Physics 052

L9

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The light rays coming from the leaves in the background of this scene did not form a focused image in the camera that took this photograph. Consequently, the background appears very blurry. Light rays passing though the raindrop, however, have been altered so as to form a focused image of the background leaves for the camera. In this lecture, we investigate the formation of images as light rays reflect from mirrors and refract through lenses.

What are we going to talk about today?

Ch22: Sound

- 22.0 Introduction:
  - Properties of Waves
  - Longitudinal and Transverse Wave
- 22.1 The Nature and sound of speed

Ch23: Wave Properties of Light

- 23.0: Introduction
- 23.3 Reflection of Light.
- 23.4 Refraction of Light.

Ch24: Mirrors, Lenses and Imaging system

- 24.1 Mirror
- 24.2 Lenses

Hasan Ibn al–Haytham
An Arab mathematician, astronomer, and physicist of the Islamic Golden Age (965 –1040)

22.0 Introduction: Properties of Waves

A wave is a kind of oscillation (disturbance) that travels through space and matter. Wave motions transfer energy from one place to another

Properties of Waves :

1) Wavelength (λ)

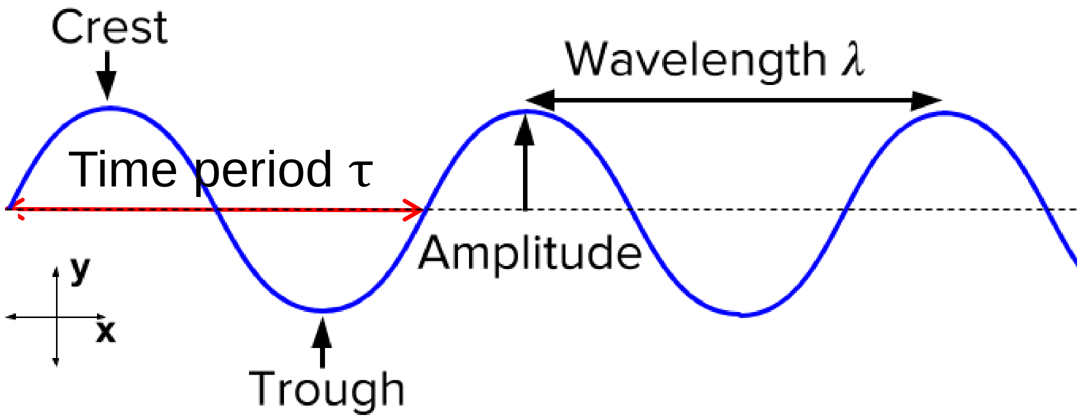
The wavelength (λ) of wave is the distance between analogous points of two successive waves. The unit of wavelength is (m).

2) Amplitude (A)

It is the maximum value of the wave displacement. The unit of amplitude is (m).

3) Period Time (τ)

The time to complete one cycle is called the cycle time or period (τ). The unit of time period is (s), and can be calculated as figure.



4) Wave speed (v)

The speed of an object refers to how fast an object is moving and is usually expressed as the distance travelled per time of travel. In the case of a wave, the speed is the distance travelled by a given point on the wave (such as a crest) in a given interval of time. In equation form:

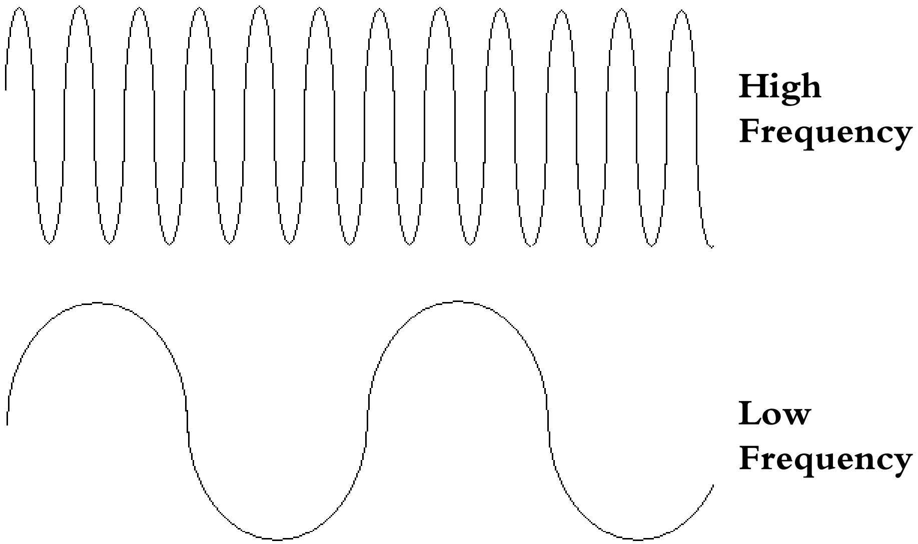
$$v = \frac{\lambda}{\tau}$$

The unit of speed of wave is (m/s).

5) Frequency (f)

It is measured as the number of waves that pass a given point in one second. The unit for frequency is cycles per second, also called hertz (Hz).

$$f = \frac{1}{\tau}$$



Therefore

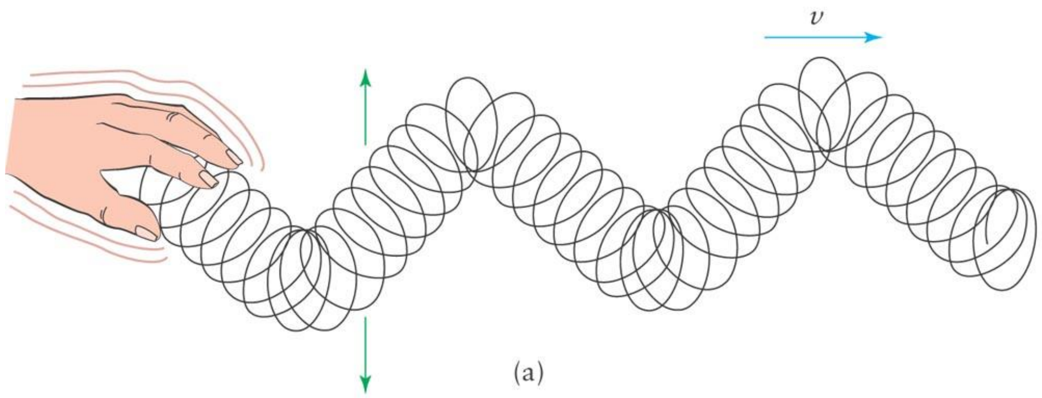
$$v = \lambda f$$

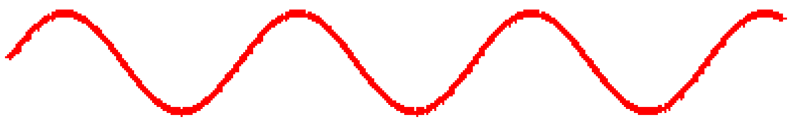
22.0 Introduction: Longitudinal and Transverse Wave

