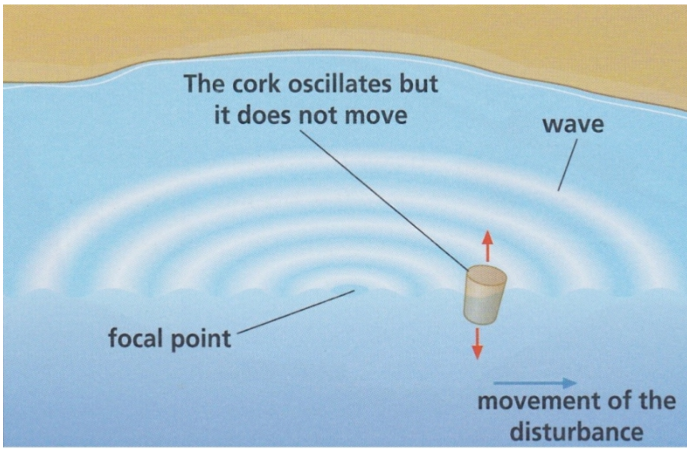
1. Waves.

Light and sound are two natural phenomena known in Physics as waves.

If we throw a small stone onto the surface of a still pond we can see that:

- Firstly, concentric circles with a growing diameter form in the water (waves), starting at the point of impact of the stone in the water (focal point). Apparently, the water is moving towards the edges of the pond.
- But, if we place a cork at a certain distance from this point, we will see that cork rises and falls as the circles pass, but it does not move sideways. This is because the particles of water oscillate upwards and downwards, but they do not move away from the focal point.



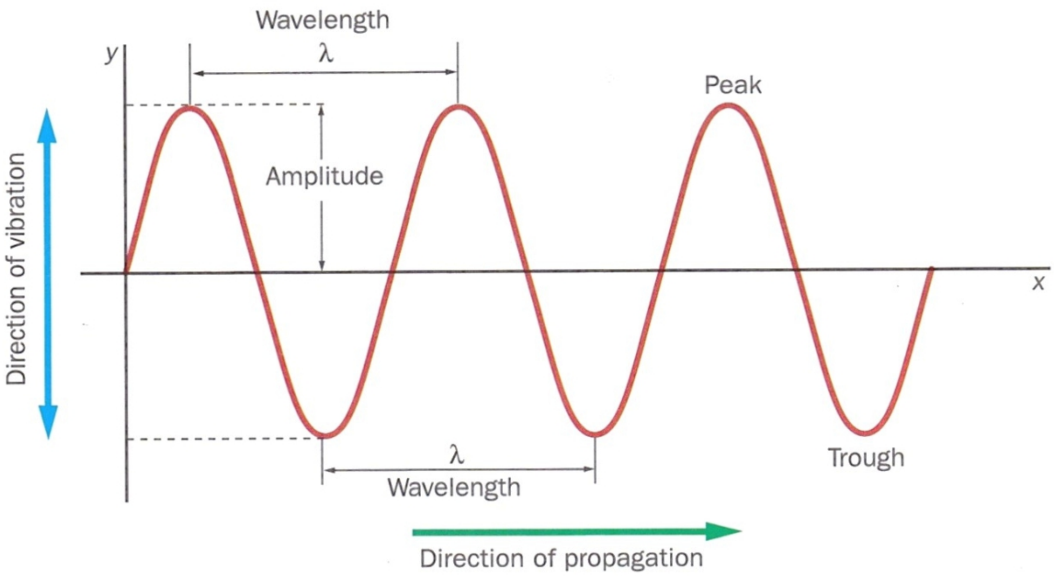
A **wave** is a disturbance (vibration or oscillation) that travels carrying the energy that generated it but not the matter through which it propagates.

This is why waves can propagate through material mediums such as water or air, but also through no material mediums, such as vacuum or outer space.

a) Characteristics of waves

Waves can be described using several physical magnitudes. They are:

- **Frequency** (**f**). It is the number of oscillations (complete movements) that a wave produces in one second. Its unit in S.I. is the ***hertz*** (**Hz**).
- **Wavelength** (**λ**). It is the distance between two consecutive **peaks** (highest points) or **troughs** (lowest points). It is usually express in meters.
- **Amplitude** (**A**). It is the maximum height reaches by a peak of a wave.
- **Time period** (**T**). It is the time a particle takes to complete an oscillation.



b) Types of waves

Waves can be classified according to the direction of the particles' oscillation they provoke, as:

- **Transversal waves**. The oscillation in particles is perpendicular to the direction of propagation of the disturbance. This is the case of light, for instance.
- **Longitudinal waves.** The oscillation in particles is parallel to the direction of propagation of the disturbance. This is the case of sound, for instance.

But they can also be classified according to where they can be transmitted, as:

- **Mechanical waves**. They propagate only in material mediums (air, water, rocks, etc.) and they carry mechanical energy. (E.g. Sound)
- **Electromagnetic waves**. They can propagate both material and non-material mediums and they carry electromagnetic energy. (E.g. Light)

READING ACTIVITIES

After reading the text, copy and answer the following questions into your notebook:
Remember: you must make complete sentences.

