2026 Sec 3 Physics Chapter 2 Optics

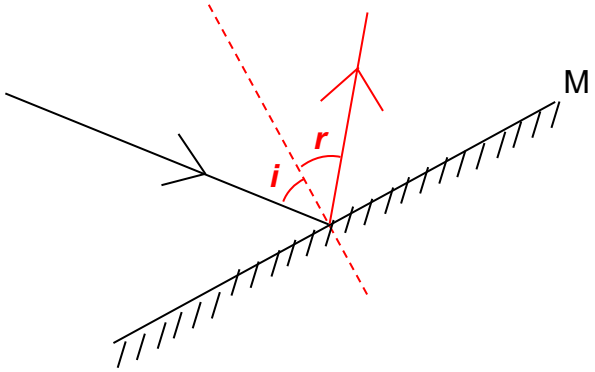
Answers to Examples and Exercises

Exercise 1

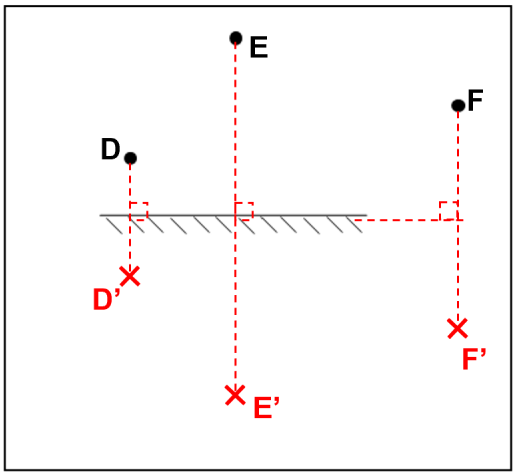
Properties of image in plane mirror
Exercise 1

1. (b) $i = 39°$ (c) $r = 39°$

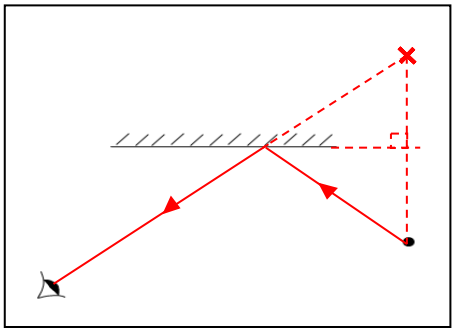
   (e) $\theta = 180° - 39° - 39° = 102°$



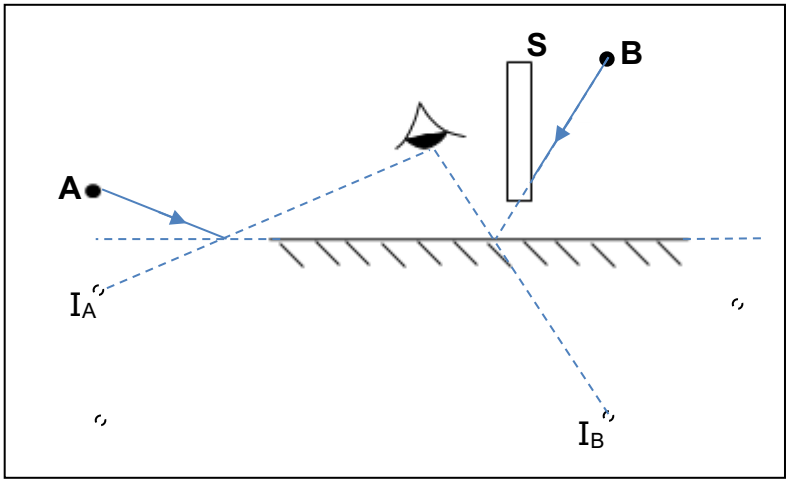
Example 1.1



Example 1.2



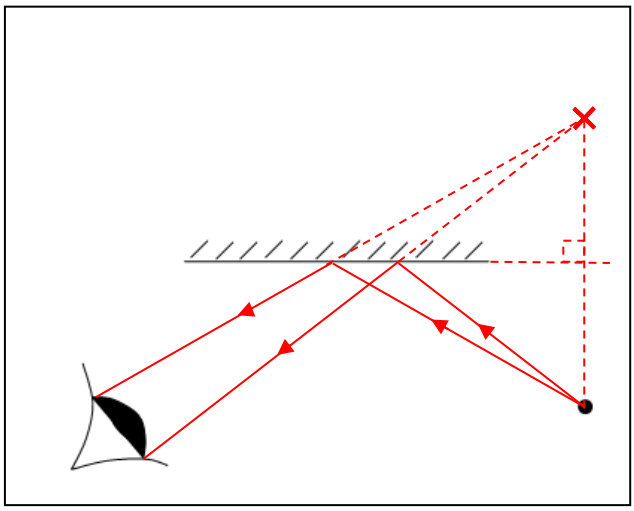
Example 1.3



***Note**: single light rays can be used instead of cones of light to determine the answers!*

(b) A cannot be seen in the mirror by the eye.
For B, the incident rays are blocked by the screen S so the rays cannot reach the eye.

