Send this to your parent →

Share with a friend

Ask Riyaz Sir