1.1. A wave has a frequency of 10 Hz.
a. How many oscillations does one of its points make in a second?
b. How many ones does it make in a minute?

1.2. How is it possible that light travels in the vacuum of the space?

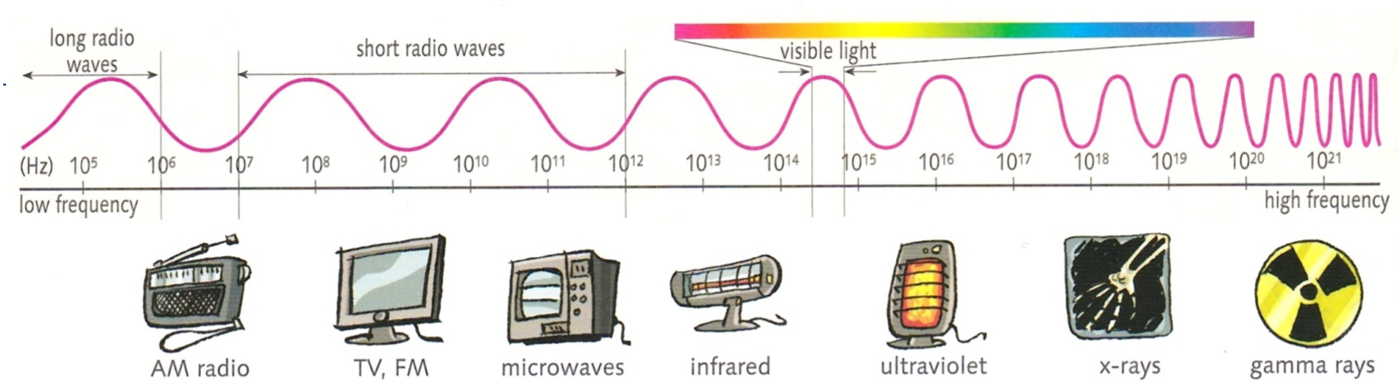
1.3. Enumerate the differences between light and sound as waves.

2. Light.

Light is a type of electromagnetic radiation that travel in form of wave. It is able to transmit through vacuum besides material mediums, such as air or water.

Electromagnetic waves are characterized by the **speed** at which they travel and their **frequency**.

- The **speed** of light in vacuum is 300,000 km/s and it is represented by "c". It is the fastest type of motion found in nature. Nothing can travel faster than light. When light goes through material mediums its speed decreases a little.
- Wave energy is proportional to wave **frequency**, so the higher the frequency of the wave is, the more energy the wave has. Electromagnetic waves are classified according to their frequency. Its graphic representation is called **electromagnetic spectrum**. Light is the visible radiation of the electromagnetic spectrum. Our eyes can detect electromagnetic waves between the frequencies of 4.10^{14} Hz (for *red* colour) and 8.10^{14} Hz (for *violet* colour).



READING ACTIVITIES

After reading the text, copy and answer the following questions into your notebook:
Remember: you must make complete sentences.

2.1. Look at the electromagnetic spectrum and identify the type of electromagnetic waves that correspond to each frequency.

a. 2.10^{14}Hz
b. 8.10^{16}Hz
c. 25.10^{11}Hz
d. 7.10^{20}Hz
e. 19.10^{9}Hz
f. 5.10^{14}Hz
g. 4.10^{18}Hz
h. 5.10^{6}Hz

2.1. Properties of light

Light has three characteristic properties:

- it travels in a straight line
- it is reflected (rebounds) when it meets a reflective surface
- it changes direction when it moves from one medium to another (it is refracted).

2.1.1. Light travels in a straight line

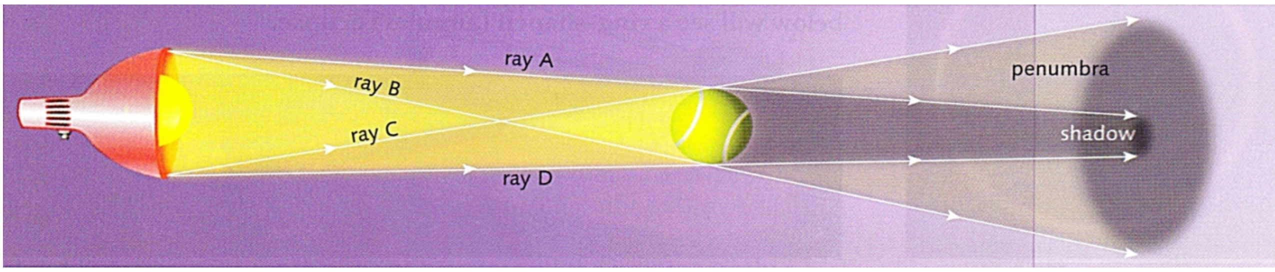
Light always travels in a straight line. This is why light produces:

- **Shadows** when its path is completely blocked by an obstacle.
- **Penumbras** when the light is partially blocked.

Generally, if a light source is very small, or very big but far away from the illuminated object (for example, the Sun), it produces a sharp, clear shadow.

But if a light source is big and close to the object, both a shadow and a penumbra are formed. In the area where no light rays from the outer edges of the source can reach, a full shadow is formed. Around this there is an area where rays from one edge of the source can reach but rays from the opposite edge of the source cannot reach. In this area, a penumbra is formed.

