Chapter 13. Light

Contents:

New word list:

Spectrum
Dispersion
Principle axis
Principle focus/principle point
Focal length
Converge
Diverge
Enlarged
Diminished
Upright
Short sight
Long sight
Retina
Magnifying glass

3.2 Light

3.2.1 Reflection of light

Core

1 Define and use the terms normal, angle of incidence and angle of reflection

2 Describe the formation of an optical image by a plane mirror, and give its characteristics, i.e. same size, same distance from mirror, virtual

3 State that for reflection, the angle of incidence is equal to the angle of reflection; recall and use this relationship

Supplement

4 Use simple constructions, measurements and calculations for reflection by plane mirrors

3.2 Light continued

3.2.2 Refraction of light

Core

1 Define and use the terms normal, angle of incidence and angle of refraction

2 Describe an experiment to show refraction of light by transparent blocks of different shapes

3 Describe the passage of light through a transparent material (limited to the boundaries between two media only)

4 State the meaning of critical angle

5 Describe internal reflection and total internal reflection using both experimental and everyday examples

Supplement

6 Define refractive index, n, as the ratio of the speeds of a wave in two different regions

7 Recall and use the equation

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

8 Recall and use the equation

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

9 Describe the use of optical fibres, particularly in telecommunications

3.2.3 Thin lenses

Core

1 Describe the action of thin converging and thin diverging lenses on a parallel beam of light

2 Define and use the terms focal length, principal axis and principal focus (focal point)

3 Draw and use ray diagrams for the formation of a real image by a converging lens

4 Describe the characteristics of an image using the terms enlarged/same size/diminished, upright/inverted and real/virtual

5 Know that a virtual image is formed when diverging rays are extrapolated backwards and does not form a visible projection on a screen

Supplement

6 Draw and use ray diagrams for the formation of a virtual image by a converging lens

7 Describe the use of a single lens as a magnifying glass

8 Describe the use of converging and diverging lenses to correct long-sightedness and short-sightedness

3.2.4 Dispersion of light

Core

1 Describe the dispersion of light as illustrated by the refraction of white light by a glass prism

2 Know the traditional seven colours of the visible spectrum in order of frequency and in order of wavelength

Supplement

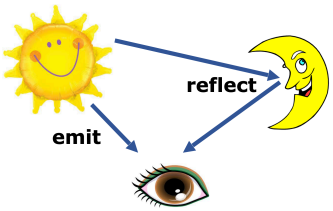
3 Recall that visible light of a single frequency is described as monochromatic

13.0 Nature of light

- Light ray travels in **straight lines**, changes its direction when hitting a shinny surface, like **particles** - [evidence: reflection, refraction]
- Light can also travel as **waves** - [evidence: diffraction]
- Can travel through empty space
- Speed of light in vacuum is the **fastest speed** in the universe
- Light is a form of radiation, transfers energy
- Light has visible and invisible region

"Wave-particle duality"

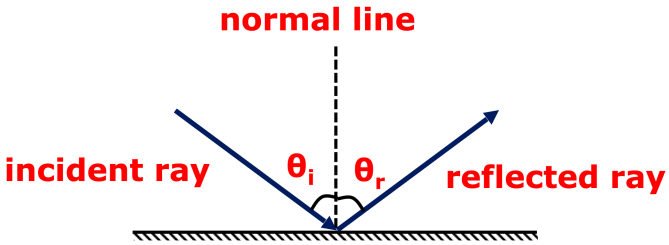
13.1 Reflection of light



- Def: the change of direction of a ray when it strikes a surface without passing through it

Reflection law: $\theta_i = \theta_r$

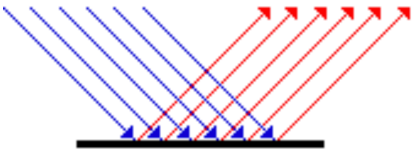
A ray of light strikes a plane mirror



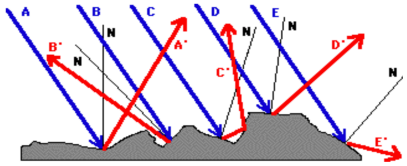
θ_i——angle of incidence

θ_r—— angle of reflection

Specular

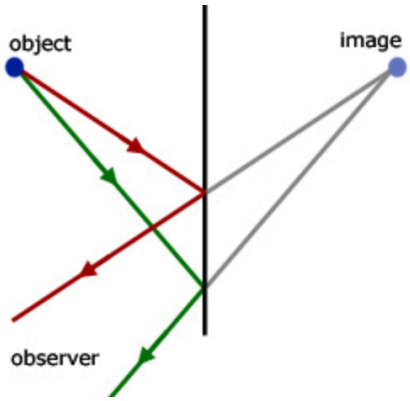


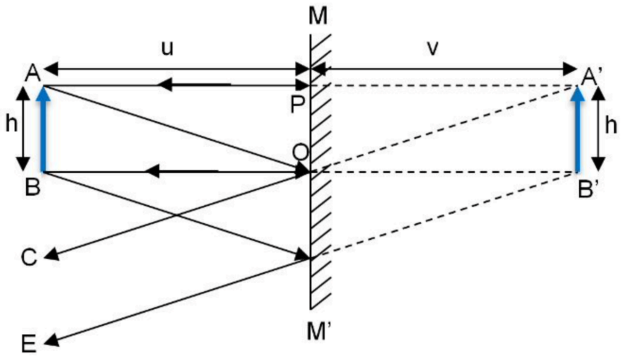
Diffuse Reflection

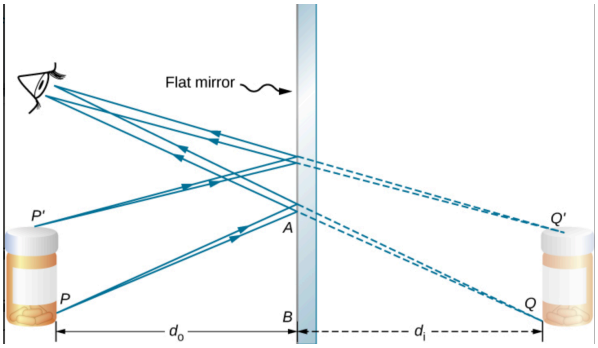


The Law of Reflection is Always Observed
(regardless of the orientation of the surface)