Example 1.4



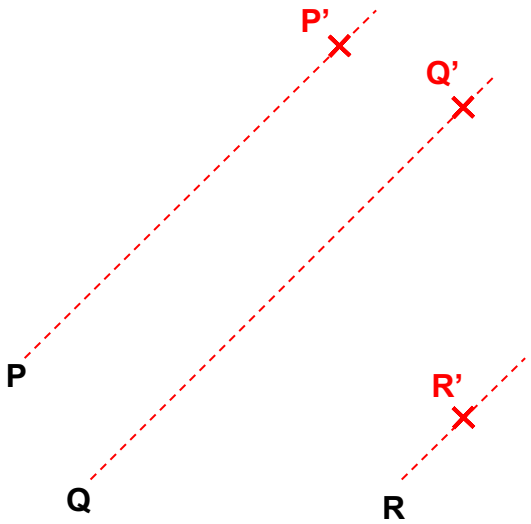
Example 1.5

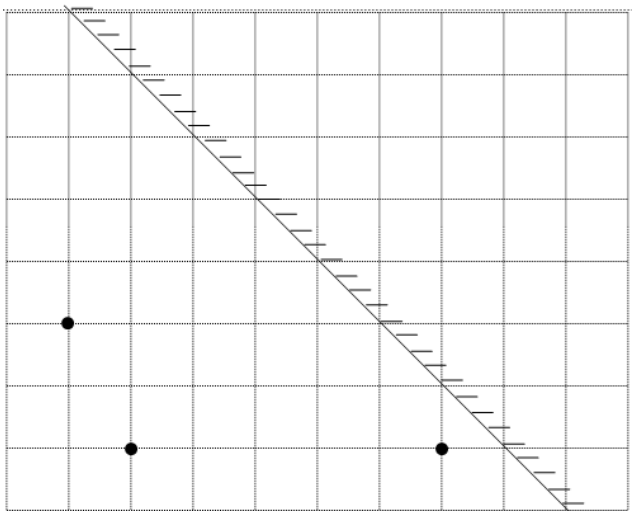
Half of 1.60 m = 0.80 m

Exercise 2

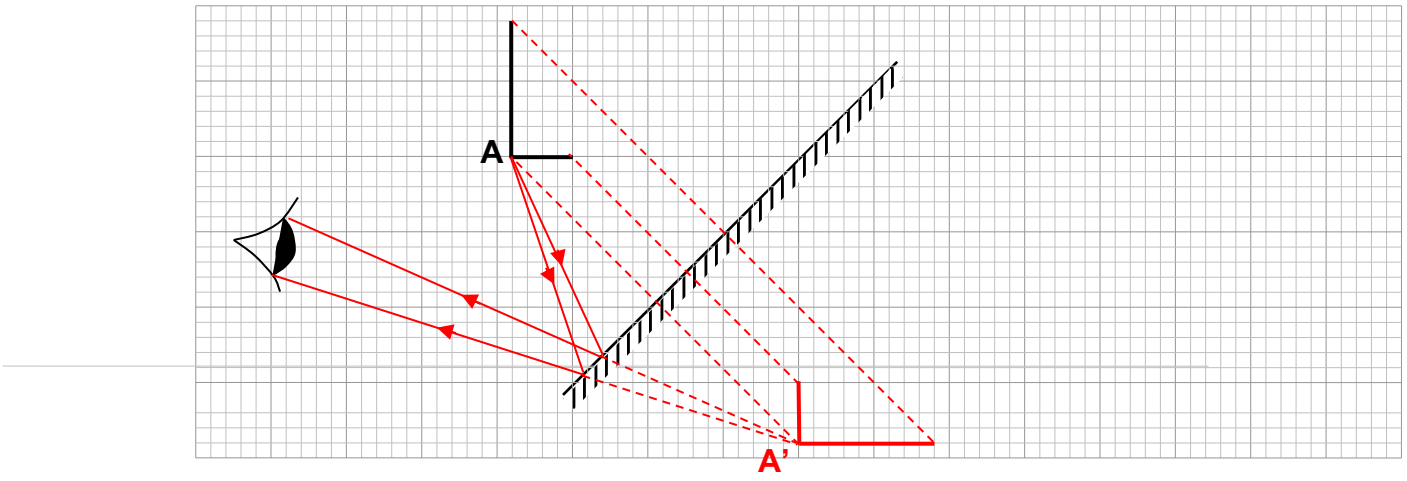
1

(b

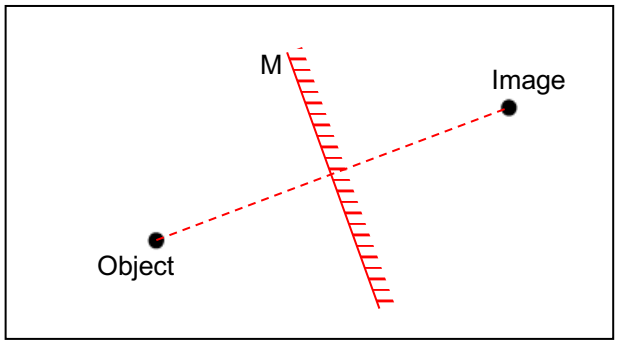




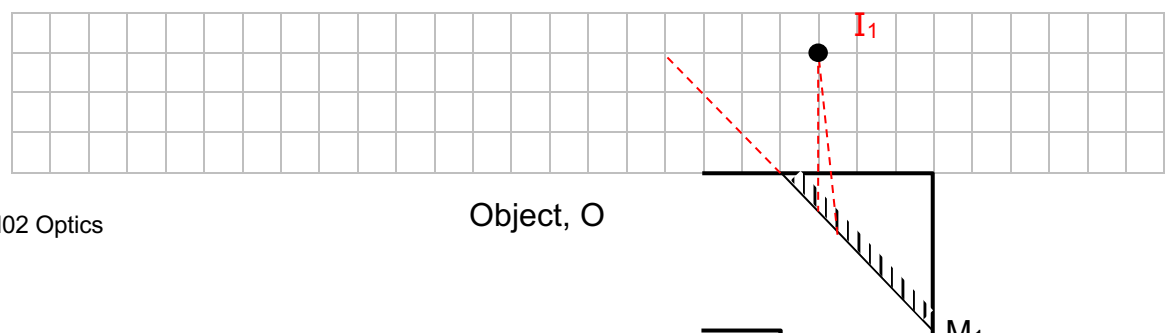
2

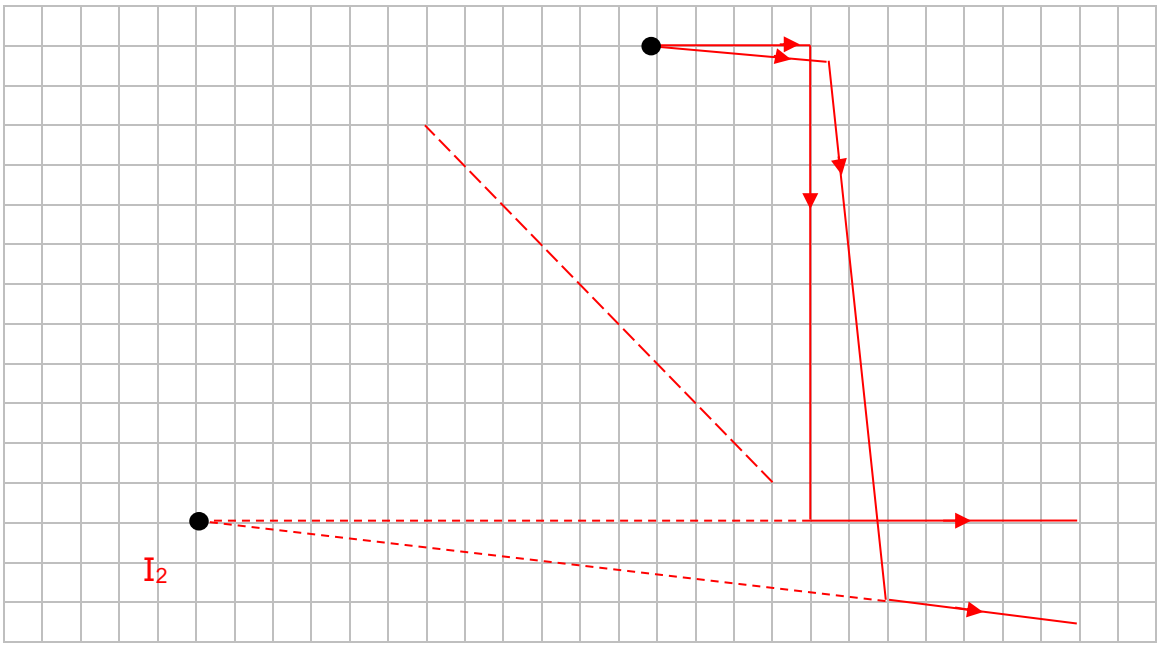


3



4.





2 Refraction

Example 2.1

Speed of light in **vacuum** = 1.33 **times** of speed of light in **water**.

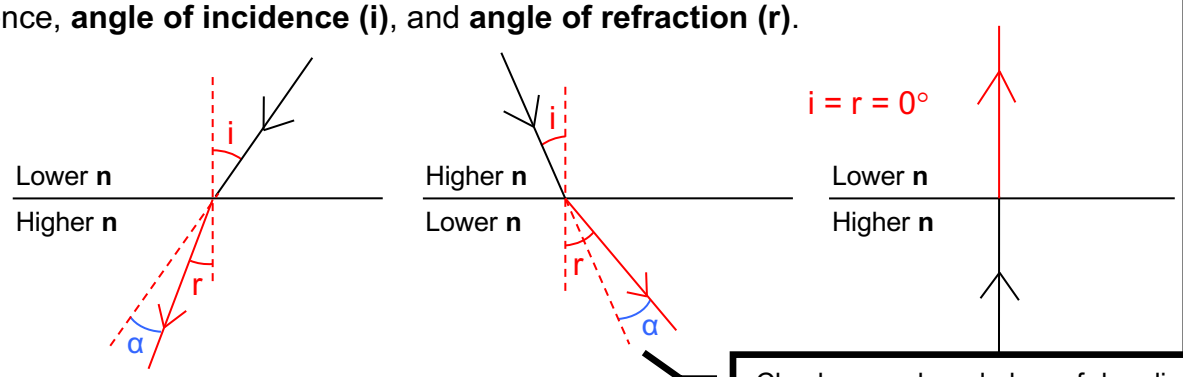
= 1.50 **times** of speed of light in **glass**.

speed of light in water = $3 \times 10^8 / 1.33 = 2.25 \times 10^8 \approx 2.3 \times 10^8$ m s^{-1}

speed of light in glass = $3 \times 10^8 / 1.50 = 2.0 \times 10^8$ m s^{-1}

Example 2.2

For each diagram below, label the **incident ray**, **refracted ray**, **normal** at the point of incidence, **angle of incidence (i)**, and **angle of refraction (r)**.