To understand how shadows and penumbras are formed we use a **ray diagram**.



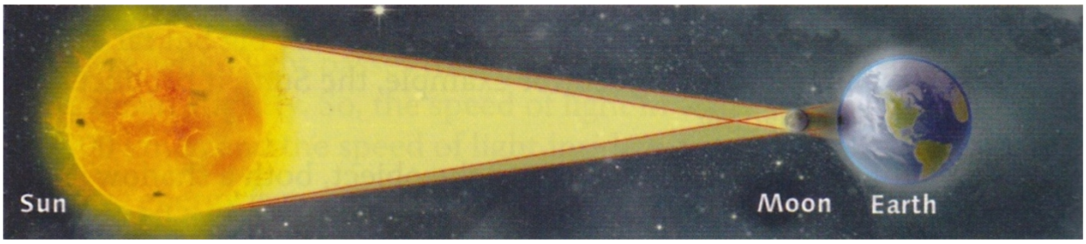
- Two lines are drawn from the top edge of the light source: one touches the upper edge of the object (*ray A*); the other one touches the lower edge of the object (*ray B*). Next, similar lines are drawn from the bottom edge of the light source (*rays C* and *D*).
- The area between *rays A* and *D* is in **shadow.** But, the top and bottom areas between *rays C* and *A* and *rays D* and *B* respectively are in **penumbra**.
- The rays that come from the bottom edge of the light source don't reach the top area of penumbra, but the rays that come from the top edge do. The opposite occurs in the bottom area of penumbra.

Eclipses are one of the most spectacular consequences of this behavior of light.

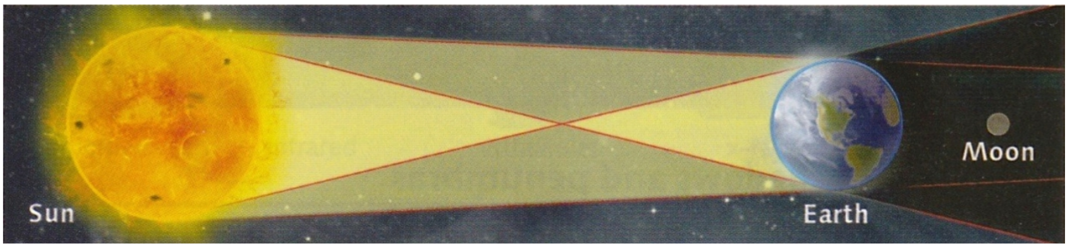
An eclipse occurs when the Sun or the Moon becomes partly or completely dark because of the position of the Sun, Moon and Earth in relation to each other. Shadows and penumbras are produced during eclipses.

During a **solar eclipse**, when the Moon moves between the Sun and the Earth, the area of shadow is very small because the Moon is small.

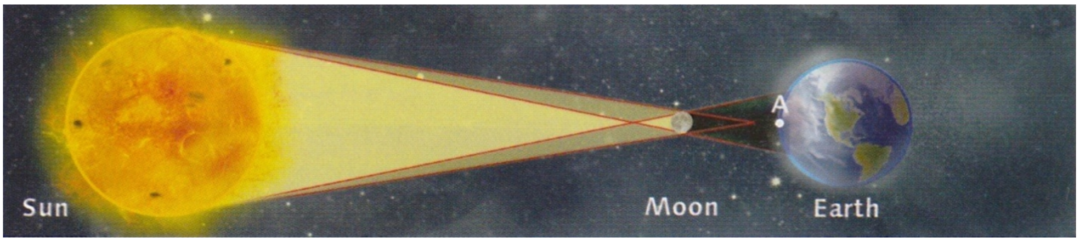
- At the place on the Earth’s surface where the shadow is formed, the day gets darker and darker, until for a few moments it seems to be night, and so we see a **total eclipse** of the Sun.
- In the area of penumbra on the Earth's surface, we see a **partial eclipse** of the Sun.



During a **lunar eclipse** our planet moves between the Sun and the Moon. Because the Earth is bigger than the Moon, the areas of shadow and penumbra formed by the Earth on the Moon are bigger than the Moon's diameter. So, a lunar eclipse can last around three hours from the time it enters the area of penumbra to the moment it leaves it, but a total solar eclipse only lasts a few minutes.



Sometimes the Moon is further away from the Earth than at other times. This is because the Moon's orbit around the Earth is not an exact circumference: it's elliptical. If an eclipse of the Sun occurs when the Moon is further away from the Earth than usual, the shadow isn't formed on the Earth, but the penumbra is. It will see a ring-shaped (**annular eclipse**).

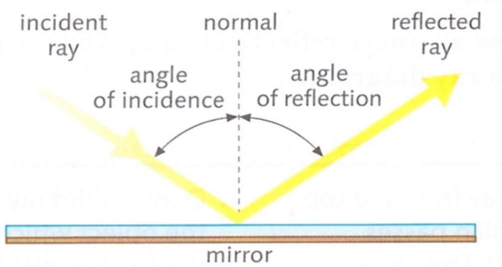


2.1.2. Light is reflected

Light reflection is the change in direction of a light ray when it hits the surface of an object. The reflected light continues travelling through the same medium as the incident light.