The image in a plane mirror

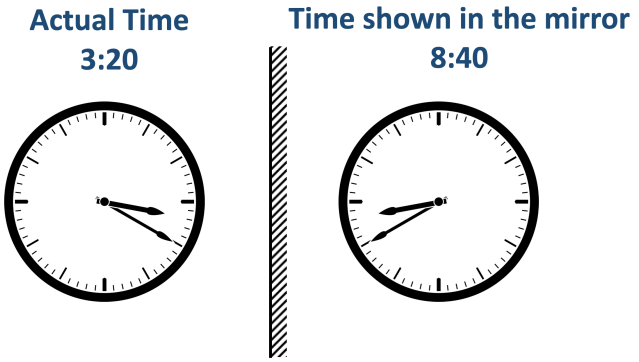


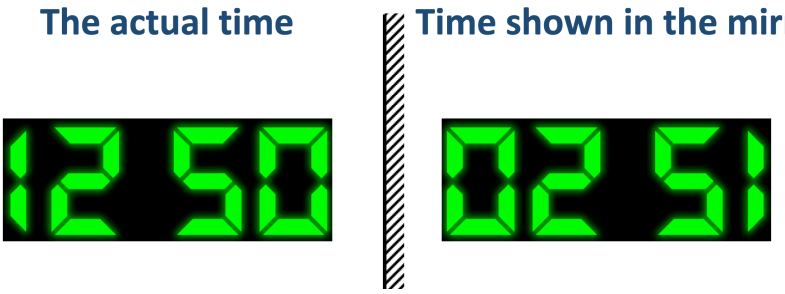




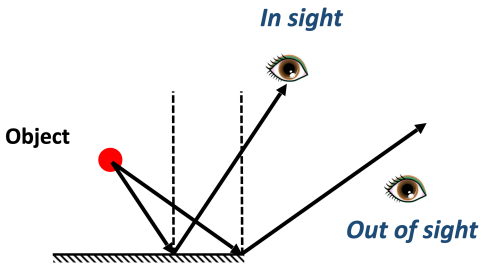
The image in a plane mirror

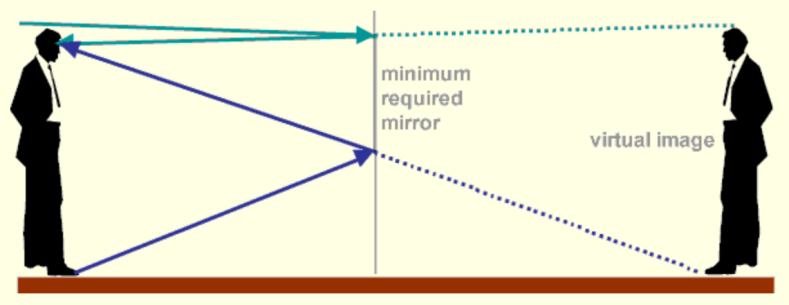
- The **same size** as object
- The **same distance** behind mirror as the object is in front of it
- **Laterally inverted**



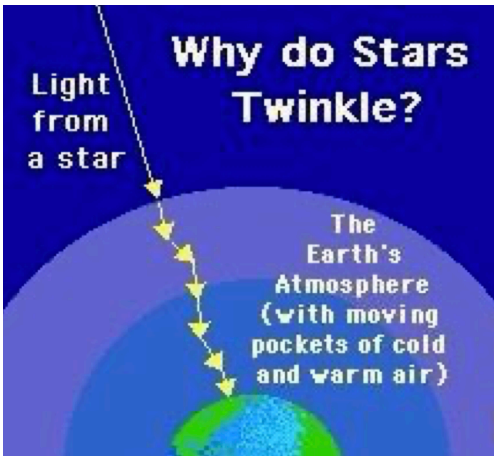


In/out of sight:

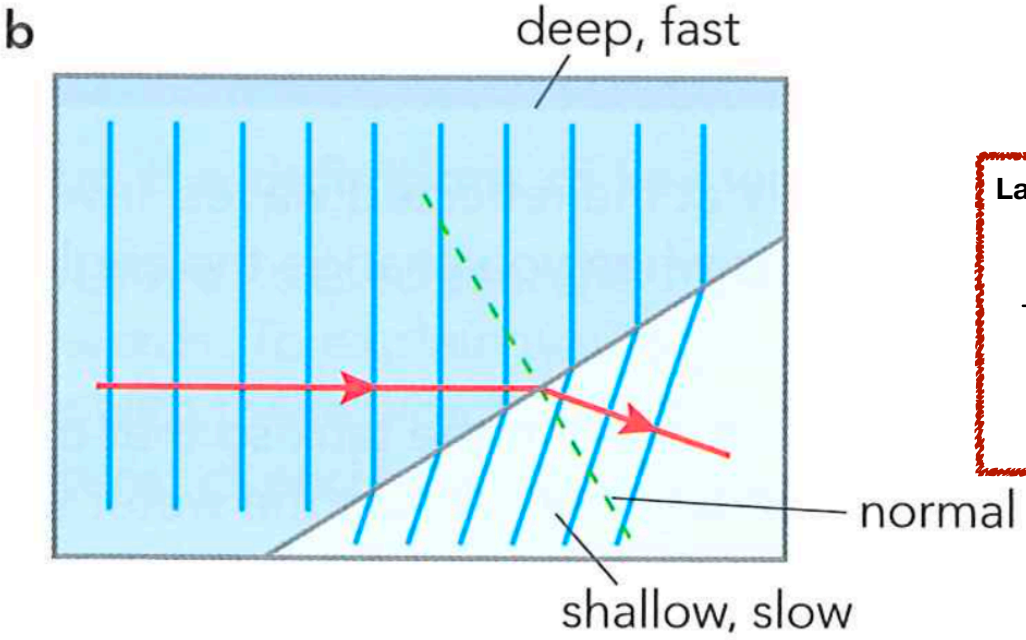




13.2 Refraction of light



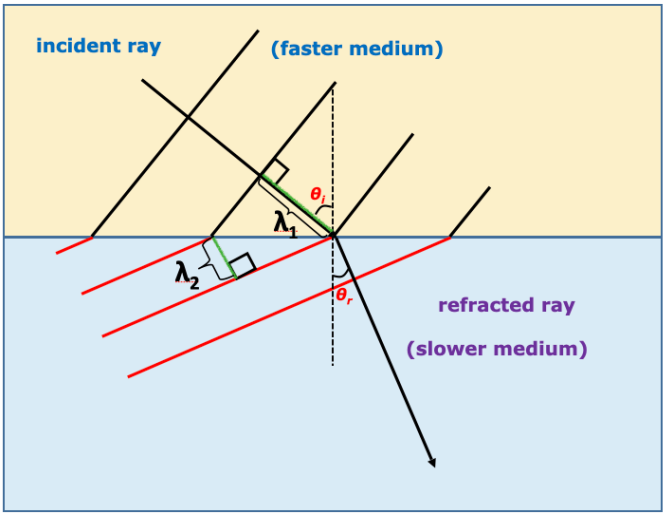
def: Refraction is the bending of the path of a light wave as it passes from one material to another material. (Incident angle = 0 => No bending)



Law of refraction:

$$\frac{\sin\theta_i}{\sin\theta_r} = \frac{n_2}{n_1}$$

Derivation of law of refraction:



$\lambda_1 = L \times \sin\theta_i$

$\lambda_2 = L \times \sin\theta_r$

$\lambda_1/\lambda_2 = \sin\theta_i / \sin\theta_r$

$$\frac{\lambda_1}{\lambda_2} = \frac{\sin\theta_i}{\sin\theta_r} \qquad v_1 = \lambda_1 f \qquad v_2 = \lambda_2 f \qquad \frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2} = \frac{\sin\theta_i}{\sin\theta_r}$$

refractive index of medium(n) ——

$$n = \frac{c}{v} = \frac{\textit{Speed of light in vacuum}}{\textit{Speed of light in medium}}$$

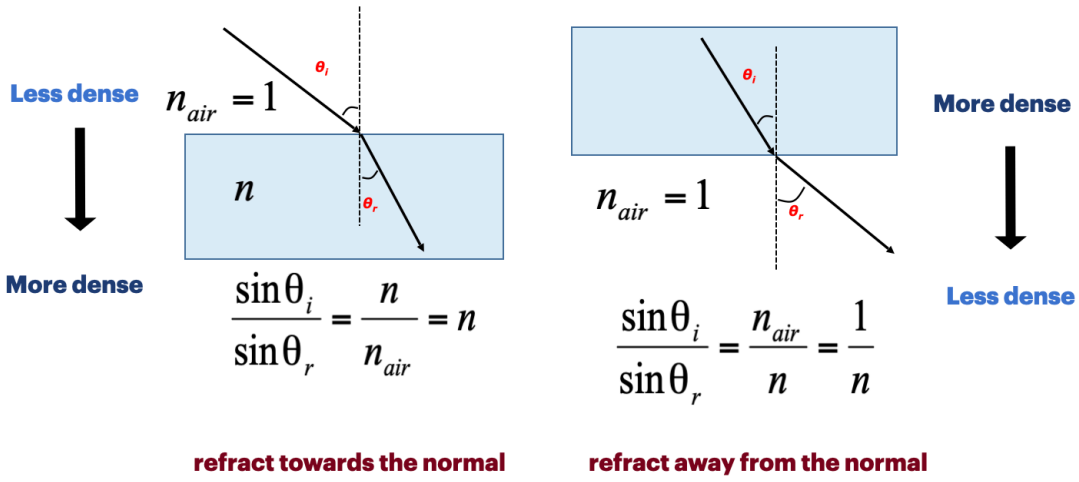
$$n_1 = \frac{c}{v_1} \qquad n_2 = \frac{c}{v_2}$$

$$\frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2} = \frac{\sin\theta_i}{\sin\theta_r} \longrightarrow \boxed{\frac{v_1}{v_2} = \frac{\sin\theta_i}{\sin\theta_r} = \frac{n_2}{n_1}}$$