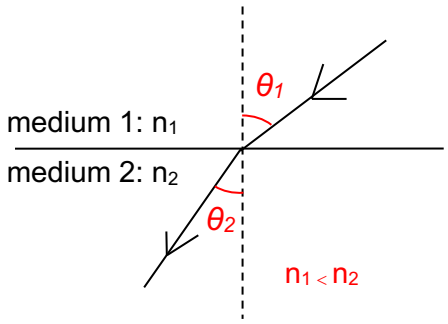


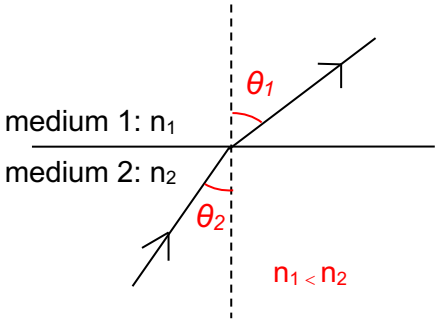
Check your knowledge of bending towards or away from normal. Also check which are angles of incidence, angles of refraction, etc.

Note:

- α *is the angle of deviation.*
- *Draw real light rays with continuous lines.*
- *Draw virtual rays & construction lines with dashed lines.*

Example 2.3


medium 1: n_1
medium 2: n_2
θ_1
θ_2
$n_1 < n_2$


medium 1: n_1
medium 2: n_2
θ_1
θ_2
$n_1 < n_2$

Example 2.4

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

$1.0 \times \sin (90 - 55)^o = n \sin (90 - 70)^o$

$$n = \frac{\sin 35^o}{\sin 20^o}$$

$= 1.68$

Example 2.5

Applying Snell's law, $n_1 \sin \theta_1 = n_2 \sin \theta_2$

$n_1 = n$, $\theta_1 = c$ and $n_2 = 1.0$, $\theta_2 = 90^o$

Hence, $n \sin c = 1.0 \sin 90° = 1$

$n = 1 / \sin c$

Example 2.6

(a) 90^o

(b) Using $n = \frac{1}{\sin \mathbf{c}}$

$$\sin \mathbf{c} = \frac{1}{n} = \frac{1}{1.5}$$

$c = 41.8^o$

Example 2.7

- *Draw the path of the rays in the diagram until it emerges out of the prism.*
- *Mark all relevant angles and show clearly all necessary calculations.*

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

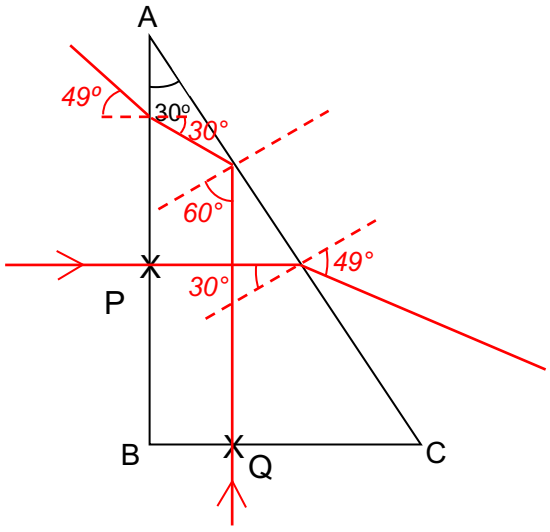
$1.5 \sin c = 1.0 \sin 90°$

$c = 42°$ (2 sf)

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

$1.5 \sin 30° = 1.0 \sin \theta_2$

$\theta_2 = 49°$ (2 sf)



Approach:

- *Whenever a light ray reaches a boundary, draw the normal & determine its angle of incidence.*
- *Compare the refractive indices of the 1st & 2nd medium and check how this ray should refract (bend).*
- *If the 1st medium is optically denser (higher refractive index), compare angle of incidence i with critical angle c. If i > c, total internal reflection occurs.*
- *Else, normal refraction occurs.*

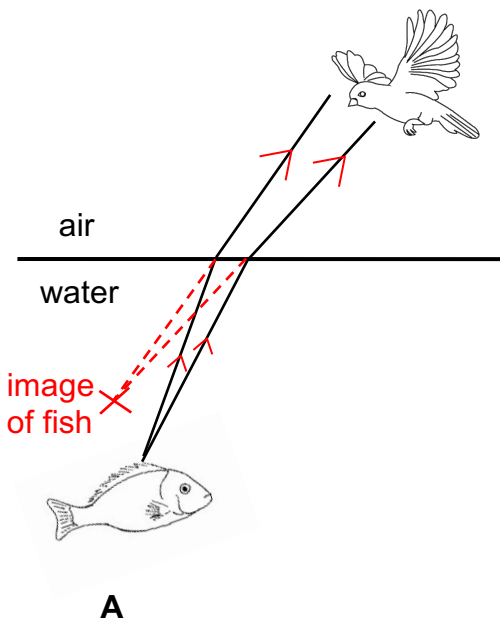
Example 2.8

Explain the purpose of cladding the glass core with another type of glass of a lower refractive index.

1. Total internal reflection can only happen when the incident ray travels from an optically denser medium to an optically less dense medium. The optically less dense cladding makes sure that this condition is always present each time the light beam hits the boundary between the glass core and the cladding.
2. Cladding the core with a material whose refractive index is known ensures a consistent critical angle for the transmission in the core
3. The cladding protects the core.

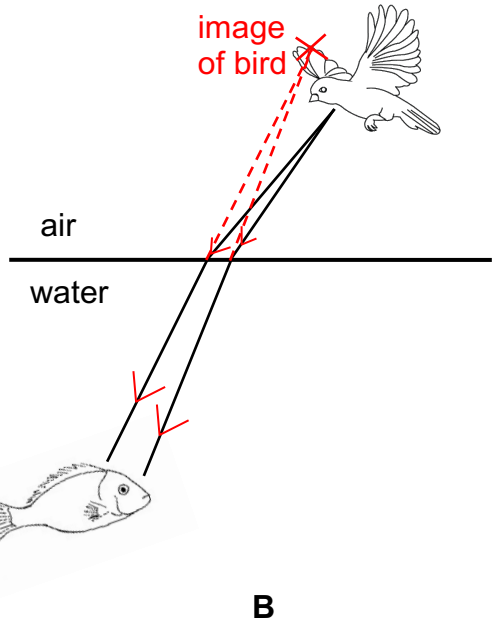
Example 2.9

(a)



A

(b)