Light reflection on a perfectly flat surface follows two basic laws:

- The incident ray, the reflected ray and the normal are all in the same plane which is perpendicular to the surface.
- The angle of incidence is equal to the angle of reflection.

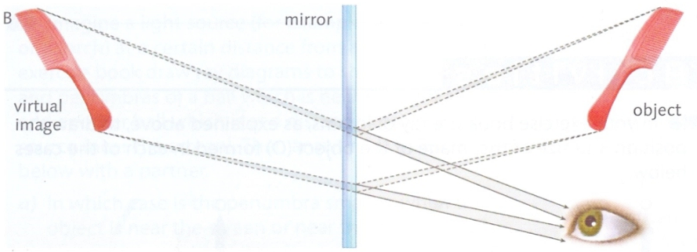


We can see objects because the light that is reflected from them reaches our eyes. There are two types of light reflection:

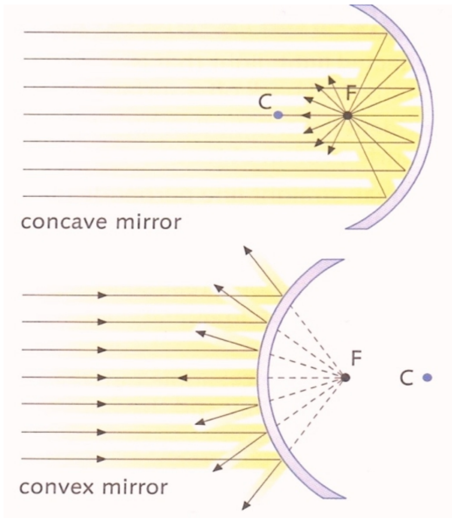
- **Specular reflection** forms images. If the surface from which the light is reflected is perfectly smooth, all the reflected rays leave the surface in the same direction. This occurs in mirrors or on the surface of very calm water.
- **Diffuse reflection** occurs when surfaces aren't smooth (on a microscopic scale), so the rays are reflected in many different directions. We can see objects and their shapes because of the diffuse reflection of light from their surfaces.

a) Images in a plane mirror

Images that are formed in plane (flat) mirrors are virtual (they appear to be behind the mirror), and they are formed at the same distance behind the mirror as the real object is in front of the mirror.



b) Images in curved mirrors



Curved mirrors can be concave or convex.

- If a mirror is **concave**, when parallel rays hit it, they are reflected and converge at one point: this is the focus (F) of the mirror.
- If a mirror is **convex**, parallel rays diverge when they are reflected. The reflected rays appear to come from a point behind the mirror. If each ray is extended on an imaginary line behind the mirror, then they all meet at the focus (F).

In both cases, because curved mirrors are sections of a sphere, the focus (F) is halfway between the centre of curvature (C) of the sphere and the mirror itself.

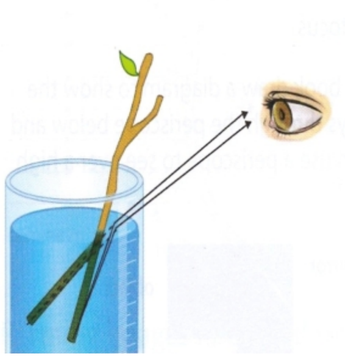
As a consequence this kind of mirrors will deform the images of the objects. Concave mirrors generate smaller images than the real objects and convex mirrors generate larger images than the real objects.

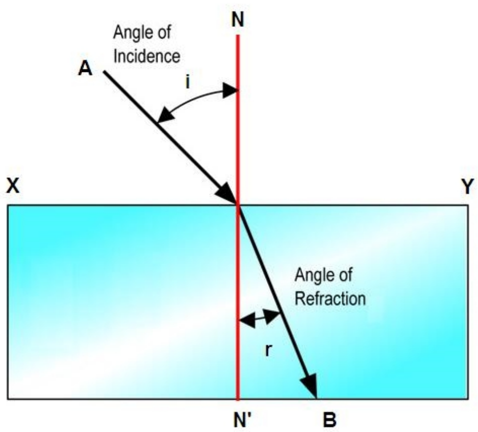
2.1.3. Light is refracted

Light refraction is the change in direction of light rays when they pass from one medium to another in which they travel at a different speed.

The basic laws of light refraction are:

- the *refracted ray*, the *incident ray* and the **normal** are all in the same plane
- the *refracted ray* moves closer to the *normal* when it passes from a medium in which it travels more quickly to another medium in which it travels more slowly. However, the *refracted ray* moves away from the *normal* when it passes into a medium in which it travels faster.

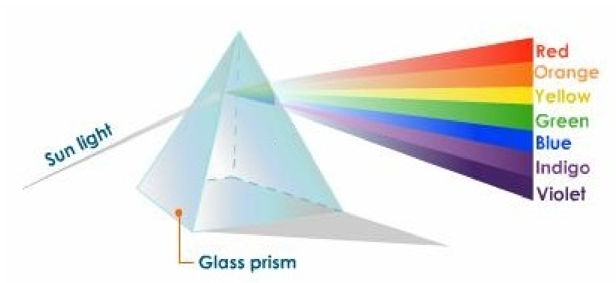




a) Light dispersion

If a beam of white light passes through a diffusing medium (for example, a triangular prism), the colours separate.