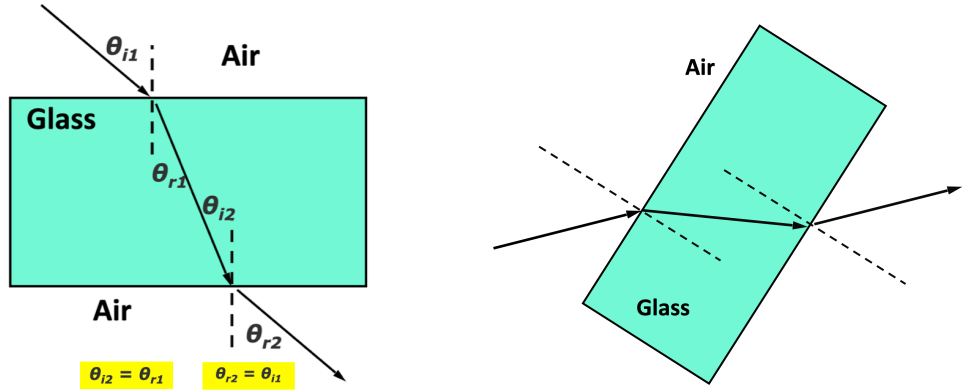
Refractive index of vacuum: $n_{vacuum} = c/c = 1$ $\qquad n_{air} \approx n_{vacuum} = 1$

n of all other materials >

Material	Speed of light / m/s	$\frac{\text{speed in vacuum}}{\text{speed in material}}$
vacuum	2.998×10^8	1 exactly
air	2.997×10^8	1.0003
water	2.308×10^8	1.33
Perspex®	2.000×10^8	1.5
glass	$(1.800–2.000) \times 10^8$	1.5–1.7
diamond	1.250×10^8	2.4

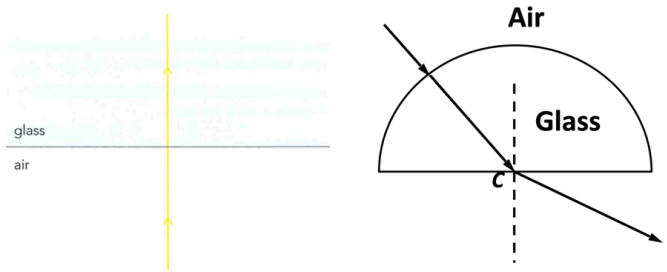


refraction though block



Refracted ray will return to its original direction, only **shifted**

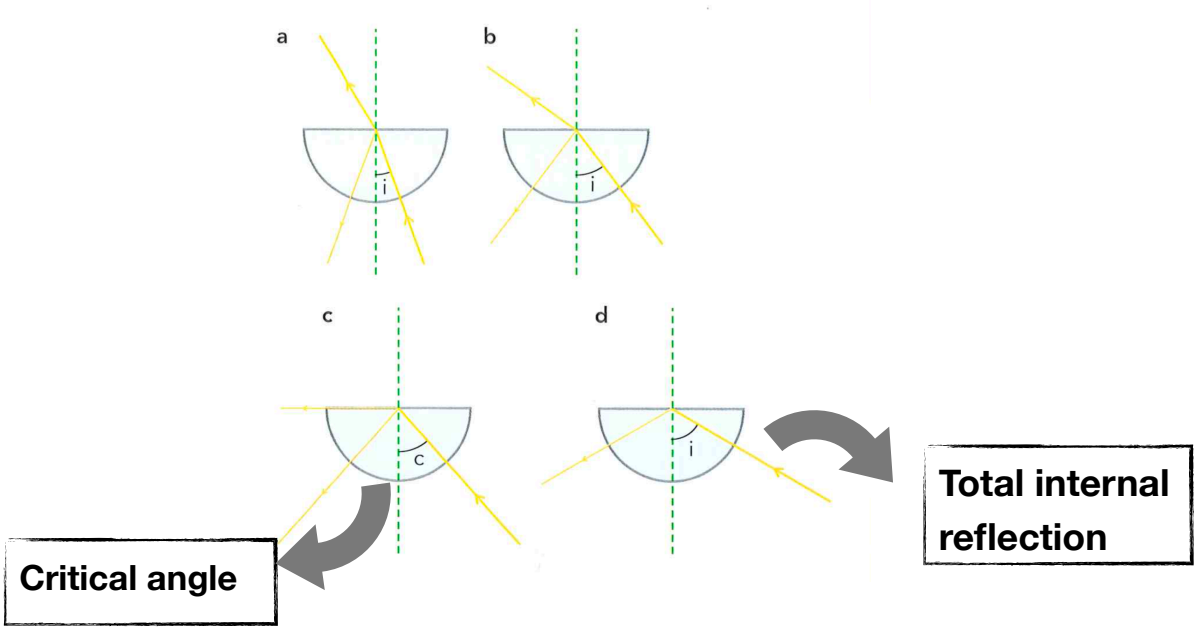
When incident angle = 0 ==> refracted angle =0



No bending when incident angle = 0

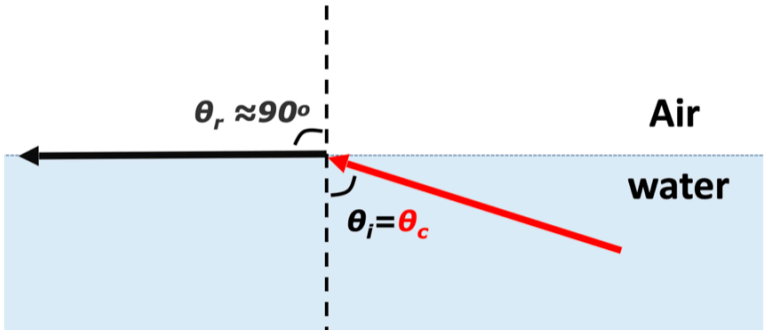
13.3 Total internal reflection

If we slowly increase incident angle, what would happen?