B

(c) Further

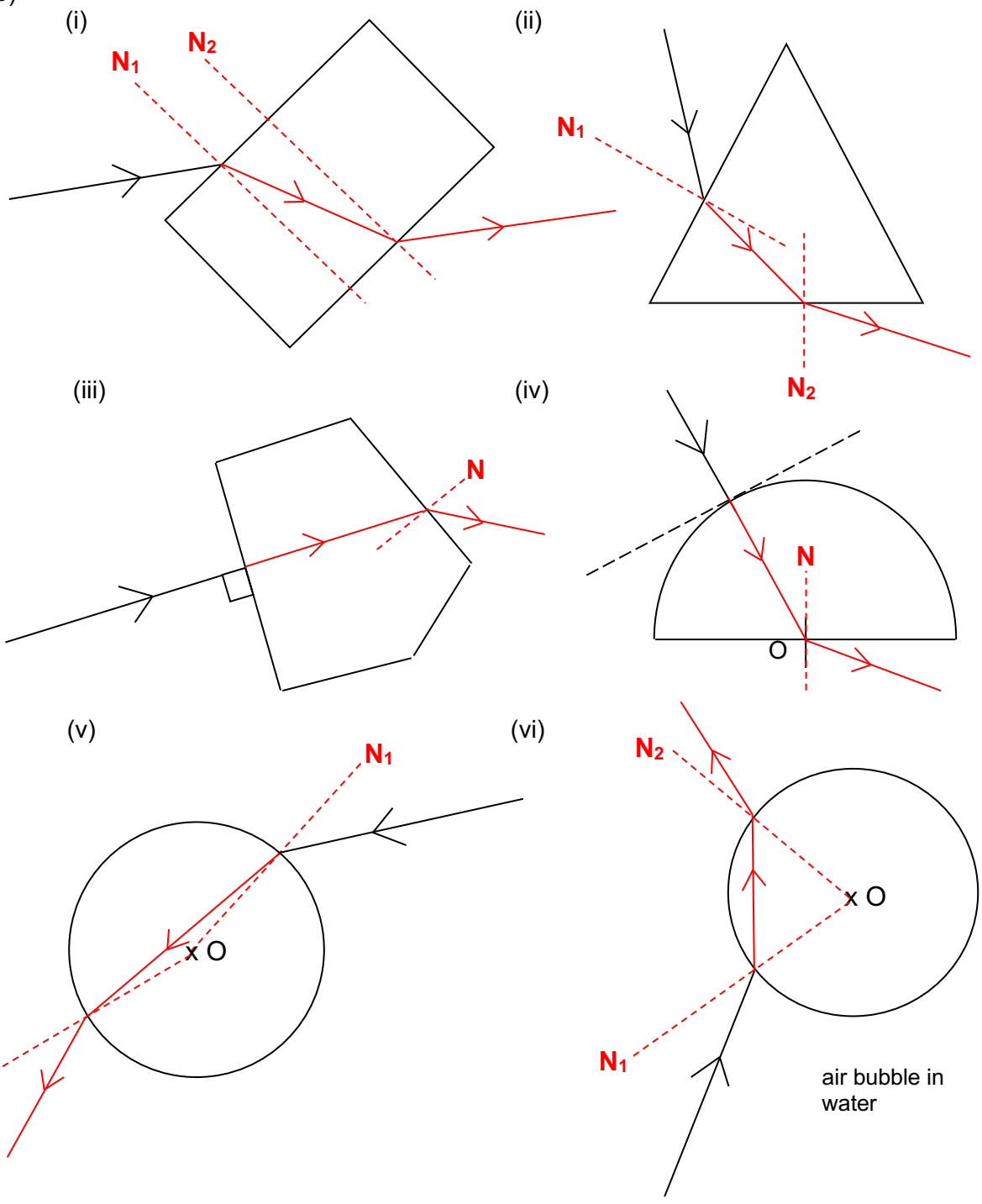
Exercises

Refraction

1 (a) Monochromatic light refers to light of a single frequency (or wavelength).

[mono: single; chroma: colour]

1 (b)



2. $n = c / v$

$2.4 = 3.0 \times 10^8 \text{ m s}^{-1} / v_{diamond}$

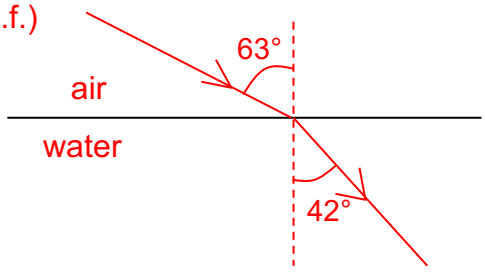
3. $v_{diamond} = 1.25 \times 10^8 \approx 1.3 \times 10^8$ m s^{-1} (2 s.f.)

Using $n_{air} \sin \theta_{air} = n_{water} \sin \theta_{water}$

$1.00 \times \sin \theta_{air} = 1.33 \times \sin 42^o$

$\sin \theta_{air} = 0.88994$

$\theta_{air} = 62.9^o$ (3 s.f.) $\approx 63^o$ (2 s.f.)



Critical Angle and Total Internal Reflection

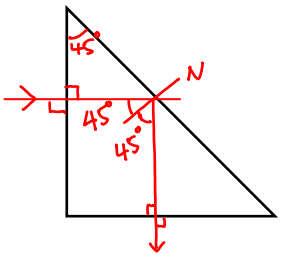
4. Using $n_1 \sin \theta_1 = n_2 \sin \theta_2$

$1.33 \sin c = (1.0) \sin 90°$

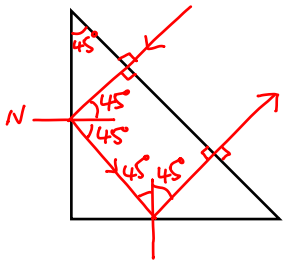
$\mathbf{c = 49°}$

OR $n = 1 / \sin c$ ➔ $\sin c = 1 / n$ ➔ Calculate c

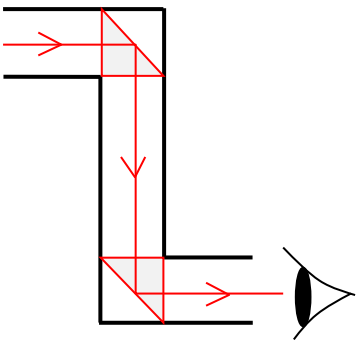
5. (a) deviate the ray of light through 90°



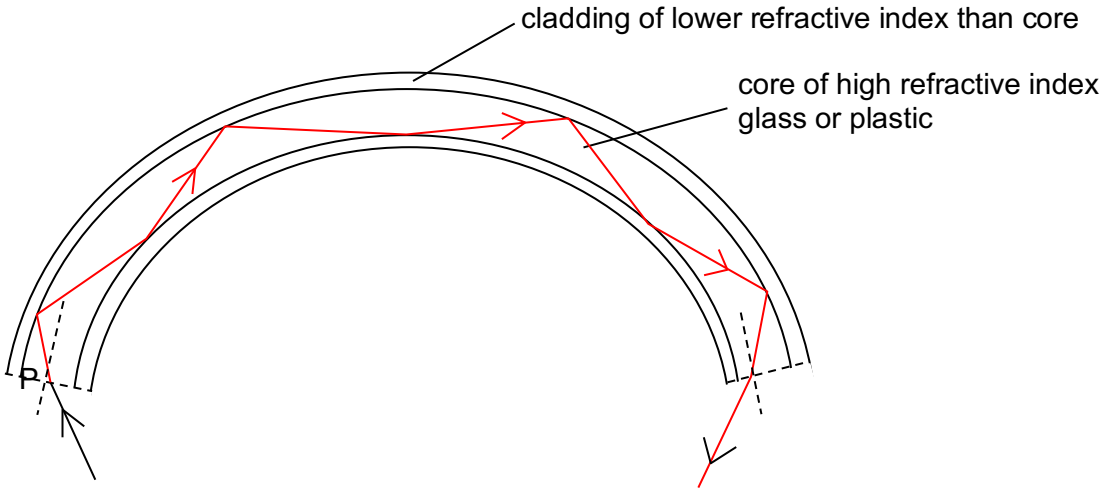
(b) deviate the ray of light through 180°



(c) Complete the diagram to show how two 45° right-angled glass prisms may be used in a periscope. Draw the path of a ray through the periscope to show how it reaches the eye.