This occurs because the refractive index of a medium varies slightly depending on the frequency of the light passing through it: the higher the frequency is, the higher the refractive index is. So, the highest frequency colour (violet) bends the most and the lowest frequency colour (red) bends the least.

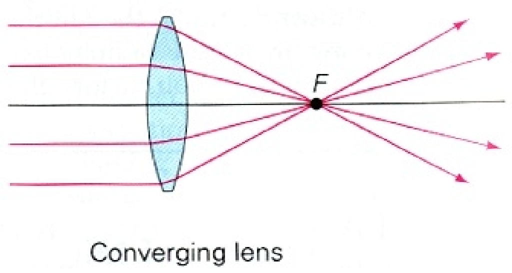


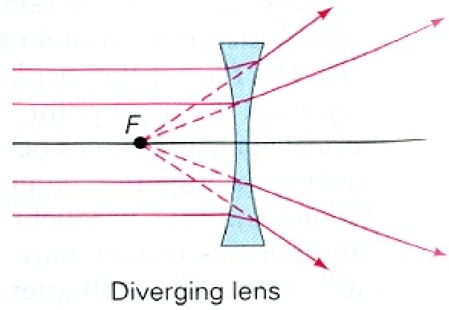
b) Lenses

A lens is a transparent piece of glass or plastic, etc. with two sides, one or both of which must be curved. Lenses are used in glasses, magnifying glasses, camera lenses, etc.

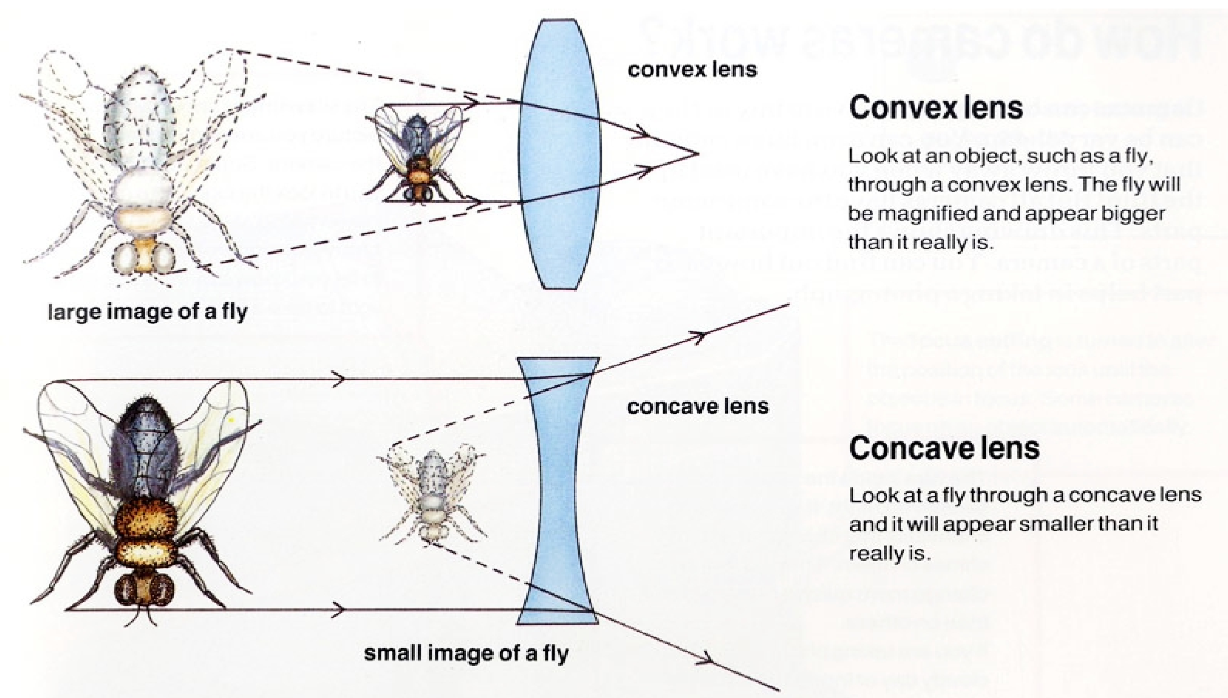
If the medium that surrounds the lens is air, then lenses can be of two types:

- **Convergent lenses** (biconvex) are thicker in the middle than at the edges. Parallel rays refracted by these lenses converge at one point called the focal point of that lens.
- **Divergent lenses** (biconcave) are thinner in the middle than at the edges. Parallel rays refracted by these lenses do not converge, instead they separate (diverge).





Images through lenses will see larger or smaller than the real object.