Critical angle: When angle of incidence is critical angle θc, refracted ray will be along the surface(θr is 90 degrees)

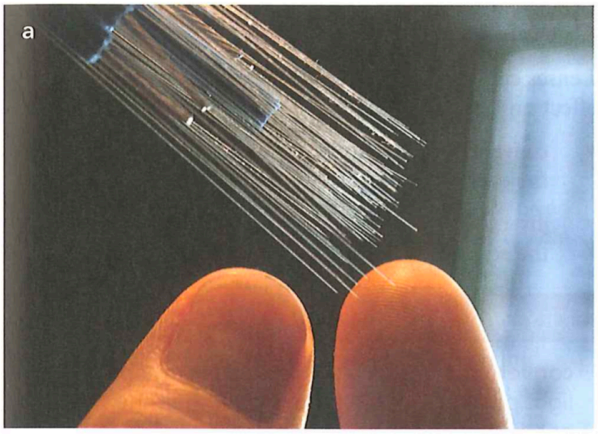
Total internal reflection (TIR): When light travels from more dense material to a less material and angle of incidence is larger than critical angle θc, all light is reflected, no light refracted.

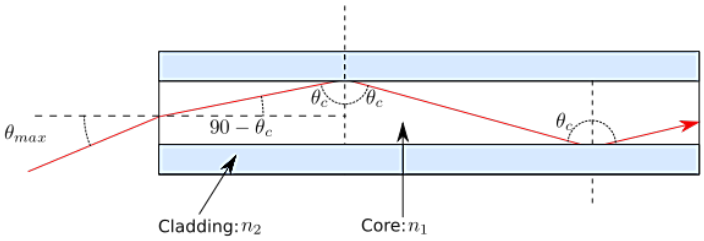


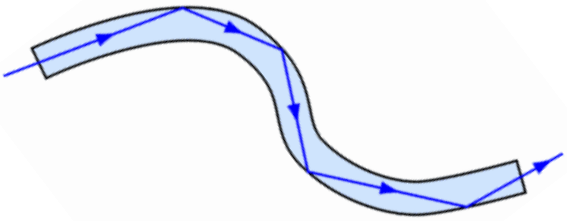
$$\frac{\sin\theta_i}{\sin\theta_r} = \frac{\sin\theta_c}{\sin 90^o} = \sin\theta_c = \frac{1}{n}$$

Conditions for TIR to happen:
1. the light is in the **more dense** medium and approaching the **less dense** medium.
2. the angle of incidence is **greater** than the critical angle.