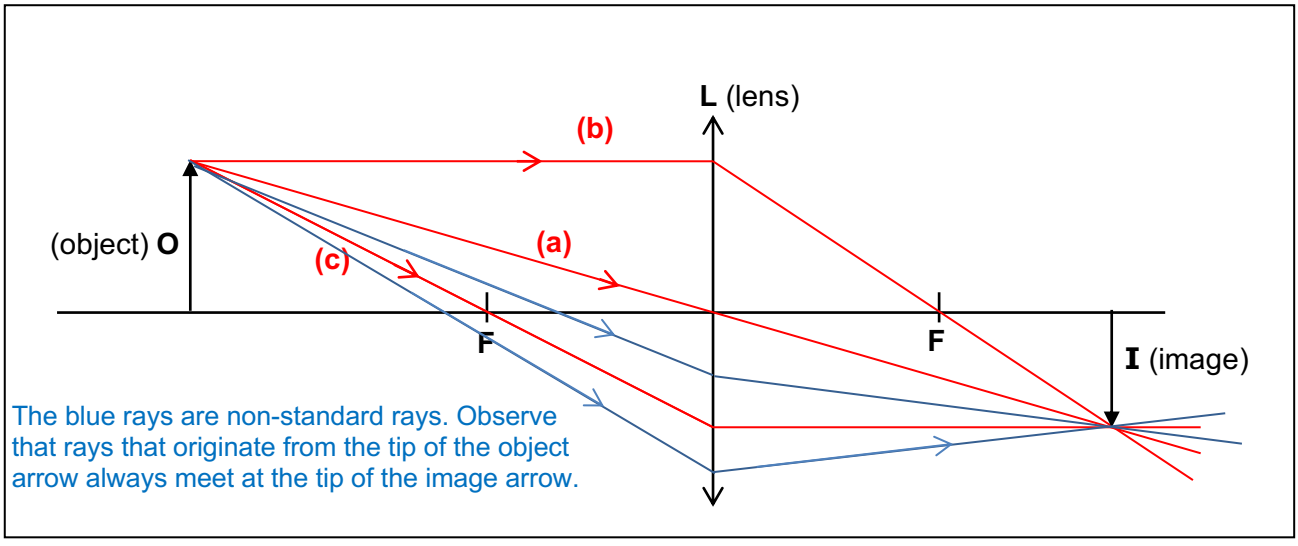
6. Optical fibres are rapidly replacing copper wires in telecommunications and computer networks.



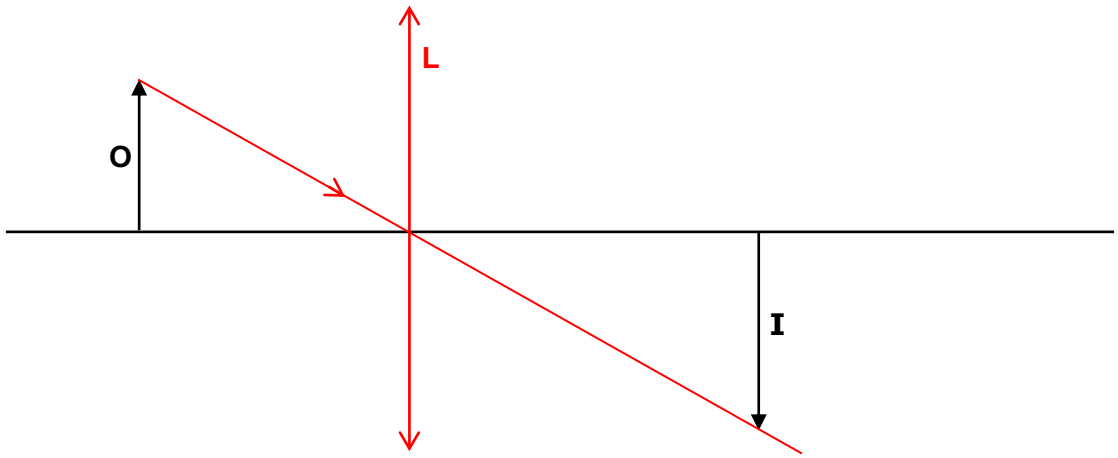
Note:

- At the entrance, the angle of refraction should be smaller than the angle of incidence
- At each reflection, check that the angle of incidence and angle of reflection look reasonably equal
- At the exit, the angle of refraction should be larger than the angle of incidence