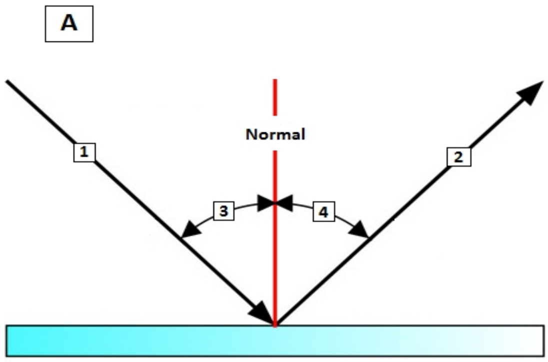
READING ACTIVITIES

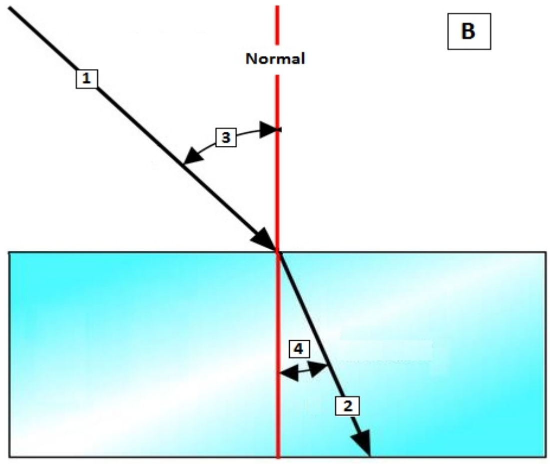
After reading the text, copy and answer the following questions into your notebook:
Remember: you must make complete sentences.

2.2. How is penumbra formed? And shadow?

2.3. Why solar eclipses are observed only in a small part of the Earth while lunar eclipses can be observed in wide areas?

2.4. Label the following diagrams and indicate which correspond to a *reflection diagram* and which to a *refraction diagram*. How do you identify each one?





2.5. If we place a teaspoon into a glass half full of water, we will observe that the handle of the spoon looks bent. Explain why it is.

2.6. What kind of lenses is used in peephole in a door, converging or diverging? Why?

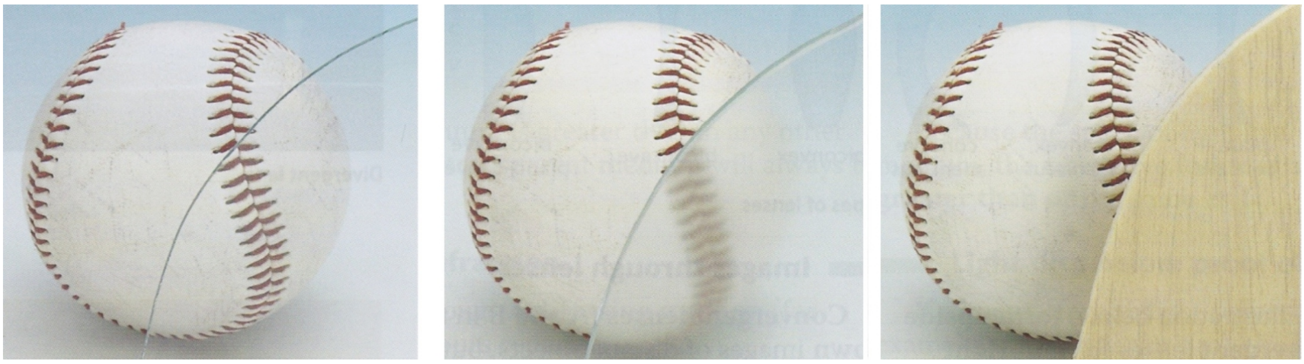
2.7. In the corner of some streets mirrors are placed in order to increase the visibility and make safer the driving. What type of mirrors are they, plane, convex or concave? Why?

2.8. Why is possible to burn a piece of paper with a magnifying glass?

2.2. Light and matter

Matter can behave in different ways when it interacts with light. Some materials allow light to travel through them, but others don't.

Depending on how they behave in light, objects can be *transparent*, *opaque* or *translucent*.



Transparent objects

Light travels through them in a straight line and comes out the other side with no change of direction.

That is why we can see clear, sharp images through transparent objects, for example, glass, air or water.

Translucent objects

These absorb or reflect light and some light can travel through them, but it is sent in different directions.

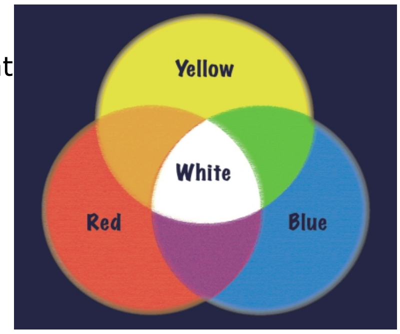
That is why we can't see clear images through translucent objects, for example, paper, thin fabrics or tracing paper.

Opaque objects

These absorb or reflect light, but light cannot pass through them.

That is why we can't see images through opaque objects. Wood, metal, porcelain and cardboard are examples of opaque objects.

a) Additive colour mixing: the sum of lights



When white light passes through a prism, it separates into the different colours that form a rainbow. The colours of a rainbow are: violet, indigo, blue, green, yellow, orange and red.

The primary colours of light are red, green and blue. When the three primary colours are mixed in the same proportions, they produce white light.

Different colours are obtained in the following way:

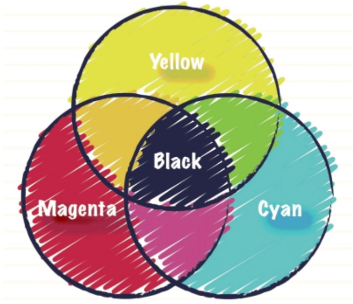
If we add the three primary colours, we get white.