Applications of TIR: Optical fibres

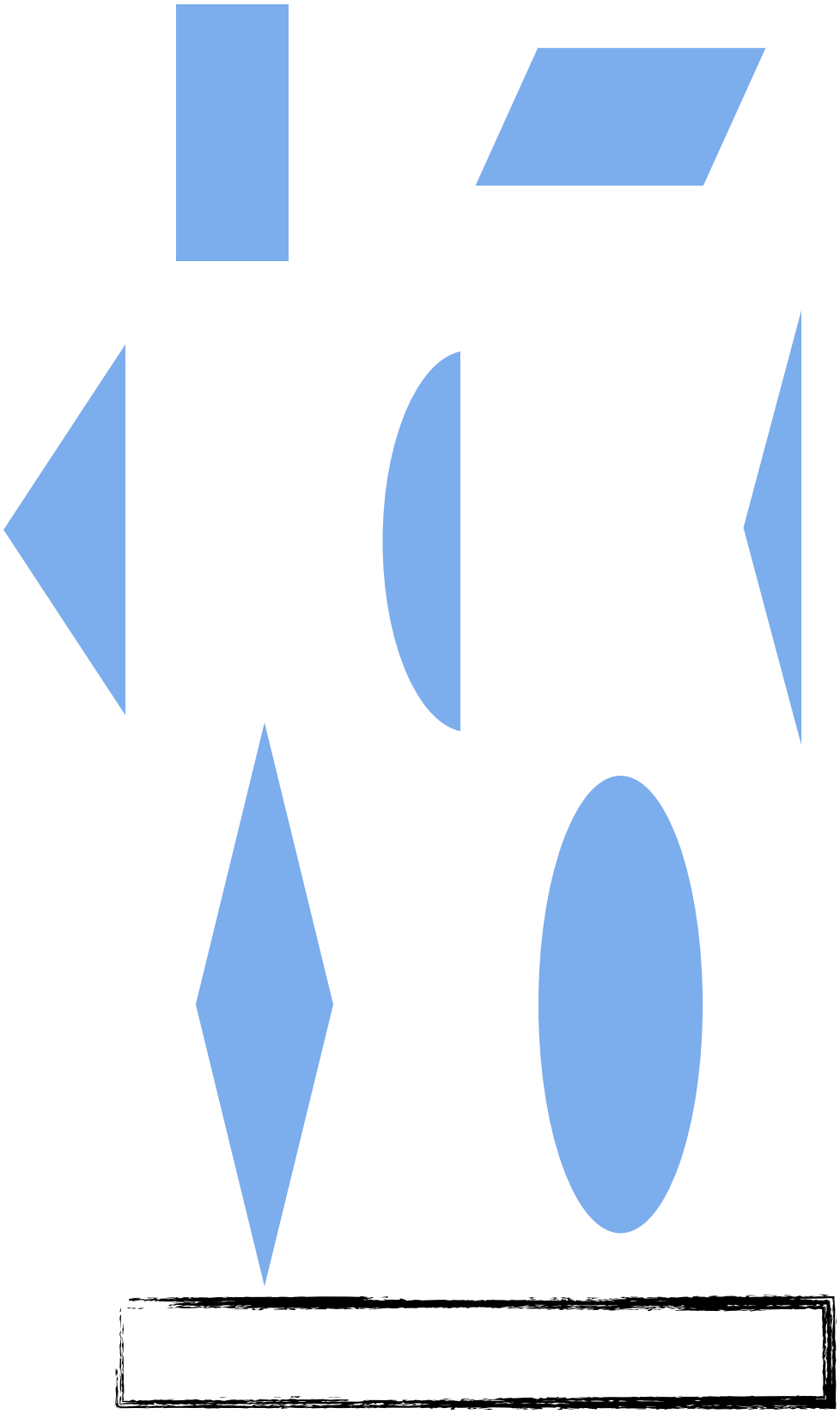




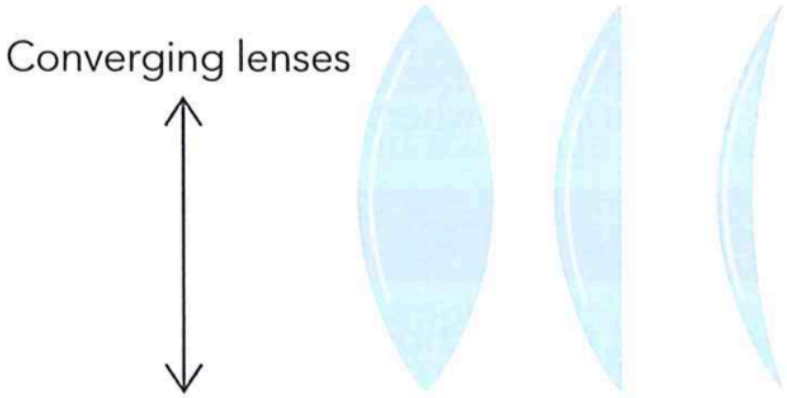


13.4 Lenses

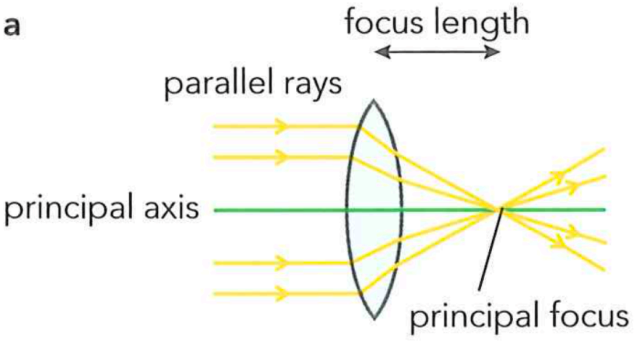
Can you draw the continuation of the light ray through the each shape of glass block?

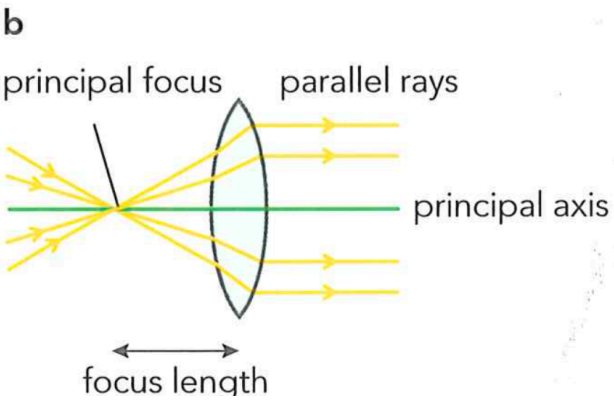


converging lens:

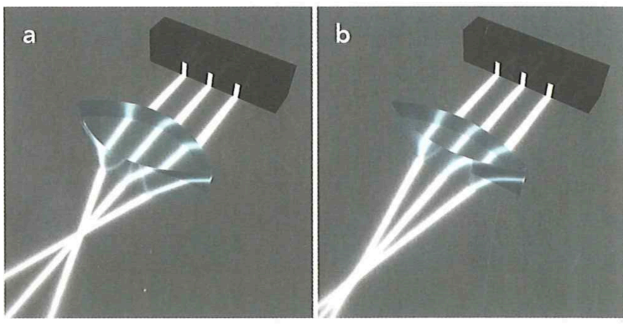


Parallel rays: Light comes from distant stars can be seen as parallel rays





Principle axis:
Focal point/principle focus:
Focal length:



fatter lens bends light more
=>

Diverging lens:

Drawing ray diagrams for lenses

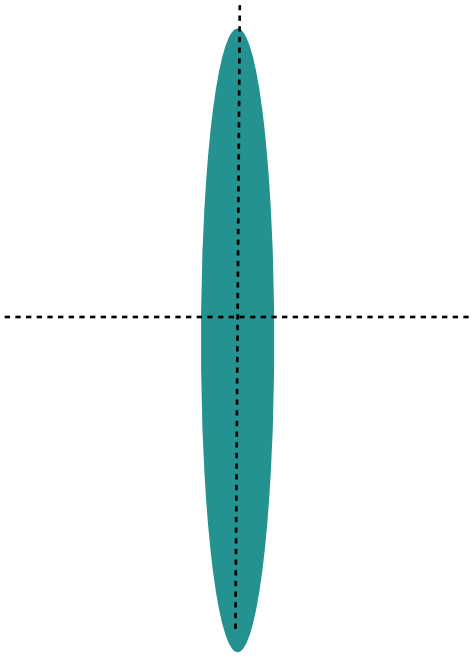
Rays can be drawn:

1.

2.

3.

To make things easier, we only show rays bending once at the center of the lens.