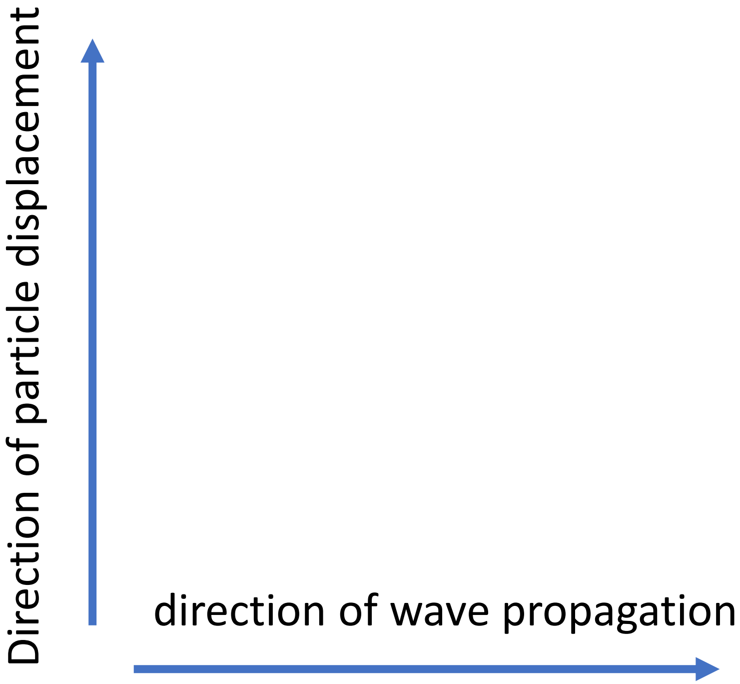
There are two basic types of wave : longitudinal waves and transverse waves

a)Transverse Waves

In a transverse wave the particle displacement is perpendicular to the direction of wave propagation, An example of longitudinal waves is compressions moving along a spring . We can make a horizontal longitudinal wave by pushing and pulling the spring horizontally.

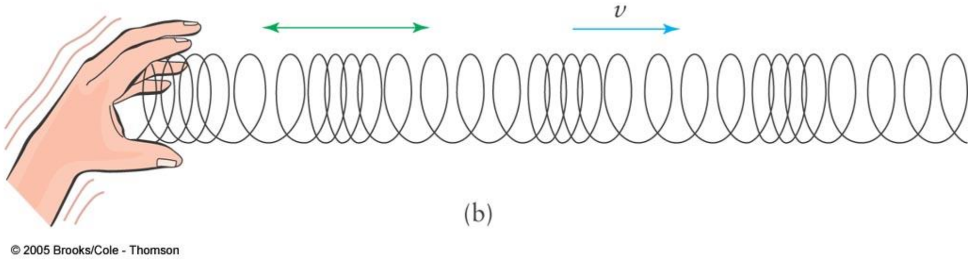






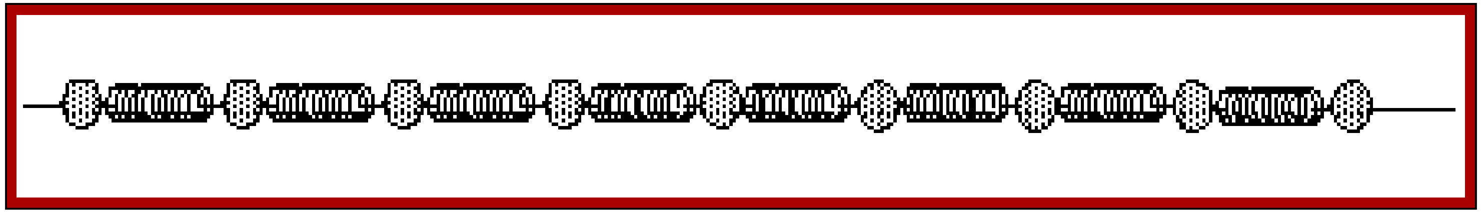
b) Longitudinal Waves

In a longitudinal wave the particle displacement is parallel to the direction of wave propagation. Examples of transverse waves include vibrations on a string and ripples on the surface of water. We can make a horizontal transverse wave by moving the spring vertically up and down.



Direction of particle displacement

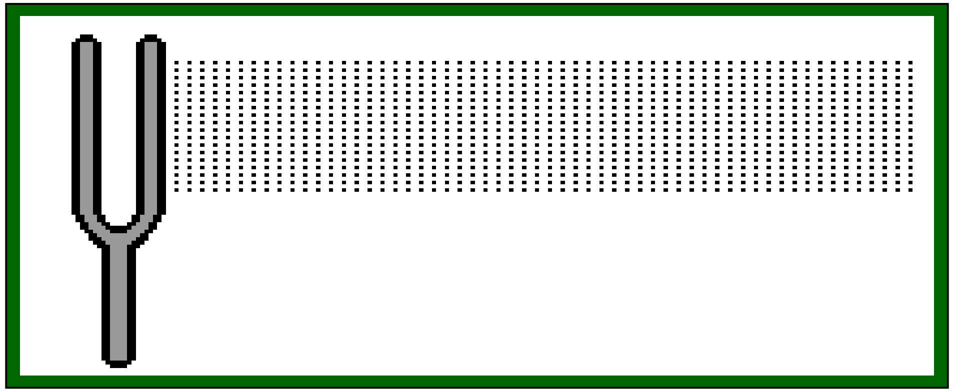
direction of wave propagation

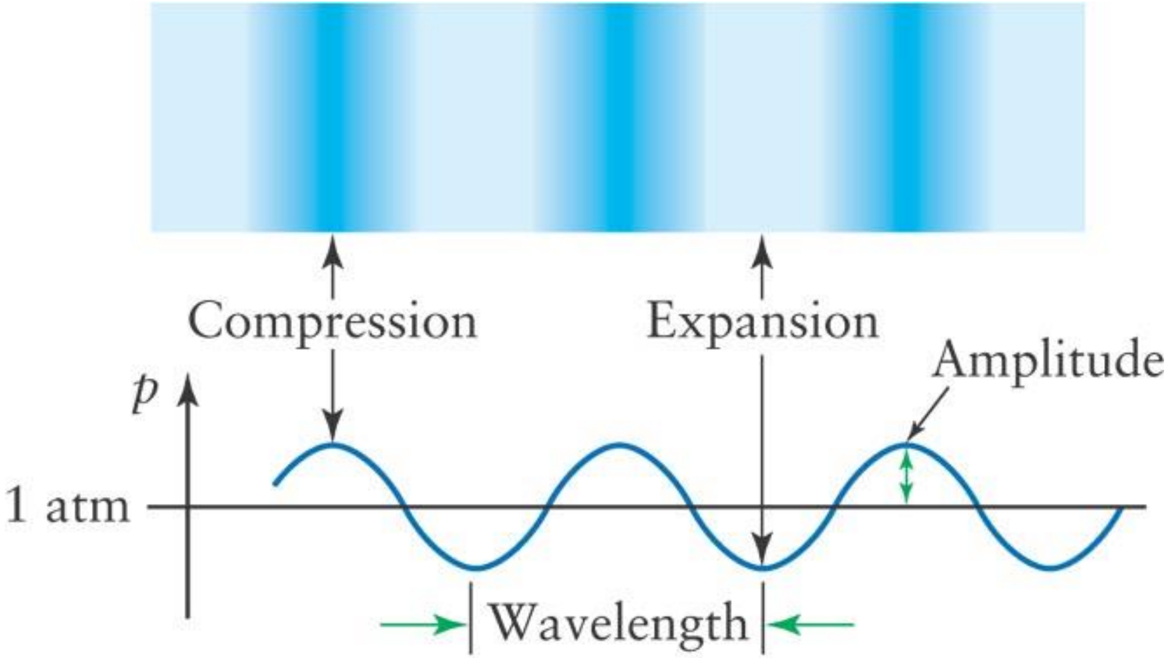


22.1 The Nature and sound of speed

Sound is a longitudinal wave (requires a medium to travel) produced when something vibrates and causes nearby air molecules to vibrate.

- Sound is produced when an object vibrates.
- When an object vibrates it exerts a force on the surrounding air
- As a sound gets louder, the amplitude of the wave increases.
- Loudness of a sound is recorded in decibels





22.1 The Nature and sound of speed

The speed of sound also depends on the temperature of the medium. For sound traveling through air, the relationship between wave speed and air temperature is:

$$v = 331\sqrt{1 + \frac{T_c}{273}}$$

Where:

- v is in meters/second.
- $331\ \mathrm{m/s}$ is the speed of sound in air at $0°C$.
- T_c is the air temperature in degrees Celsius.

Using this equation, one finds that at $20°C$, the speed of sound in air is approximately $343\ \mathrm{m/s}$.

Example

What is the speed of sound in air at room temperature (30°C)

Example 22.1. P:526

Two children are at opposite ends of iron pipe. One strikes an end of the pipe with a stone. What is the ratio of times it takes the second waves in air and in iron to reach the second child? $(v_{air} = 344\frac{m}{s}, v_{iron} = 5120\frac{m}{s})$

(**Ans:** $\frac{t_{air}}{t_{iron}} = 14.9$)

Example 22.3. P:527

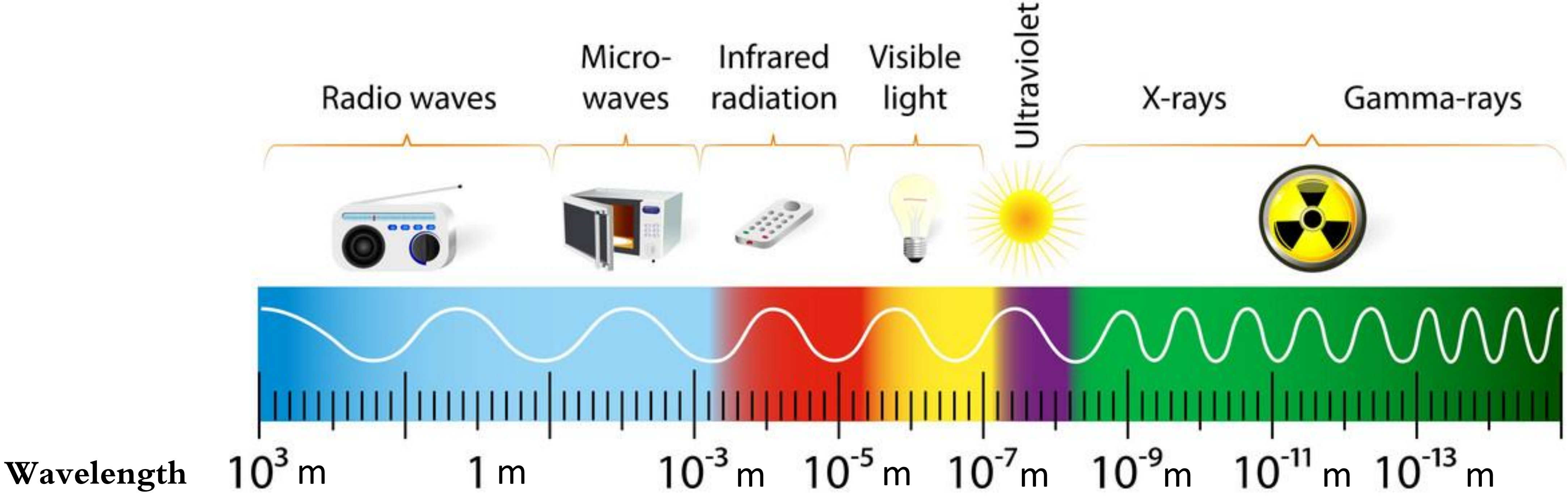
A bat can hear sound at frequencies up to 120,000 HZ. What is the wavelength of sound in air at this frequency? ($v_{air} = 344\frac{m}{s}$)

(Ans: $\lambda = 0.287\ cm$)

23.0: Introduction

What is the light ? [Click Here]

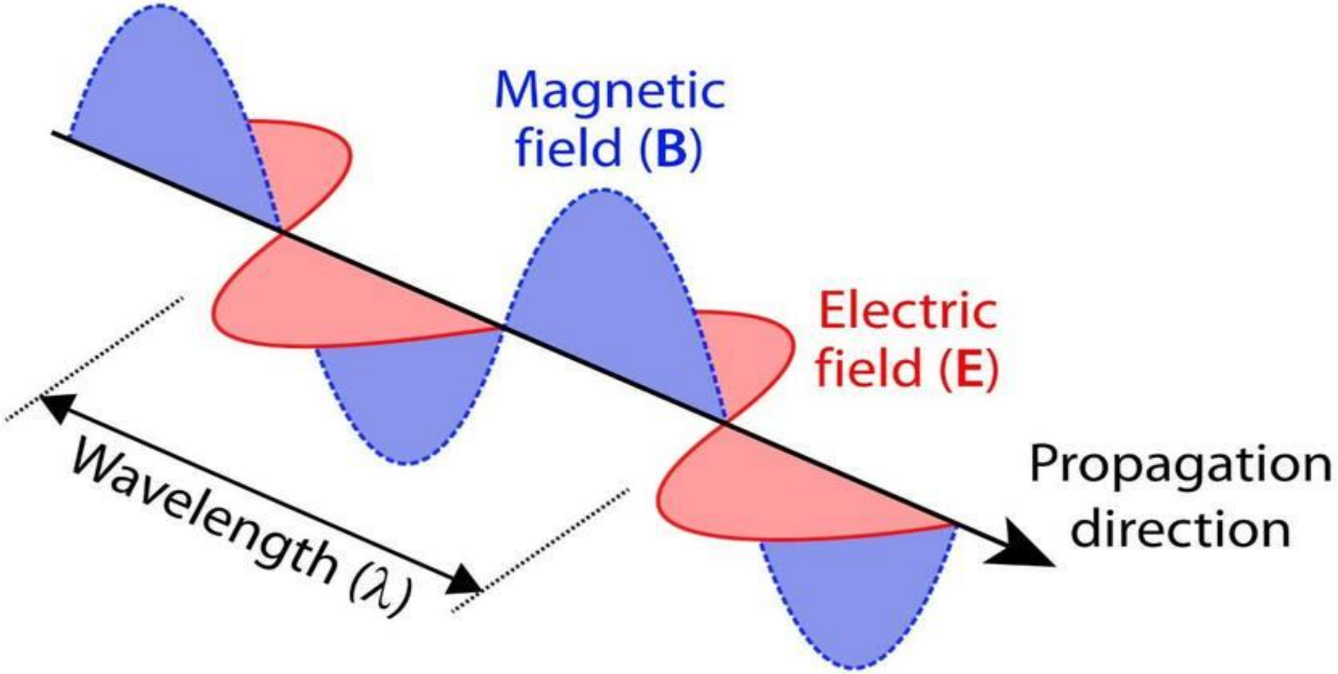
Light is a transverse wave ,it is part of the electromagnetic spectrum, which ranges from radio waves to gamma rays. Visible light is not inherently different from the other parts of the electromagnetic spectrum with the exception that the human eye can detect visible waves.



23.0: Introduction

What is the light ?

Electromagnetic radiation waves, as their names suggest are fluctuations of electric and magnetic fields, which can transport energy from one location to another. All electromagnetic waves have the same speed $c = 3 \times 10^{8}\ m/s$ and the same fundamental properties of reflection, refraction, diffraction and interference, and all waves have a, frequency, speed , wavelength and amplitude.

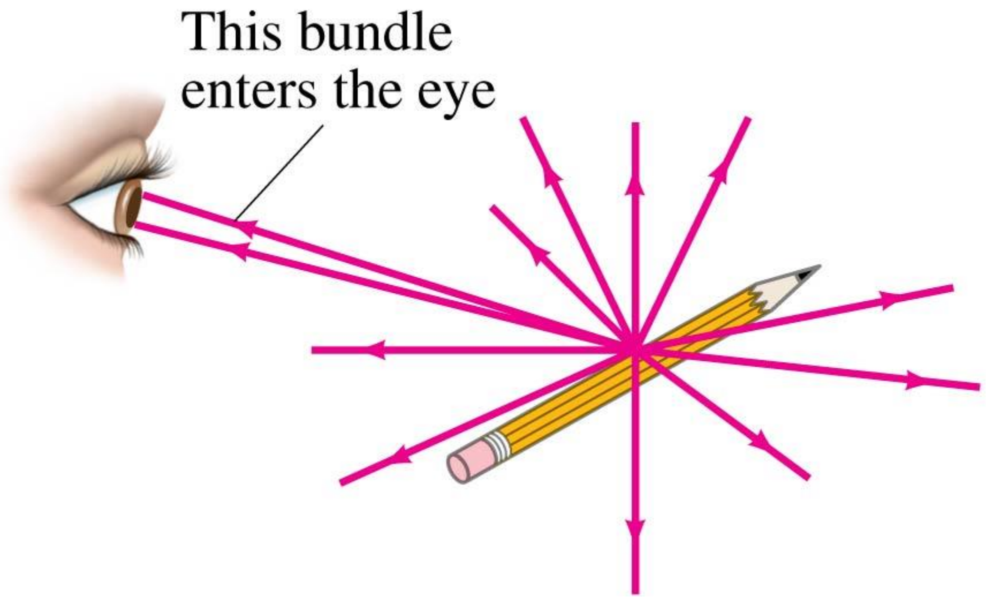


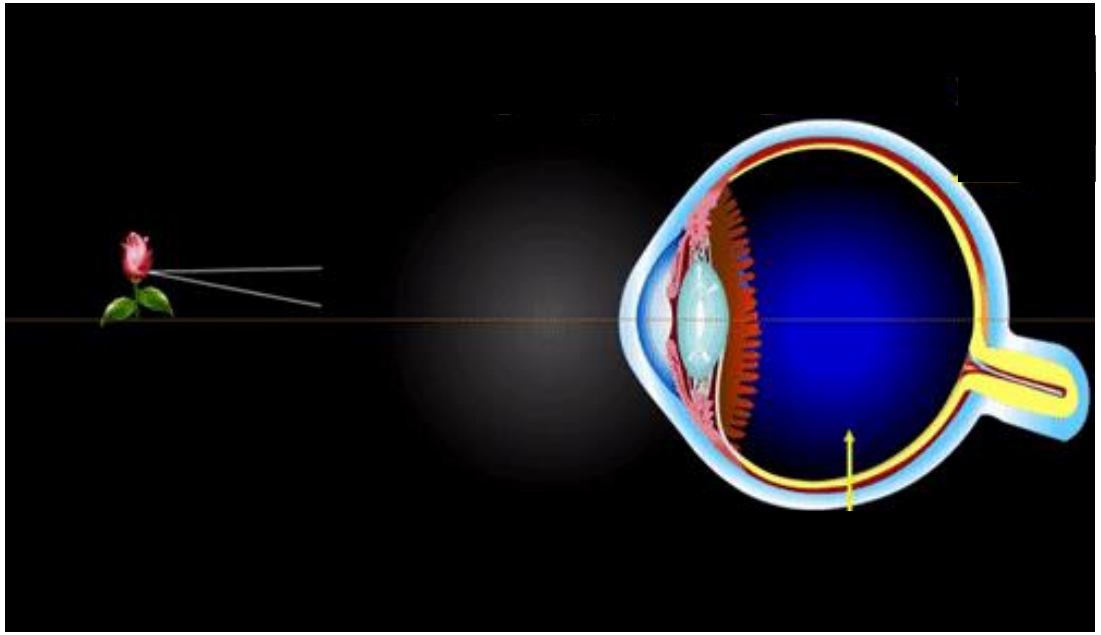
23.0: Introduction

How we can see things ?! [Click Here]

Light very often travels in straight lines. We represent light using rays, which are straight lines emanating from an object.

We see things because they reflect light into our eyes! This is literally the only way we get to see things! ALL objects we see either create light or reflect light!!





23.3 Reflection of Light & 24.1 Mirror

Law of reflection: the angle of reflection (that the ray makes with the normal to a surface) equals the angle of incidence.(Figure 1)

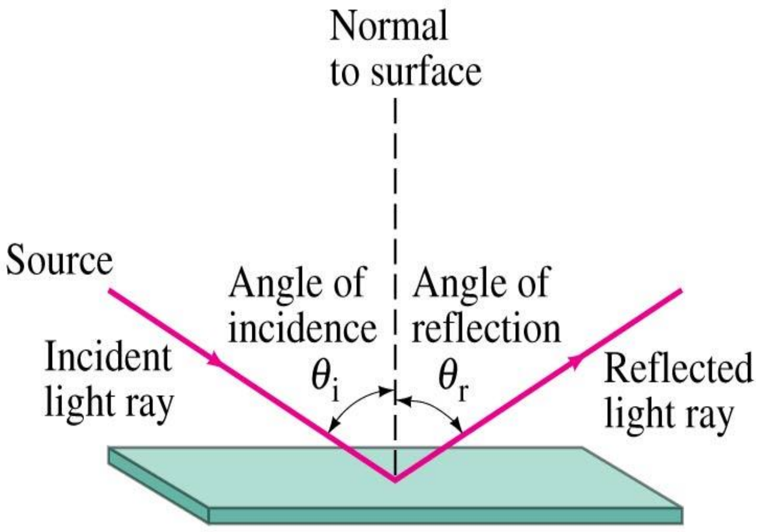
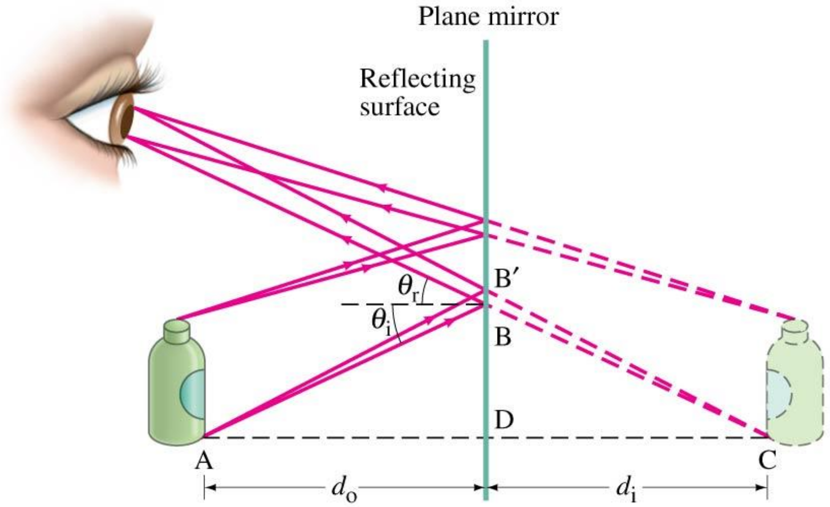


Fig. 1: Law of reflection

Plane mirror:

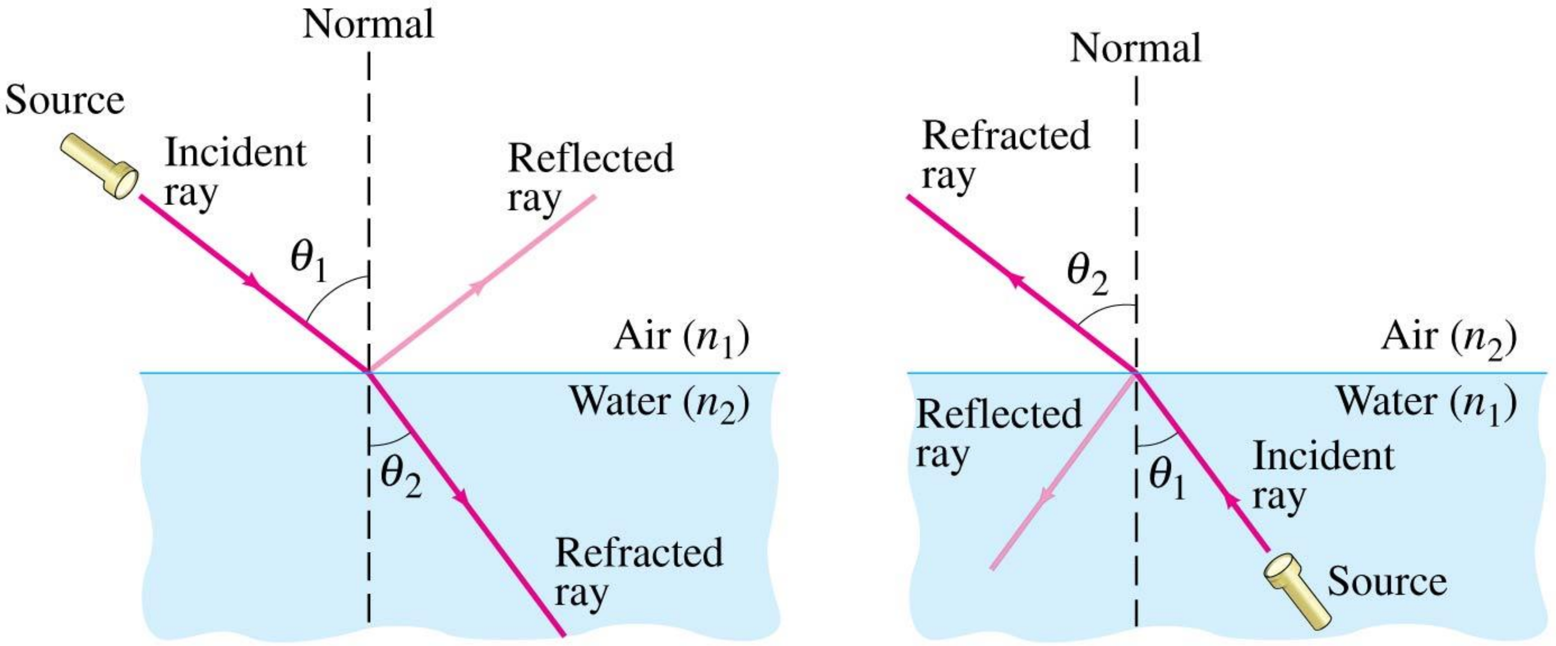
What you see when you look into a plane (flat) mirror is an image, which appears to be behind the mirror. The distance of the image from the mirror d_i is equal to the distance of the object from the mirror d_o.



23.4 Refraction of Light.

Snell's law

Light changes direction when crossing a boundary from one medium to another. This is called refraction, and the angle the outgoing ray makes with the normal is called the angle of refraction.



(a) $n_2 > n_1$: Ray bends toward ⊥ (b) $n_1 > n_2$: Ray bends away from ⊥

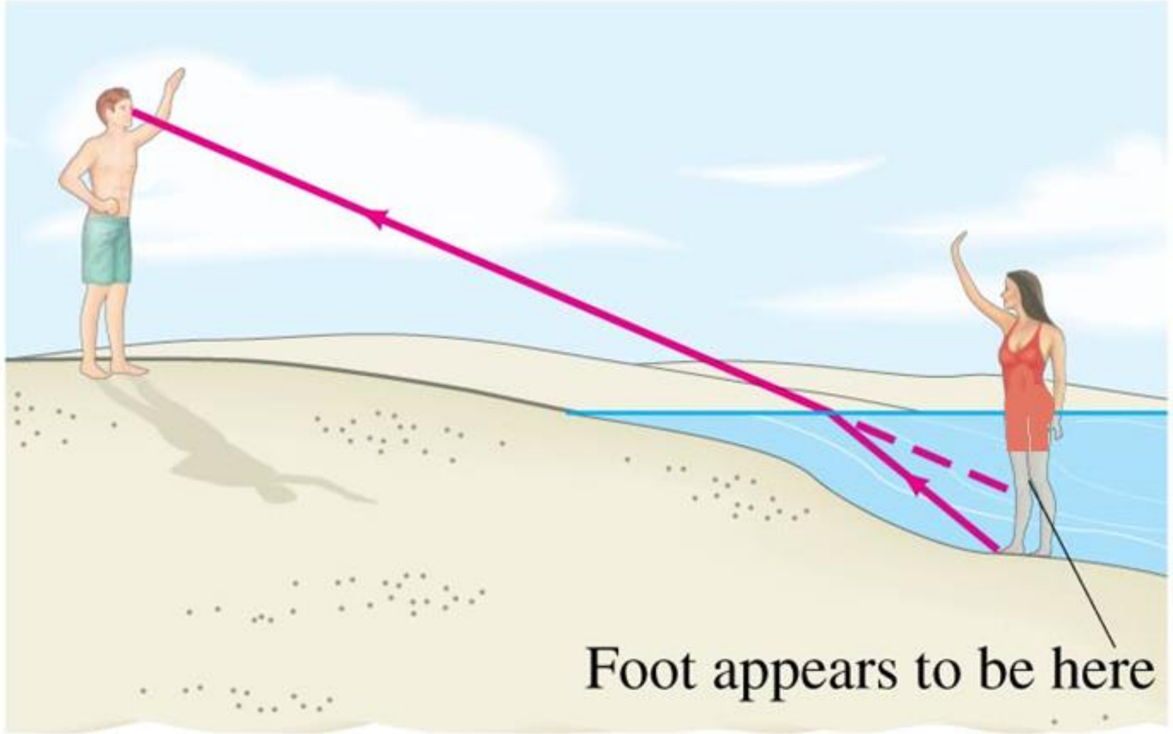
23.4 Refraction of Light.

The angle of refraction depends on the indices of refraction (n) , and is given by Snell's law:

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

Refraction is what makes objects half–submerged in water look odd.

(a)



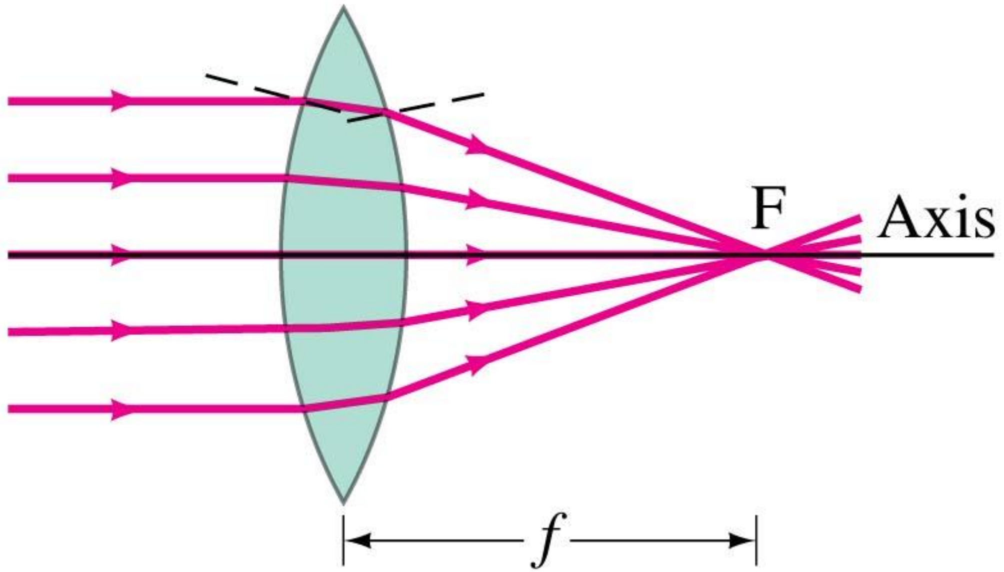
(b)

24.2 Lenses

Thin lenses are those whose thickness is small compared to their radius of curvature. They may be either converging (a) or diverging (b).

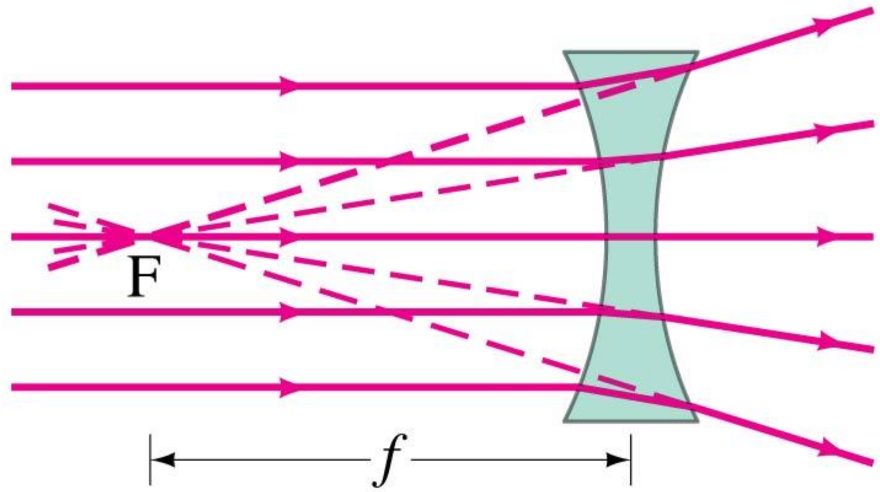
(a) Converging lens

Parallel rays are brought to a focus by a converging lens (one that is thicker in the centre than it is at the edge).



(b) Diverging lens

A diverging lens (thicker at the edge than in the centre) make parallel light diverge; the focal point is that point where the diverging rays would converge if projected back.



24.2 Lenses

Where f is the focal point is where the rays converge. Using geometry, we find that the focal length is half the radius of curvature:

$$f = \frac{r}{2}$$

The power of a lens is the inverse of its focal length:

$$D = \frac{1}{f}$$

Lens power is measured in diopters, D.

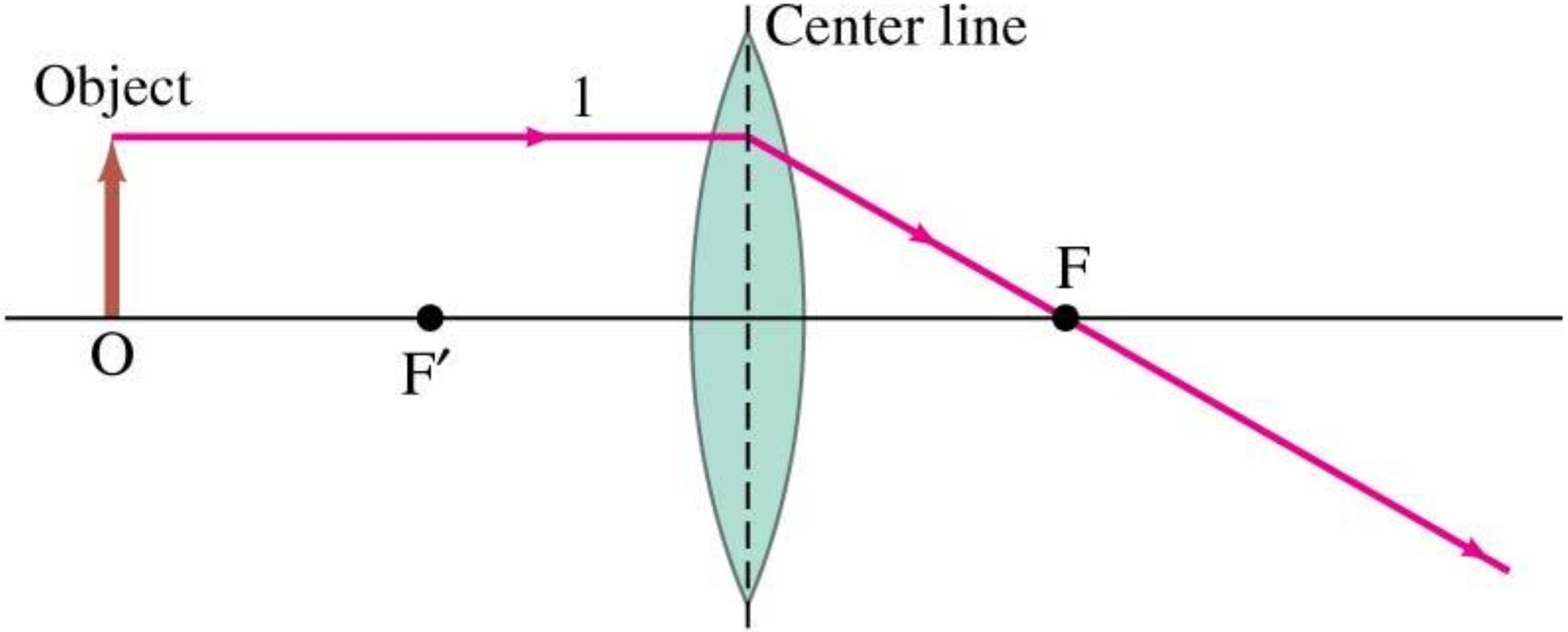
1D = 1 m^{-1} or $1/m$

24.2 Lenses

Ray Tracing: (Converging lens)

We use ray diagrams to determine where an image will be. We have three key rays:

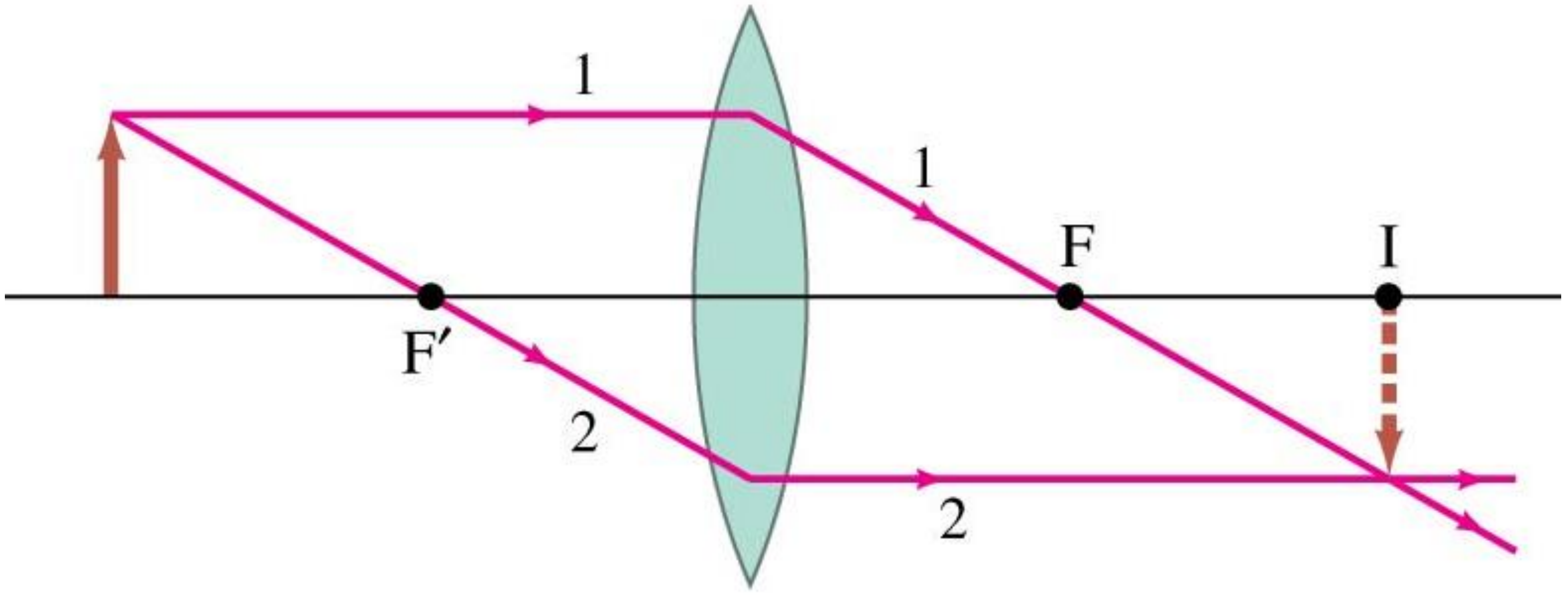
1. This ray comes in parallel to the axis and exits through the focal point.



Ray Tracing: (Converging lens)

We use ray diagrams to determine where an image will be. We have three key rays:

2. This ray comes in through the focal point and exits parallel to the axis.

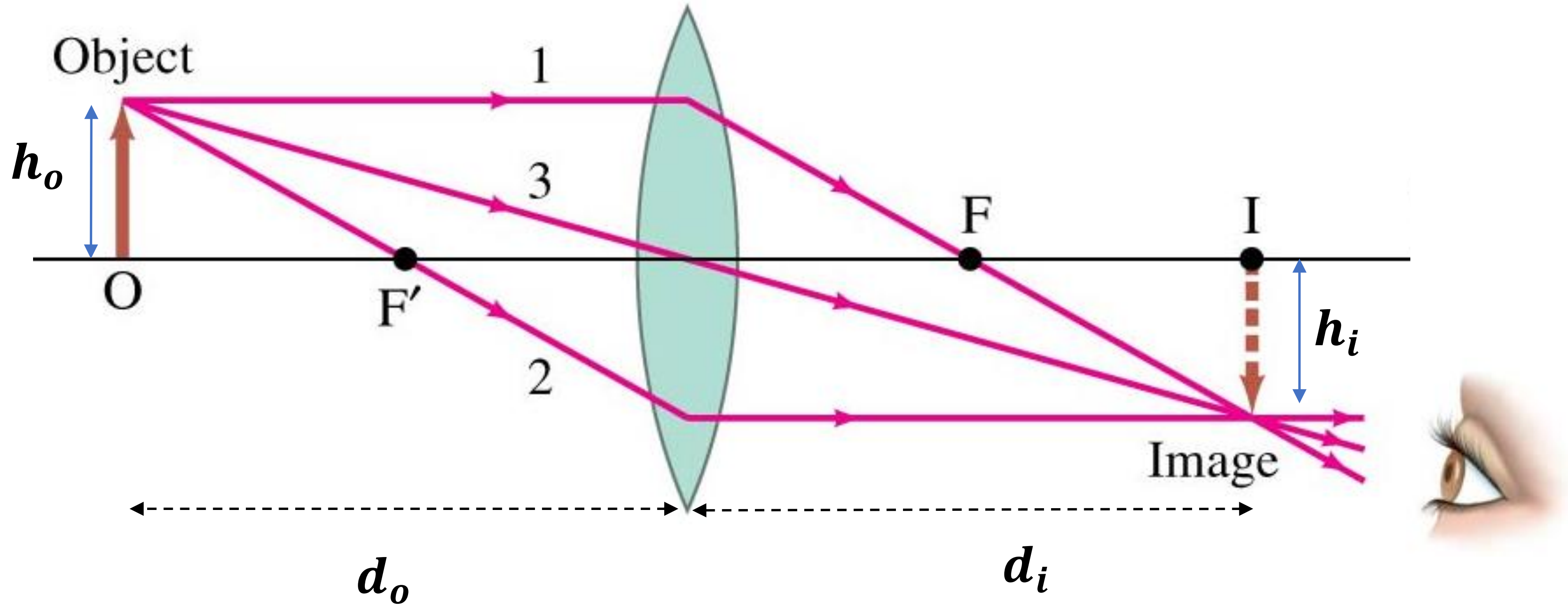


24.2 Lenses

Ray Tracing:(Converging lens)

We use ray diagrams to determine where an image will be. We have three key rays:

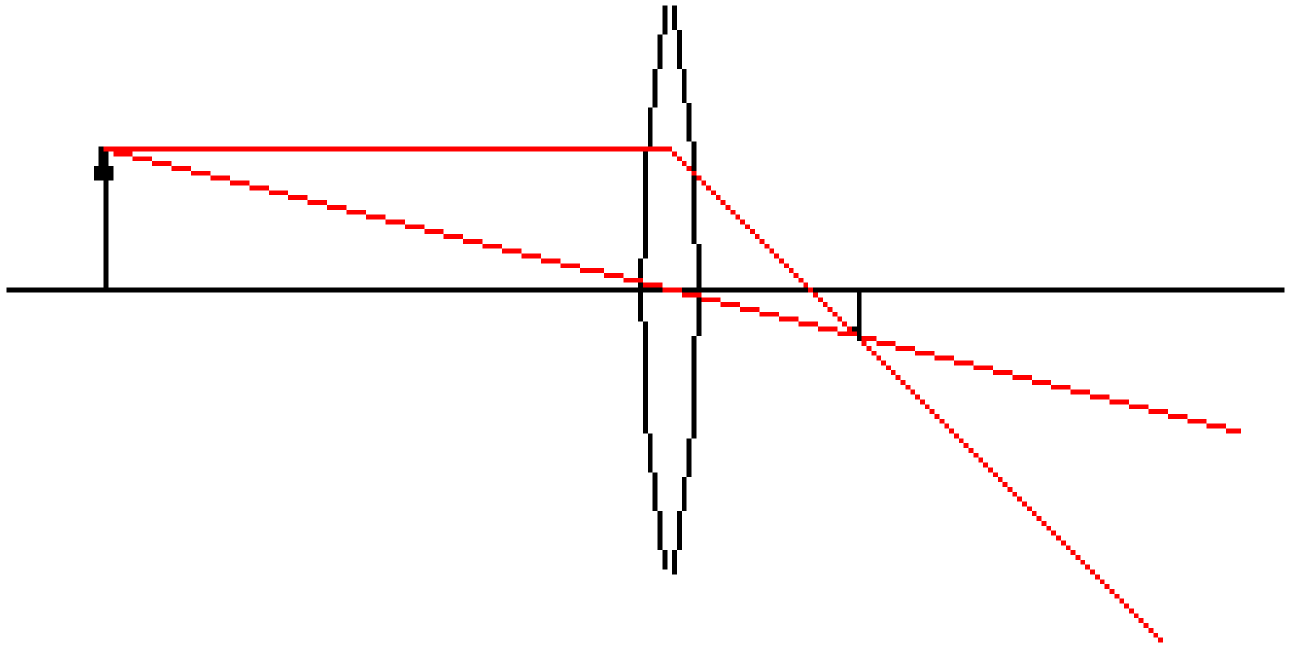
3. This ray goes through the centre of the lens and is undeflected.



24.2 Lenses

Ray Tracing:(Converging lens)

As long as the object is outside of the focal point the image is real and inverted. When the object is inside the focal point the image becomes virtual and upright.



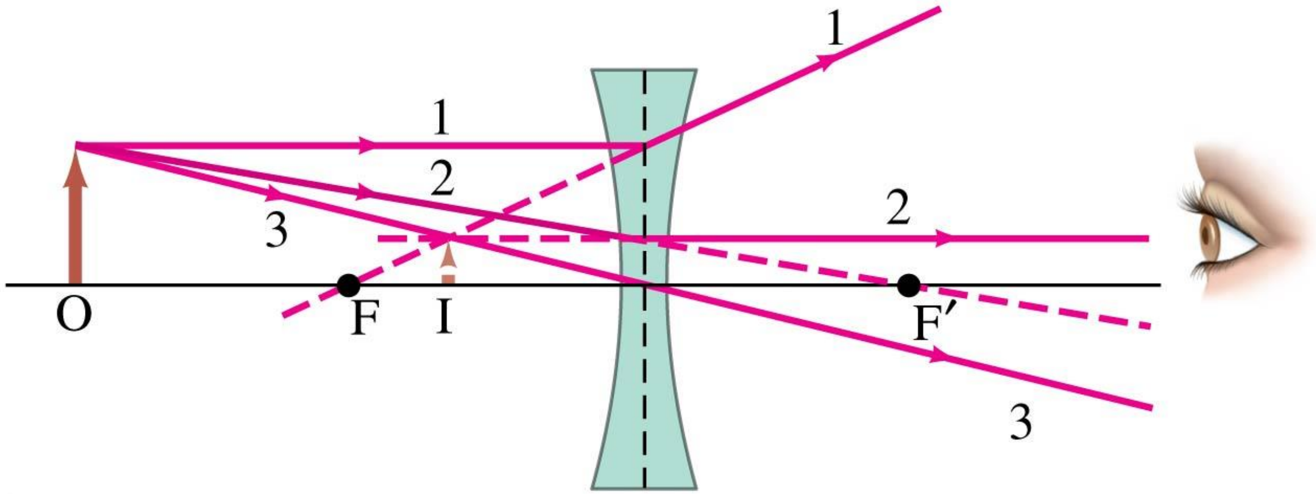
Ray Tracing: (Diverging lens)

For a diverging lens, we can use the same three rays; the image is upright and virtual.

Ray 1 enters parallel to the axis and is bent so that it appears to originate from the focal point.

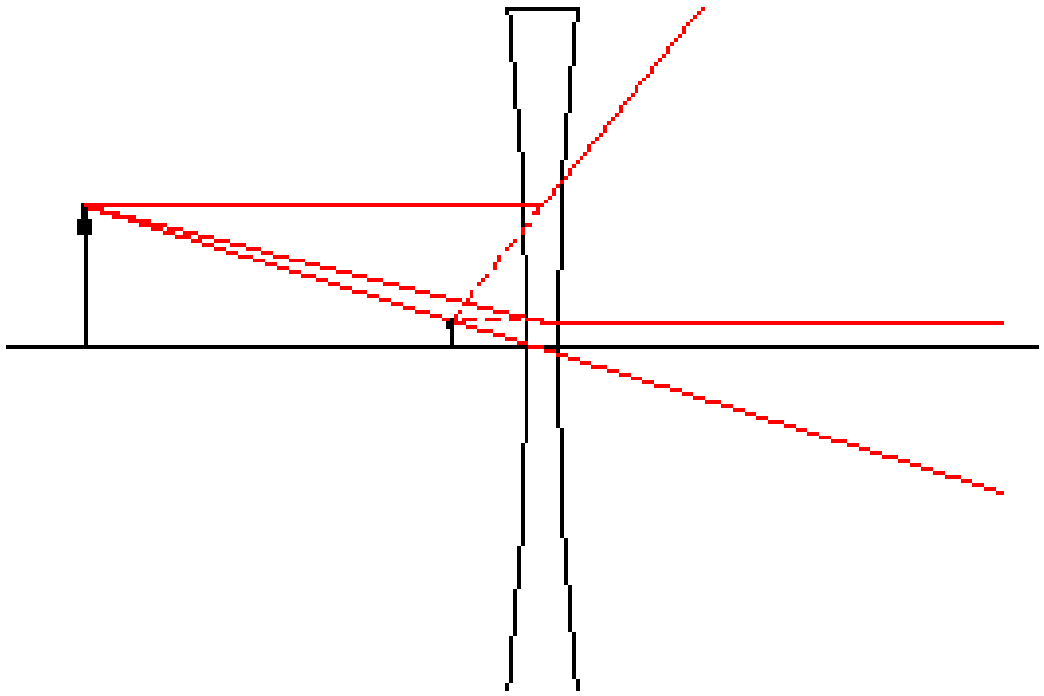
Ray 2 traveling towards the focal point will refract and travel parallel to the principal axis

Ray 3 passes through the centre of the lens without changing path.



Ray Tracing: (Diverging lens)

The image is always virtual and is located between the object and the lens.



The thin lens equation is

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

The sign conventions are slightly different:

Type	Focal	Object distance d_o	Image distance d_i		Object and image height
Converging lens	Always +	Always +	+ if d_i is on same side of d_o	– if d_i is on opposite side of d_o	+ upright
Diverging lens	Always –	Always +	+ if d_i is on opposite side of d_o	– if d_i is on same side of d_o	– inverted

The magnification formula is also the same as that for a mirror:

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

The power of a lens is positive if it is converging and negative if it is diverging.

Problem Solving: Thin Lenses

1. Draw a ray diagram. The image is located where the key rays intersect.
2. Solve for unknowns.
3. Follow the sign conventions.
4. Check that your answers are consistent with the ray diagram.

Example 24.3 P:598

A lens has a focal length of + 0.1m. Find the image distance when the object distance is (a) 0.5 m; (b) 0.08 m. (**Ans:** $(a)8\ D, (b) - 2.5D$)

Example 24.4 P:599

A camera lens has a focal length of +0.1m.

(a) If the camera focused on a child 2m from the lens, what is the distance from the lens to the film ? (**Ans**: $\mathbf{9.5}\ \boldsymbol{D}$)

(b) If the child has a height of 1 m, how tall is the image on the film? (**Ans**: $\mathbf{-0.05}\ \boldsymbol{m}$)

Example 24.3 P:600

A diverging lens has a focal of –0.4m.

(a) Find the image location for an object placed 2m from the lens. **(Ans: $-3\ D$)**

(b) If there is a real image 1 m from the lens, where is the object ? **(Ans: $-3.5\ D$)**