

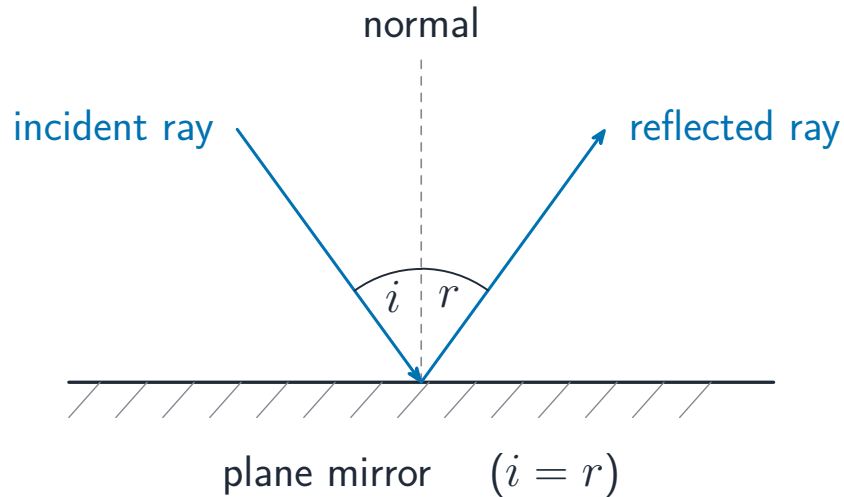
Exercise walk-through

3.2

Light

IGCSE Physics

Try it: measure from the mirror or the normal?



Schematic; do not measure this drawing.

An incident ray makes an angle of 30° with a plane mirror's **surface**.

Use the **normal** to find the angle of incidence i and angle of reflection r .

A student writes $i = r = 30^\circ$. Explain the mistake and describe how to draw the reflected ray.

Construct the normal before using the law

The **normal** is perpendicular to the mirror at the point where the incident ray meets it. It makes 90° with the surface.

The given surface angle $\theta = 30^\circ$ is not the angle of incidence:

$$i = 90^\circ - \theta = 90^\circ - 30^\circ = 60^\circ$$

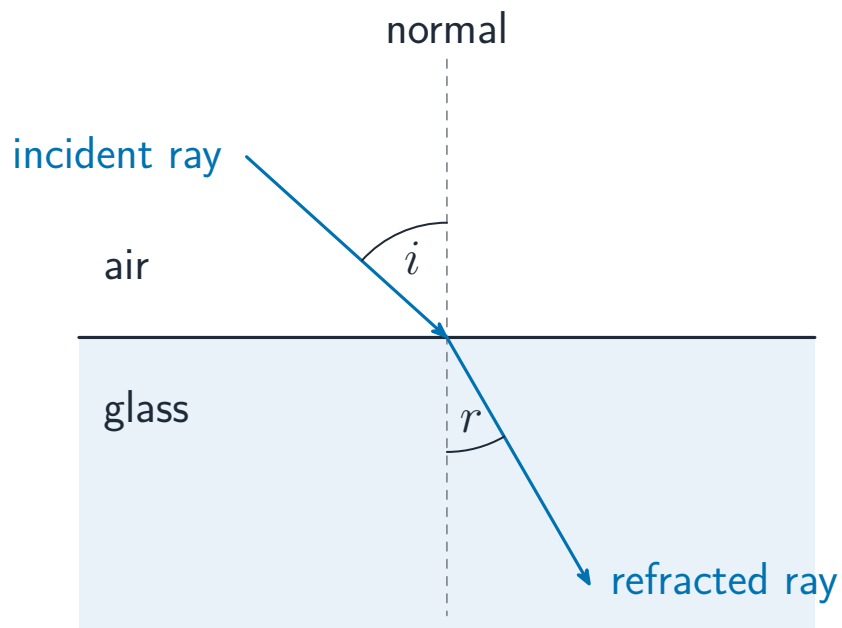
Reflection gives equal angles on opposite sides of the normal:

$$r = i = 60^\circ$$

Draw the reflected ray away from the mirror at 60° to the normal. The incident ray, normal and reflected ray lie in one plane.

Measure i and r from the normal. The reflected ray makes 30° with the mirror surface, just like the incident ray.

Refraction



bends towards the normal ($i > r$)

Light bends as it changes speed.

Refractive index :

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

$$i = 60^\circ, r = 35^\circ$$

$$n = \frac{0.87}{0.57} = 1.5$$

The words a refraction question uses

The two angles

The angle of incidence is measured in the first material, the **angle of refraction** in the second – both from the *normal*.

Which way it bends

Into a denser material: slower, and bent *towards* the normal. Out into a less dense one: faster, and bent away.

Wave speed

The frequency never changes; it is the **wave speed** and the wavelength that do – and $v = f\lambda$ ties them together.

Propagation

Refraction is a change in the direction of **propagation**, caused entirely by the change in speed.

Always measure from the normal, never from the surface. Half the lost marks in this topic are that one habit.

Total internal reflection

Light going from a denser medium towards a less dense one: if the angle of incidence is greater than the **critical angle**, it reflects entirely. Optical fibres use this to carry signals.

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

Exercises 2.1·2.3

2.1 State the law of reflection.

[1]

2.2 An object is 5 cm in front of a plane mirror. State three characteristics of its image.[3]

2.3 Light enters glass with $\sin i = 0.80$ and $\sin r = 0.50$. Find the refractive index. [2]

Exercises 2.1·2.3

2.1 State the law of reflection. [1]

2.1

- the angle of incidence equals the angle of reflection, both measured from the normal
-

2.2 An object is 5 cm in front of a plane mirror. State three characteristics of its image.[3]

2.2

- any three of: virtual; the same size as the object; 5 cm behind the mirror (the same distance as the object is in front); laterally inverted
-

2.3 Light enters glass with $\sin i = 0.80$ and $\sin r = 0.50$. Find the refractive index. [2]

2.3

- $n = \sin i / \sin r$

$$n = \frac{0.80}{0.50} = \mathbf{1.6}$$

Exercises 2.4·2.5

2.4 Light enters a plastic block of refractive index 1.4 at an angle of incidence of 50° . Calculate the angle of refraction. ($\sin 50^\circ = 0.766$) [3]

2.5 Diamond has a refractive index of 2.4. Calculate its critical angle. [2]

Exercises 2.4·2.5

2.4 Light enters a plastic block of refractive index 1.4 at an angle of incidence of 50° . Calculate the angle of refraction. ($\sin 50^\circ = 0.766$) [3]

2.4

- $\sin r = \sin i / n$

$$\sin r = \frac{0.766}{1.4} = 0.547$$

- $r = \mathbf{33^\circ}$

2.5 Diamond has a refractive index of 2.4. Calculate its critical angle. [2]

2.5

- $\sin c = 1/n$

$$\sin c = \frac{1}{2.4} = 0.417 \Rightarrow c = \mathbf{25^\circ}$$

Exercises 2.6·2.7

2.6 Describe what happens to a ray inside glass that meets the surface at an angle greater than the critical angle, and give one use of this effect. [2]

2.7 Define the terms focal length and principal focus of a converging lens. [2]

Exercises 2.6·2.7

2.6 Describe what happens to a ray inside glass that meets the surface at an angle greater than the critical angle, and give one use of this effect. [2]

2.6

- it is totally internally reflected: none of the light leaves the glass and the angle of reflection equals the angle of incidence
- use: optical fibres (or prisms in binoculars, or road and bicycle reflectors)

2.7 Define the terms focal length and principal focus of a converging lens. [2]

2.7

- focal length: the distance from the centre of the lens to the principal focus
- principal focus: the point on the principal axis where rays parallel to the axis meet after passing through the lens

Exercises 2.8-2.9

2.8 A converging lens is used as a magnifying glass. State where the object must be placed, and describe the image using three words. [3]

2.9 State the order of the colours of the spectrum, starting with the one of highest frequency, and state what monochromatic light is. [2]

Exercises 2.8-2.9

2.8 A converging lens is used as a magnifying glass. State where the object must be placed, and describe the image using three words. [3]

2.8

- between the lens and its principal focus (closer to the lens than F)
- the image is enlarged, upright and virtual

2.9 State the order of the colours of the spectrum, starting with the one of highest frequency, and state what monochromatic light is. [2]

2.9

- violet, indigo, blue, green, yellow, orange, red
- monochromatic light is light of a single frequency (a single colour)

Exercise 3.1

3.1 A ray of light travelling in glass ($n = 1.5$) meets a glass–air surface at an angle of incidence of 45° . What happens to the ray? [1]

☐

A It refracts into the air, bending towards the normal.

B It refracts into the air, bending away from the normal.

C It travels along the surface.

D It is totally internally reflected.

Exercise 3.1

3.1 A ray of light travelling in glass ($n = 1.5$) meets a glass–air surface at an angle of incidence of 45° . What happens to the ray? [1]

☐

A It refracts into the air, bending towards the normal.

B It refracts into the air, bending away from the normal.

C It travels along the surface.

D It is totally internally reflected.

3.1 D

- the critical angle is $\sin^{-1}(1/1.5) = 42^\circ$, and 45° is larger, so the ray cannot escape
- A** describes light entering glass; **B** is refraction below the critical angle; **C** happens only exactly at 42°

Exercise 3.2

3.2 Which row describes the image of a person standing in front of a plane mirror? [1]

☐

A virtual, same size, laterally inverted

B real, same size, upright

C virtual, diminished, upright

D real, enlarged, laterally inverted

Exercise 3.2

3.2 Which row describes the image of a person standing in front of a plane mirror? [1]

☐

A virtual, same size, laterally inverted

B real, same size, upright

C virtual, diminished, upright

D real, enlarged, laterally inverted

3.2 A

- a plane mirror image is virtual, the same size, and laterally inverted
- it is never real (**B**, **D**) and never diminished (**C**)

Exercise 3.3 (a)

3.3 A semicircular block of plastic has a refractive index of 1.5. A ray of light travelling inside the block, along a radius, reaches the centre of the flat face.

(a) Calculate the critical angle for the plastic.

[2]

Exercise 3.3 (a)

3.3 A semicircular block of plastic has a refractive index of 1.5. A ray of light travelling inside the block, along a radius, reaches the centre of the flat face.

(a) Calculate the critical angle for the plastic.

[2]

(a) $\sin c = 1/n$

$$\sin c = \frac{1}{1.5} = 0.667 \Rightarrow c = \mathbf{42^\circ}$$

Exercise 3.3 (b)

3.3 A semicircular block of plastic has a refractive index of 1.5. A ray of light travelling inside the block, along a radius, reaches the centre of the flat face.

(b) The ray meets the flat face at an angle of incidence of 50° . State and explain what happens to the ray. [2]

Exercise 3.3 (b)

3.3 A semicircular block of plastic has a refractive index of 1.5. A ray of light travelling inside the block, along a radius, reaches the centre of the flat face.

(b) The ray meets the flat face at an angle of incidence of 50° . State and explain what happens to the ray. [2]

(b) the ray is totally internally reflected at the flat face

- because 50° is greater than the critical angle of 42°

Exercise 3.3 (c)

3.3 A semicircular block of plastic has a refractive index of 1.5. A ray of light travelling inside the block, along a radius, reaches the centre of the flat face.

(c) A different ray, in the air, meets the flat face at an angle of incidence of 40° . Calculate the angle of refraction inside the plastic. ($\sin 40^\circ = 0.643$) [3]

Exercise 3.3 (c)

3.3 A semicircular block of plastic has a refractive index of 1.5. A ray of light travelling inside the block, along a radius, reaches the centre of the flat face.

(c) A different ray, in the air, meets the flat face at an angle of incidence of 40° . Calculate the angle of refraction inside the plastic. ($\sin 40^\circ = 0.643$) [3]

(c) $\sin r = \sin i / n$

$$\sin r = \frac{0.643}{1.5} = 0.429$$

- $r = 25^\circ$

Exercise 3.3 (d)

3.3 A semicircular block of plastic has a refractive index of 1.5. A ray of light travelling inside the block, along a radius, reaches the centre of the flat face.

(d) State two uses of total internal reflection.

[2]

Exercise 3.3 (d)

3.3 A semicircular block of plastic has a refractive index of 1.5. A ray of light travelling inside the block, along a radius, reaches the centre of the flat face.

(d) State two uses of total internal reflection. [2]

(d) any two of: optical fibres for telephone and internet signals; prisms in binoculars or periscopes; reflectors on bicycles and roads; endoscopes in medicine

Exercise 3.3 (e)

3.3 A semicircular block of plastic has a refractive index of 1.5. A ray of light travelling inside the block, along a radius, reaches the centre of the flat face.

(e) State what happens to the speed of the light as it passes from the air into the plastic.[1]

Exercise 3.3 (e)

3.3 A semicircular block of plastic has a refractive index of 1.5. A ray of light travelling inside the block, along a radius, reaches the centre of the flat face.

(e) State what happens to the speed of the light as it passes from the air into the plastic.[1]

(e) it slows down

Setup for exercise 3.4

3.4 Fig. 3.1 shows an object 2.0 cm tall placed 6.0 cm from a converging lens. The two principal foci are marked F.

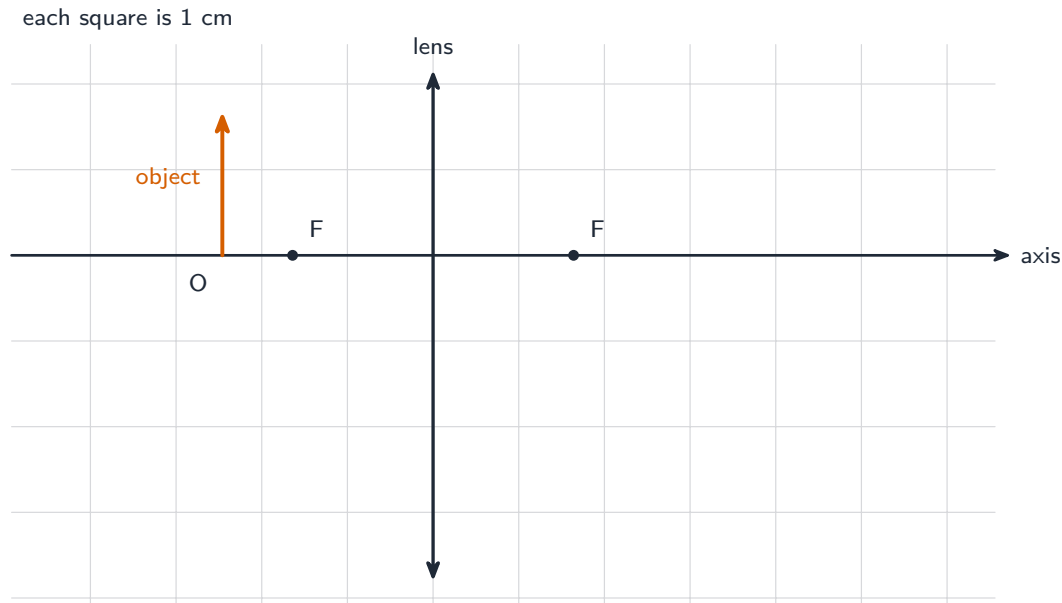


Fig. 3.1 (each square is 1 cm)

Exercise 3.4 (a)

(a) On Fig. 3.1, draw two rays from the top of the object to locate the image. Label the image I, and determine the distance of the image from the lens. [3]

Exercise 3.4 (a)

(a) On Fig. 3.1, draw two rays from the top of the object to locate the image. Label the image I, and determine the distance of the image from the lens. [3]

(a) ray from the top of the object parallel to the axis, refracting at the lens through the far F

- ray from the top of the object through the centre of the lens, undeviated
- the two rays cross 12 cm beyond the lens, 4 cm below the axis, so the image I is 12 cm from the lens

Exercise 3.4 (b)

(b) Describe the image using three words.

[2]

Exercise 3.4 (b)

(b) Describe the image using three words.

[2]

(b) real, inverted and enlarged

Exercise 3.4 (c)

(c) The object is moved to 3.0 cm from the lens. State two ways in which the image changes. [2]

Exercise 3.4 (c)

(c) The object is moved to 3.0 cm from the lens. State two ways in which the image changes. [2]

(c) the object is now inside F , so the image becomes virtual and upright, on the same side of the lens as the object

- it is still enlarged

Exercise 3.4 (d)

(d) Explain how a diverging lens placed in front of an eye corrects short-sightedness. [2]

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(d) Explain how a diverging lens placed in front of an eye corrects short-sightedness. [2]

(d) the eye focuses light from a distant object in front of the retina

- the diverging lens spreads the rays out before they enter the eye, so they now meet on the retina

Exercise 3.5 (a)

3.5 A narrow beam of white light enters a glass prism.

(a) Describe what is seen on a screen placed after the prism, and name this effect. [2]

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(a) Describe what is seen on a screen placed after the prism, and name this effect. [2]

(a) a band of colours (a spectrum) from red to violet

- the effect is dispersion

Exercise 3.5 (b)

3.5 A narrow beam of white light enters a glass prism.

(b) State which colour is refracted the most, and explain why in terms of frequency. [2]

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3.5 A narrow beam of white light enters a glass prism.

(b) State which colour is refracted the most, and explain why in terms of frequency. [2]

(b) violet

- it has the highest frequency (shortest wavelength), and the glass slows and bends higher-frequency light more

Exercise 3.5 (c)

3.5 A narrow beam of white light enters a glass prism.

(c) A student says that the image in a plane mirror can be shown on a screen. Explain why the student is wrong. [2]

Exercise 3.5 (c)

3.5 A narrow beam of white light enters a glass prism.

(c) A student says that the image in a plane mirror can be shown on a screen. Explain why the student is wrong. [2]

(c) the image is virtual

- the reflected rays only appear to come from behind the mirror, so no light actually passes through the image position and none can fall on a screen there