★ **Example:** draw a ray diagram to find the image formed of 3cm tall object placed 12cm from a converging lens which has a focal length of 5cm

Step 1:

Step 2:

Step 3:

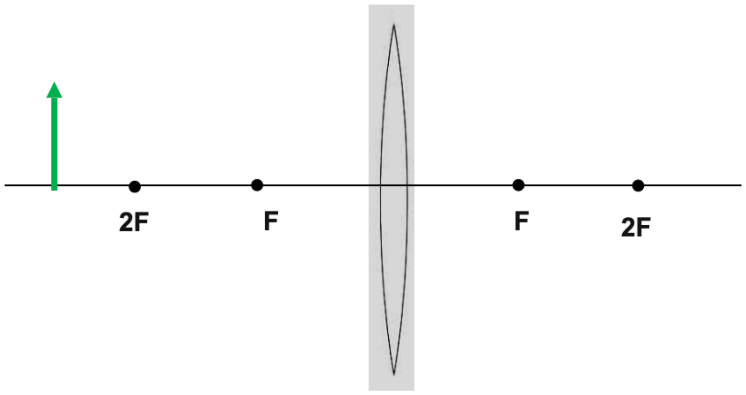
Step 4:

Images formed by lens could be described as:

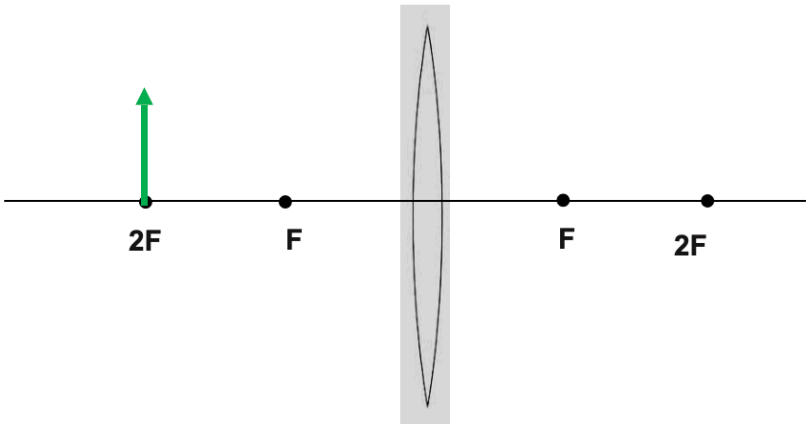
1.
2.
3.
4.