We see objects when light from them enters our eyes. The colour of an object depends on the colour of light that comes from it, that is to say that its colour dependes on which colours it reflects and which it absorbs.

So, an object is red if it only reflects red. An object is white when it reflects all of the colours and an object is black when it absorbs all of the colours and doesn't reflect any of them.

An object's colour depends on the colour of the light that illuminates it. If a white object is illuminated with a green light, it can only reflect green light and so it appears to be green.
However, a blue object cannot reflect green (because it absorbs it), so blue objects which are illuminated with a green light appear to be black.

b) Subtractive colour mixing: pigments



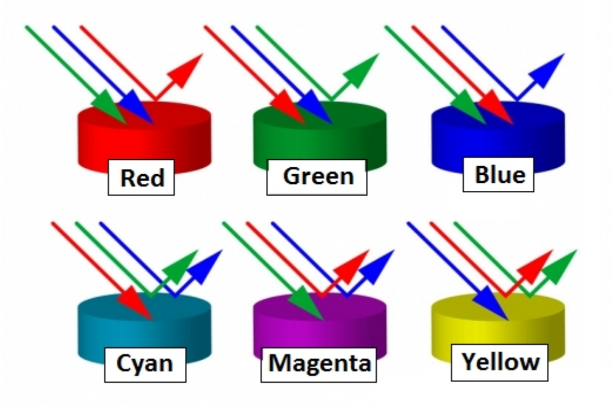
Paints, inks and dyes contain **pigments**. Pigments have colour because they absorb certain colours from light but reflect others.

There are three pure pigments or primary pigments: cyan, magenta and yellow. We can mix these in different proportions to make any colour.

If we add the three pigment primary colours, we get black.

For example, a cyan pigment reflects green and blue, but absorbs red. A yellow pigment reflects green and red, but absorbs blue.

If we mix cyan and yellow pigments together to make a paint, the cyan absorbs the red component from the yellow and the yellow absorbs the blue component from the cyan: the result is that only green is reflected, so green is the final paint colour.



READING ACTIVITIES

After reading the text, copy and answer the following questions into your notebook:
Remember: you must make complete sentences.

2.9. Classify these objects into transparent, translucent and opaque:

a. Clean water
b. A plastic bag
c. A china plate
d. A magnifying glass
e. A shelf of wood
f. A glass cup
g. A page in a book
h. Onionskin paper
i. A piece of cardboard
j. The lenses in a pair of glasses

2.10. Which colours of white light does a green body absorb? Which ones does it reflect?

2.11. If you mix cyan pigment with red pigment, which colour will be the mixture? Explain why.

3. Sound.

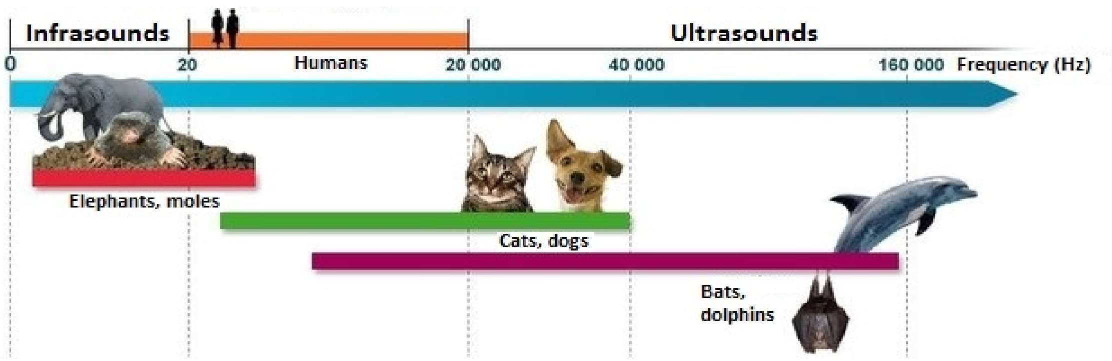
Sound is a form of mechanical energy which is produced by the vibration of an object. The vibration provokes a disturbance that is transmitted in form of wave.

Sound travels through a **material medium**, solid, liquid or gaseous, but it cannot be transmitted through the vacuum.

The speed of sound depends on the characteristics of the medium:

- **Density**. In general, the denser the substance the faster the sound travels through it. For example, sound's speed in air is 340 m/s while in water is 1,500 m/s.
- **Elasticity**. It is the ability of the medium to return to its initial state after the disturbance. The more elastic the medium, the faster the sound travels through it. Solids are more elastic and transmit sounds faster than liquids and liquids faster than gases.

Humans can hear sounds with a frequency between 20Hz and 20,000Hz.



3.1. Characteristics of sound

In all the sounds that we hear, three different characteristics can be perceived: *loudness*, *pitch* and *timbre*. These are subjective characteristics, but they are related to three physical quantities that can be measured:

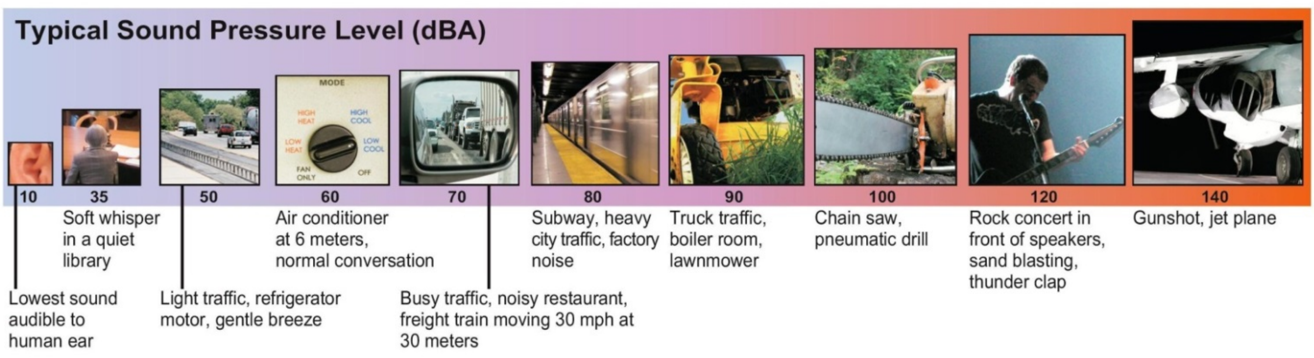
- *Loudness* is related to the **intensity** of the sound.
- *Pitch* is related to the **frequency** of the sound wave.
- *Timbre* is related to the **shape of the sound wave** when it is drawn as a graph.

a) Loudness

Loudness refers to the **intensity** of sound. It is related to the amount of energy that reaches our ear per unit of time.

Depending on how intense they are, sounds can be classified as:
- **Soft (quiet) sounds** (e.g. the sound a leaf makes as it falls from a tree).
- **Loud sounds** (e.g. the sound of a pneumatic drill).

The **decibel scale** measures the intensity of a sound: how loud a sound is. The unit of measurement of loudness is the **decibel** (dB). The table below shows the link between the loudness of noises or sounds (in decibels) and the sensation they produce.



b) Pitch

The pitch of a sound is how high or low it is. Pitch is related to the **frequency** of the vibration that makes the sound. Sounds with a low frequency have a low pitch and sounds with a high frequency have a high pitch.

Generally, a man's voice has a lower pitch than a woman's voice (high-pitched) from adolescence on. This difference in pitch is due to the difference in size of the vocal cords. Men have longer vocal cords so they vibrate less quickly and women have shorter vocal cords so they vibrate more quickly.

Sound becomes attenuated and quieter with distance, but low-pitched sounds are less attenuated and can travel further through air than high-pitched sounds.

c) Timbre

The timbre of a sound is what makes it different to other sounds. It is related to the shape of the graphic representation of the wave.

Timbre is the quality that allows our ears to distinguish sounds that have the same intensity (loudness) and frequency (pitch) but are emitted by different instruments. So, timbre lets us identify a variety of musical instruments even though they are all playing the same note.

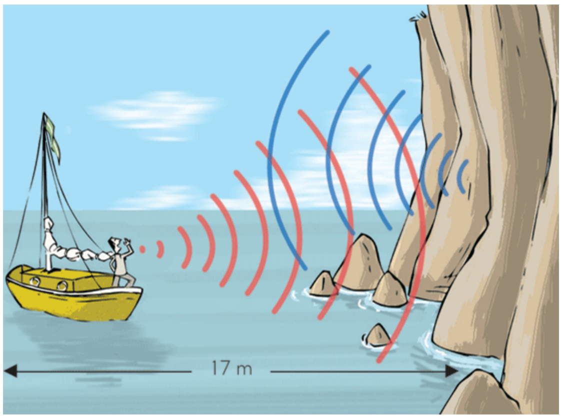
3.2. Properties of sound: reflection.

When sound waves meet an obstacle they change direction and are **reflected**. The reflection of sound produces two phenomena: *echo* and *reverberation*.

The human ear needs at least 0.1 seconds between the first sound and the reflected sound to hear them separately. This reflected sound is called an echo. So, in order to hear an echo, we must be at a minimum distance from the surface that is reflecting the sound.

An **echo** is produced when sound is reflected from a surface that is at least 17 m away from the source of the sound.

If the distance is less than 17 m, we don't hear two separate sounds; we only hear one single prolonged sound, and this is called **reverberation**.



READING ACTIVITIES

After reading the text, copy and answer the following questions into your notebook:
Remember: you must make complete sentences.

3.1. In a storm, a few seconds after lightning strikes, thunder is heard. If you hear thunder four seconds after a bolt of lightning, how far are you from the storm?

3.2. A scientific boat uses sonar to detect a whale. The receptor makes a sound wave and 0.2 seconds later it detects the echo. Sounds travels through water at 1,500 m/s, so calculate:

a. The distance travelled by the sound wave in 0.2 s.
b. The distance from the boat to the whale.

3.3. If you touch a ring when it is ringing, the sounds stop immediately. Why?

3.4. Explain why if we put our ear on a railway track, we know that a train is coming sooner than when we hear it through air.