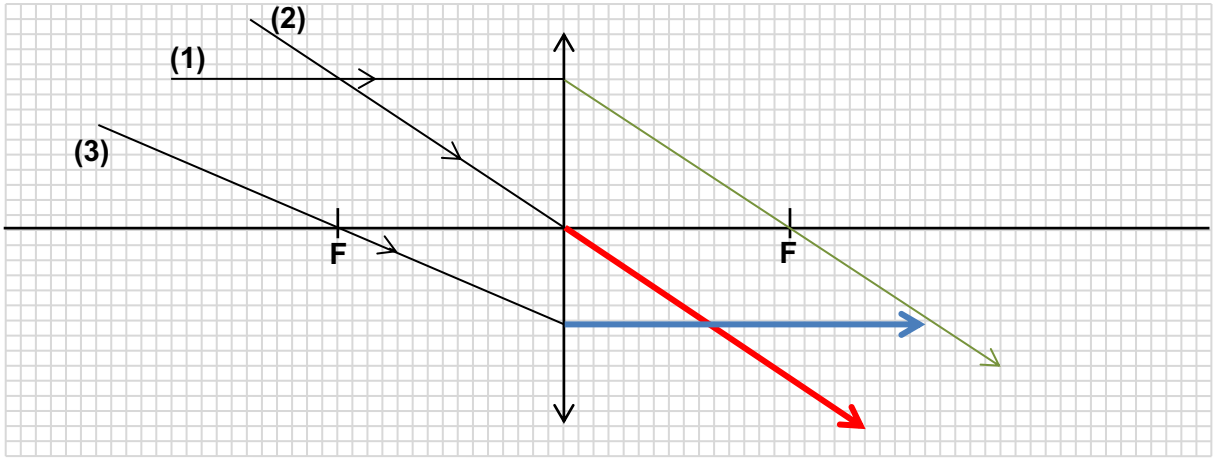
Lenses
Example 3.1



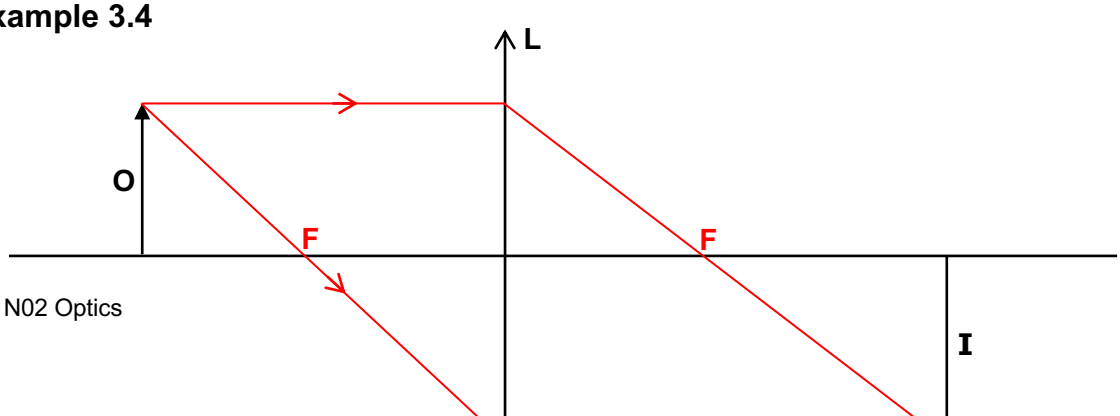
Example 3.2



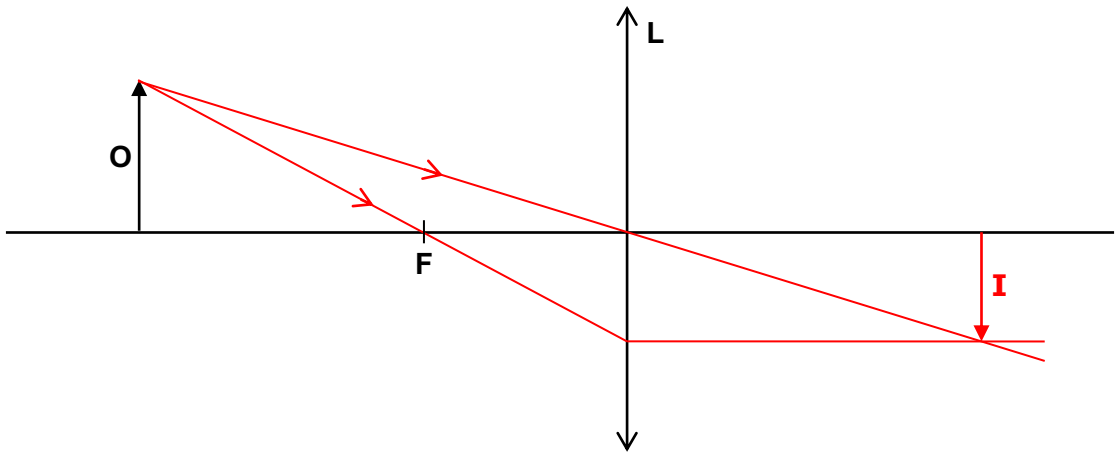
Example 3.3



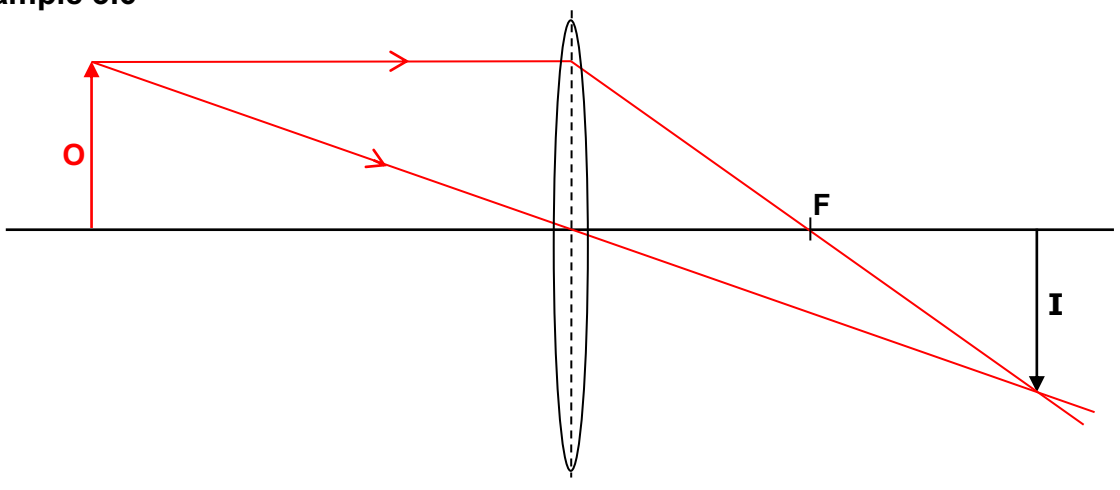
Example 3.4



Example 3.5

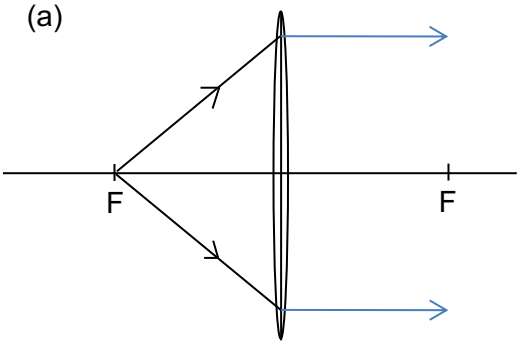


Example 3.6

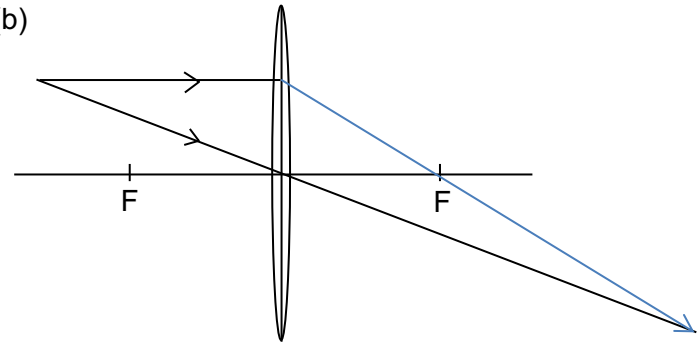


Exercises

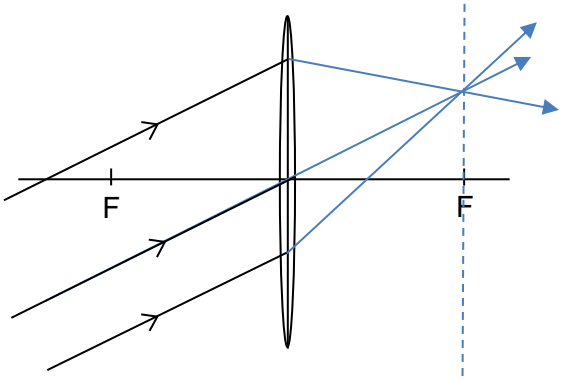
1 (a)



(b)



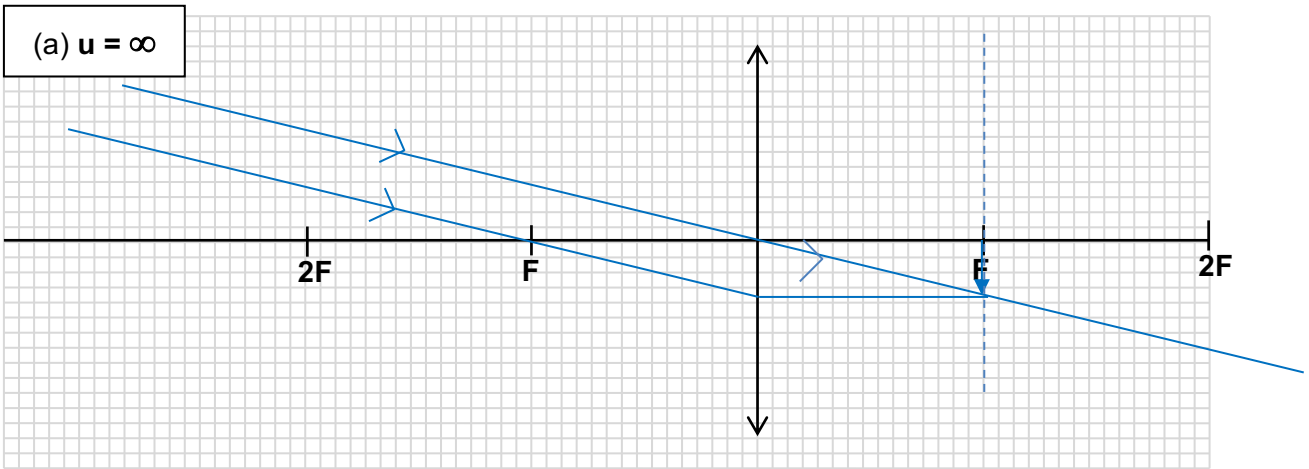
(c)



3.4 Ray Diagrams and Applications

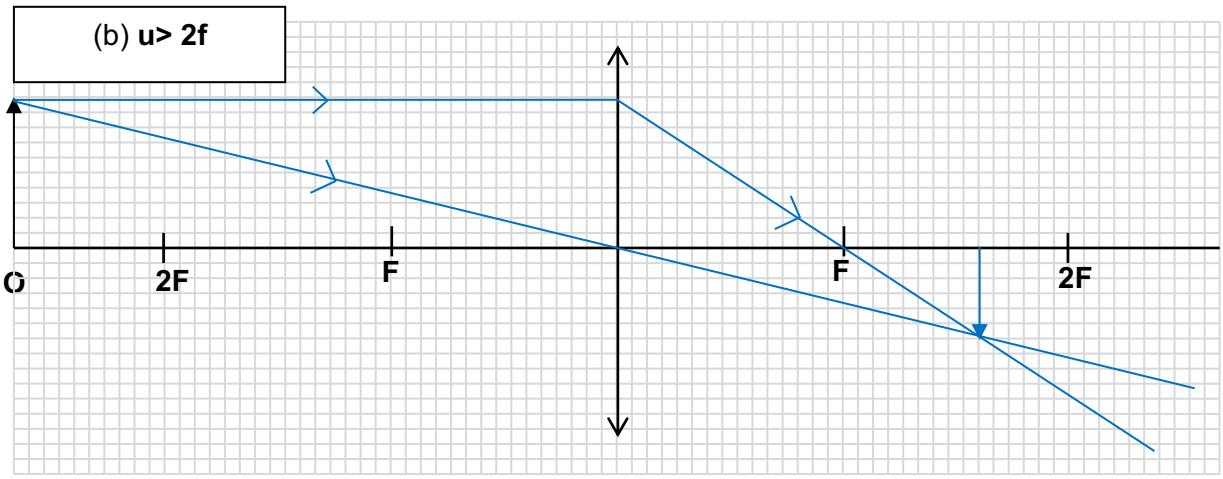
3.4.1 Important Ray Diagrams

Example 3.7



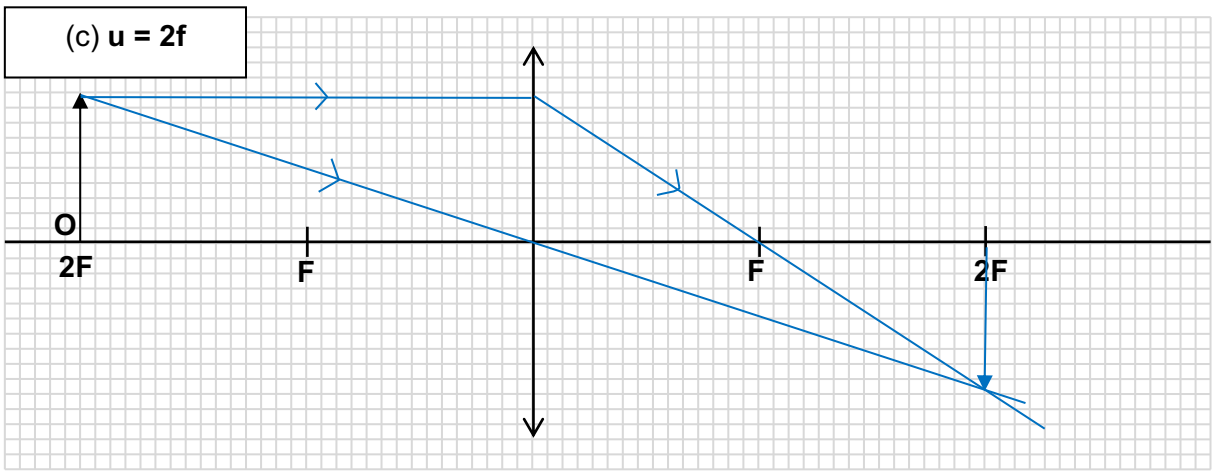
(i) Description of the image formed: real, inverted, diminished

(ii) u = ∞ v = f = 15.0 cm



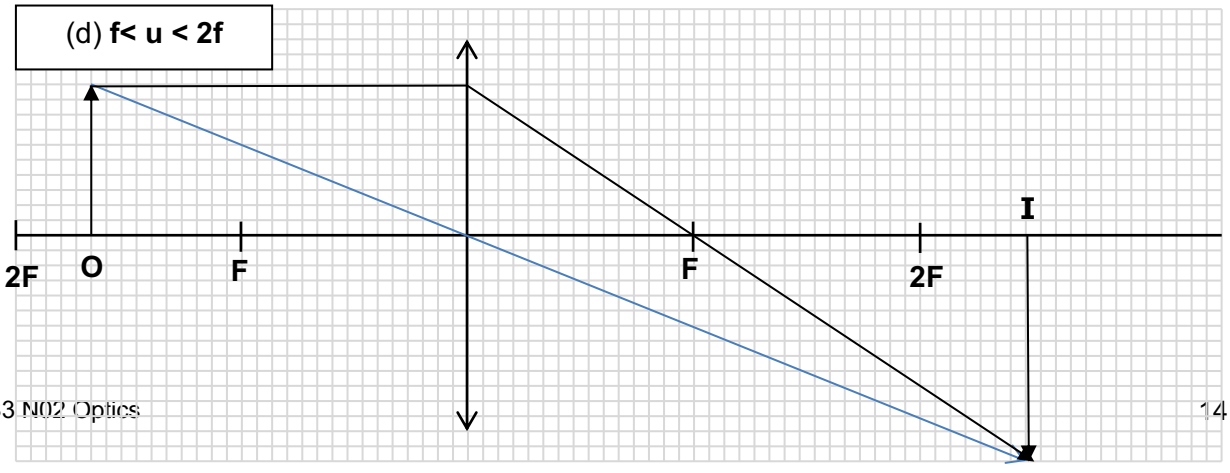
(i) Description of the image formed: inverted, diminished, real

(ii) u = 40.0 cm. v = 24.0 cm



(i) Description of the image formed: real, same sized, inverted

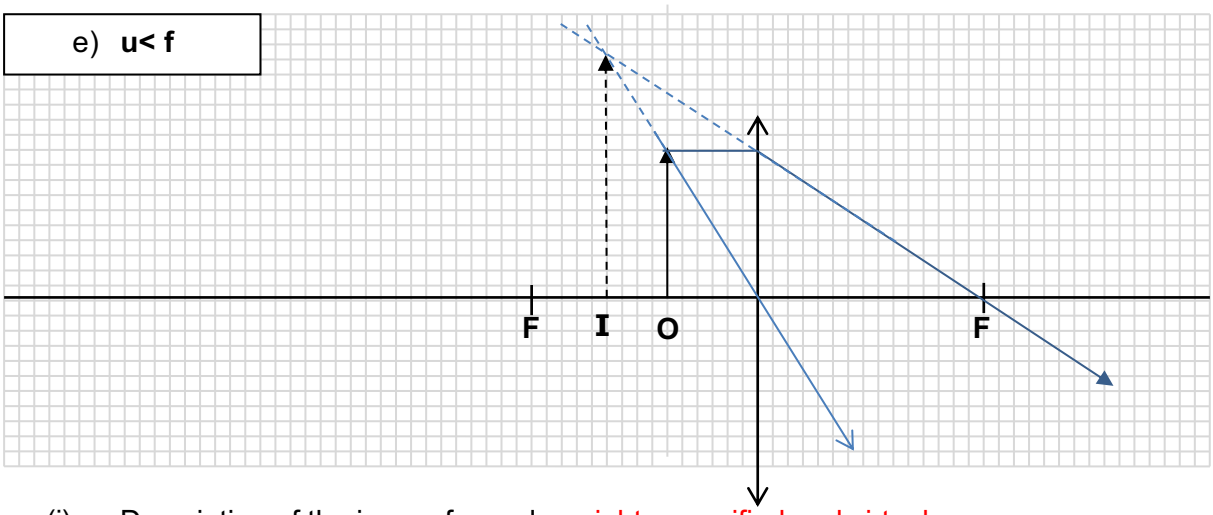
(ii) u = 30.0 cm v = 30.0 cm



(i) Description of the image formed: inverted, magnified and real.

(ii) u = 25.0 cm v = 37.5 cm

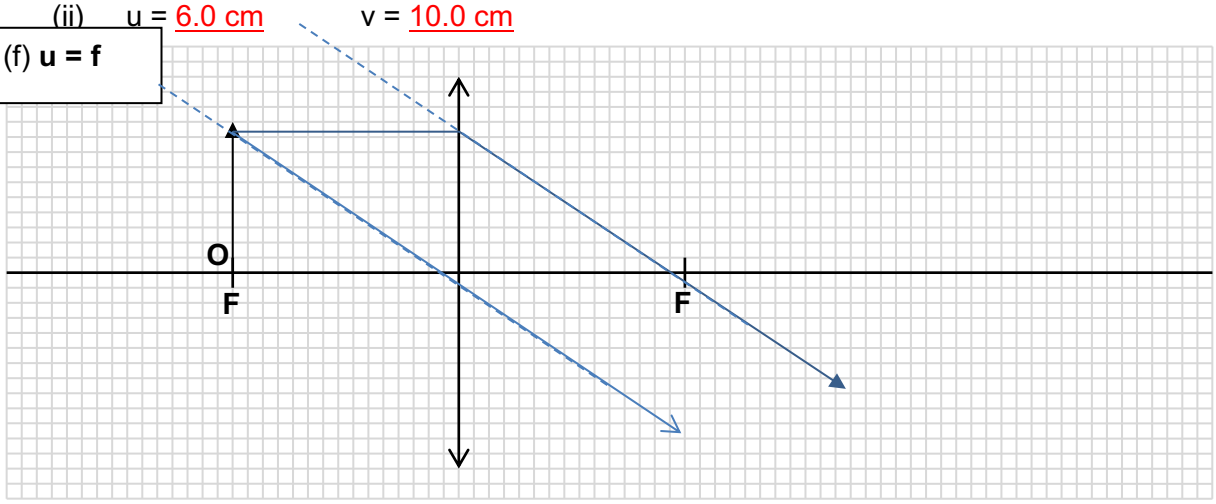
e) **u< f**



(i) Description of the image formed: upright, magnified and virtual

(ii) u = 6.0 cm v = 10.0 cm

(f) **u = f**



(i) Description of the image formed: magnified, upright and virtual

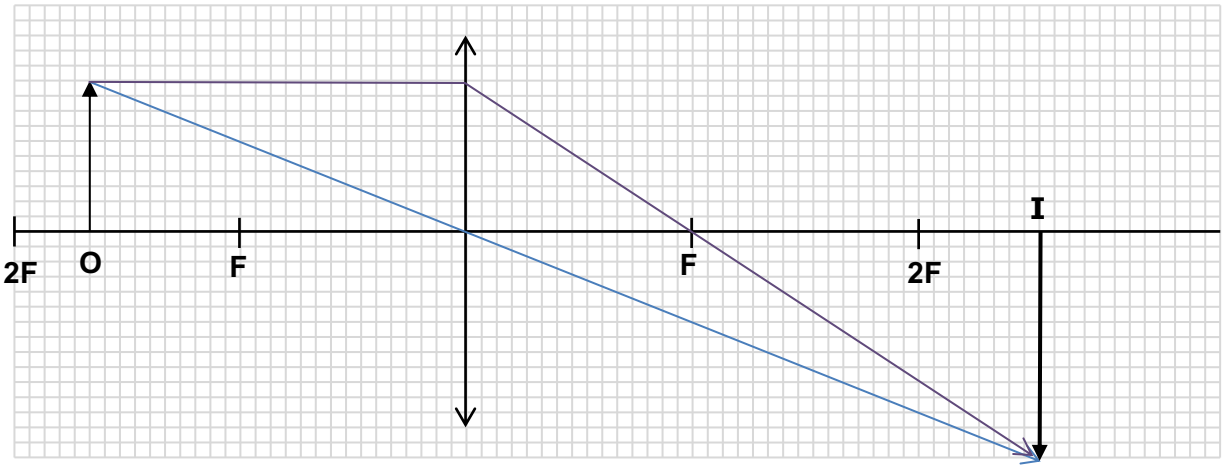
(ii) u = 15.0 cm v = ∞

3.4.3 Applications

3.4.4

Location of object	Characteristics of image	Location of image	Uses
u < f	- Virtual - Upright - Magnified	Same side as object	- Magnifying glass
u = f	- Depends on usage	v = ∞	- Spotlight
f < u < 2f	- Real - Inverted - Magnified	2f < v < ∞	- Projector - Photograph enlarger
u = 2f	- Real - Inverted - Same size	v = 2f	- Photocopier making same-sized copy
2f < u < ∞	- Real - Inverted - Diminished	f < v < 2f	- Camera - Eye
u = ∞	- Real - Inverted - Diminished	v = f	- Object lens of a telescope

Example 3.8

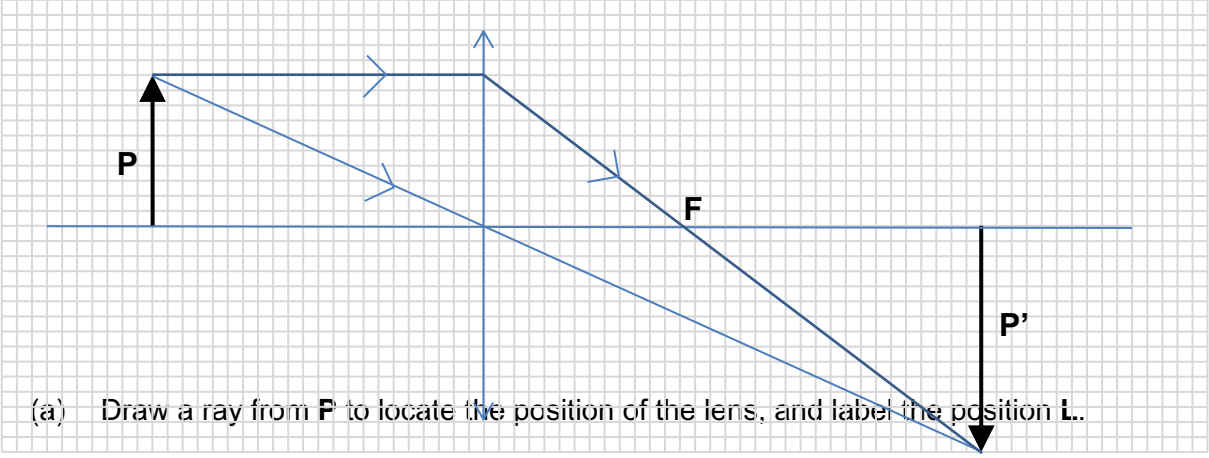


(i) Description of the image formed: real, inverted and magnified.

u = 25.0 cm. v = 37.5 cm m = 1.50

Exercises

1



(a) Draw a ray from **P** to locate the position of the lens, and label the position **L**.

(b) Draw a second ray from **P** to determine the focal length of the lens.

Focal length = 13.0 cm (assuming 1.0 cm:5.0 cm)

(c) The object is then moved slightly further from the lens. State the change to the:

(i) Image position nearer to the optical centre

(ii) the image height shorter

2 A converging lens with a focal length of 20.0 cm is used to create an image of the sun on a paper screen.

How far from the lens must the paper be placed to produce a clear image? Explain with the aid of a sketch of a ray diagram.

The lens must be at a distance of f (20.0 cm). Rays of distant objects (considered to be parallel) will converge along the focal plane. Refer to the ray diagram where u = ∞.

3 The entire image will still be visible but will be less bright.