Images formed by converging lens

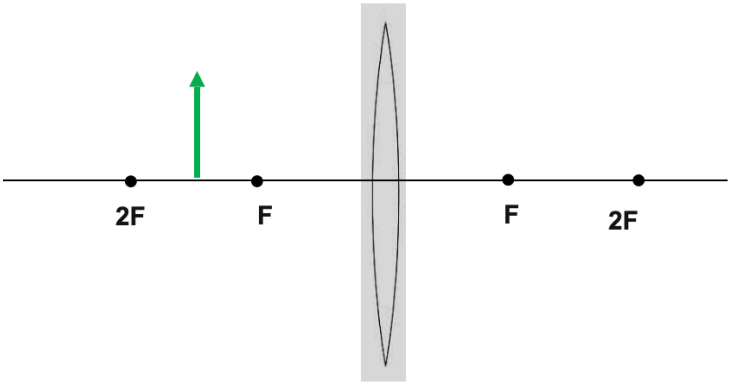
1. object is placed beyond 2F



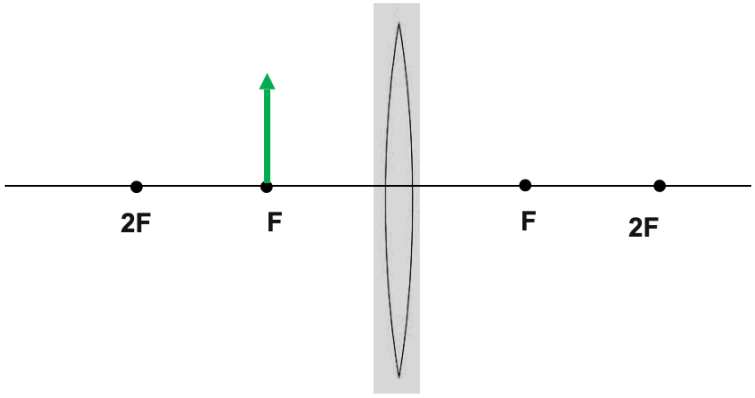
2. Object is placed at 2F



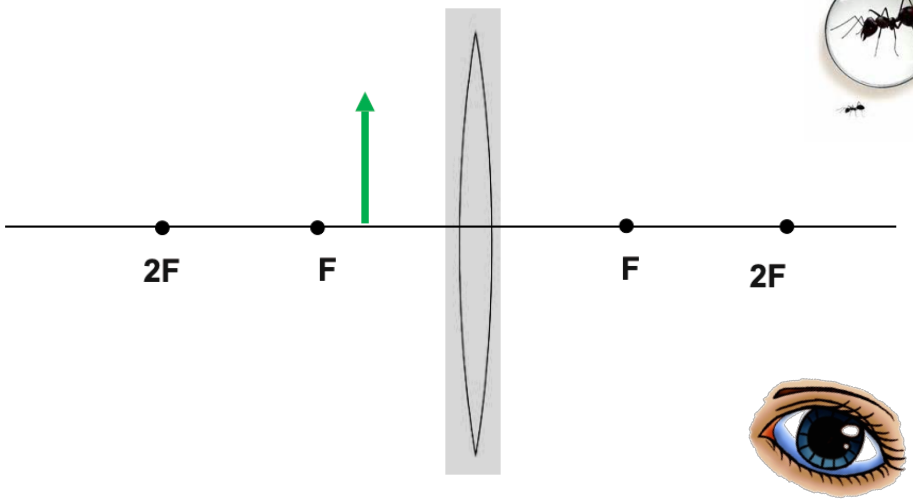
3. Object is placed between F and 2F



4. Object is placed at F

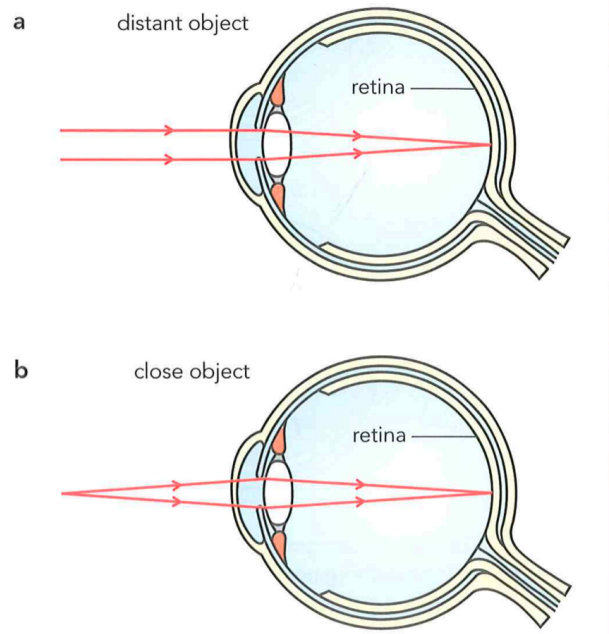


5. Object is placed within F

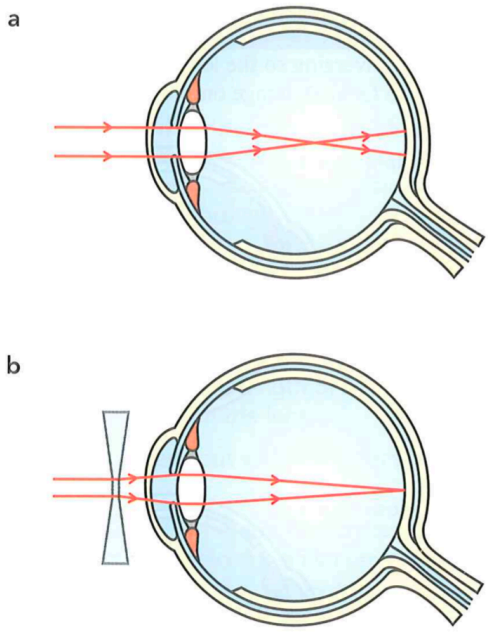


Using lenses to correct poor eyesight

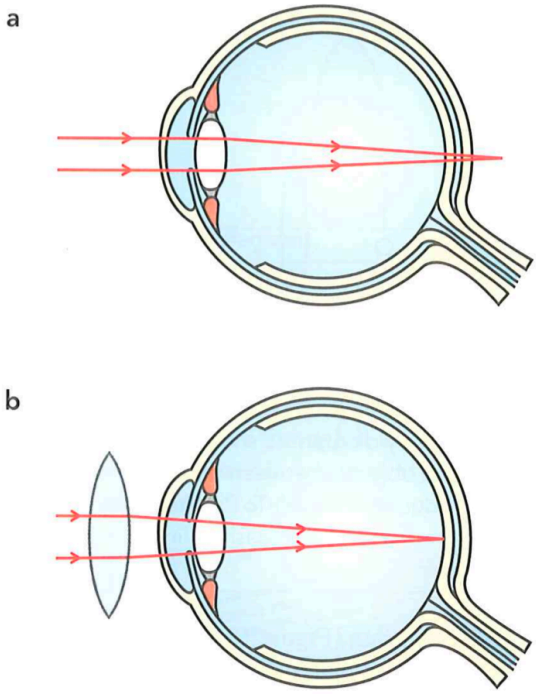
Normal eyes:



Short sight:

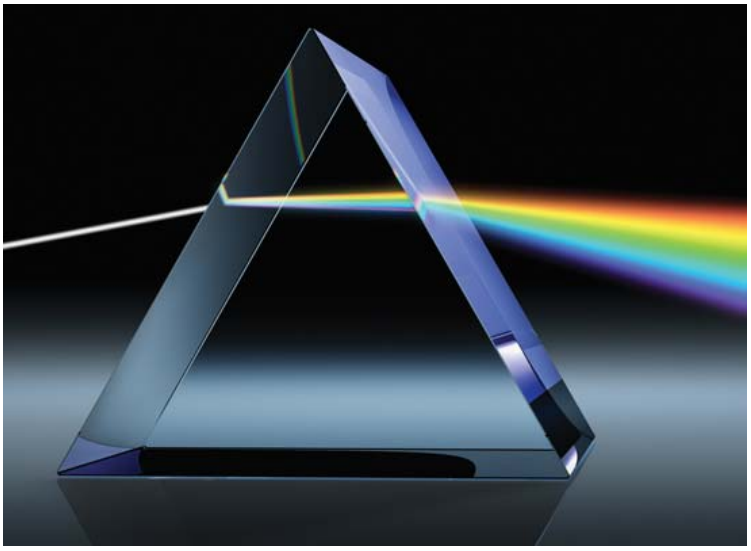


Long sight:



13.5 Dispersion of light

White light passing through a prism, form a spectrum. => dispersion.
How does this happen? What determines color?



	Wavelength	Frequenzy
Red	~ 625 – 740 nm	~ 480 – 405 THz
Orange	~ 590 – 625 nm	~ 510 – 480 THz
Yellow	~ 565 – 590 nm	~ 530 – 510 THz
Green	~ 520 – 565 nm	~ 580 – 530 THz
Blue	~ 445 – 520 nm	~ 675 – 580 THz
Indigo	~ 425 – 445 nm	~ 700 – 675 THz
Violet	~ 380 – 425 nm	~ 790 – 700 THz

Def of dispersion:

Monochromatic light:

Explaining dispersion: