Light

Light is produced when atoms within a material **absorb energy**. This puts the electrons in an atom into an "**excited state**" where they jump to a higher **energy level** (**orbit**). When these electrons return to their original orbit (**ground state**) they **release the energy** and often give off **light**.

Light can come from natural or artificial (man-made) sources. Light sources can be either direct or indirect.

Direct light – comes from **luminous objects** which are able to **produce their own light** (ex: **Sun, firefly**, etc…)

Indirect light – comes from **non-luminous** objects which **reflect light** and are not able to produce their own (ex: **Moon, bicycle reflectors** etc…)

Categories of Luminous Objects

Object	Description
Incandescent	Emit light because they are hot Ex.
Fluorescent	Emit light when excited by other radiation Ex.
Phosphorescent	Emit light when excited and emission continues after input is removed Ex.
Chemiluminescent	Emit light because of a chemical reaction Ex.
Bioluminescent	Living things that emit light because of a chemical reaction Ex.
Triboluminecent	Light emitted when a material is crushed Ex.

Sunlight

- **Nuclear Fusion reactions** occur in the Sun's core (**hydrogen** atoms collide and fuse to form **helium**) and the energy produced is transferred to the gases near the Sun's surface.
- This excites the atoms near the surface (**photosphere**) and they release their energy in the form of light.

Incandescence

- Light is emitted by a **very hot object**.
- Older light bulbs pass an electric current through a **tiny tungsten wire**. The wire is **heated** (atoms are excited) and glows brightly to produce light.
- Incandescent bulbs are only **5% efficient** in producing light. **95%** of the energy used is **lost as heat**.

Electrical Discharge

- Current is passed through a **gas instead of a wire**.
- Bulb (tube) has an **electrode at either end** and is filled with a vapour (usually **mercury** or **sodium**). An electric current passes through the vapour and excites the electrons, which causes them to jump to an excited state, and when they return to their ground state, they **emit this energy as light**.
- Each gas will emit a different wavelength of light (**colour**) when excited.

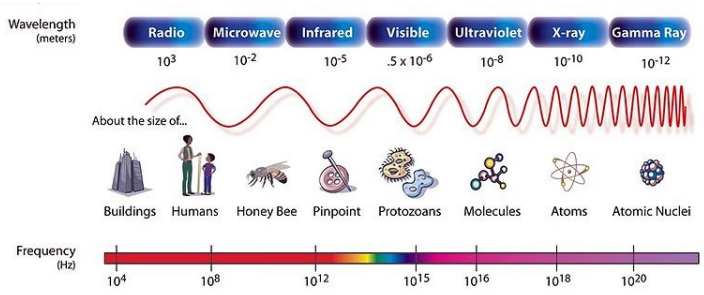
- **Fluorescent light bulbs** (ex. **CFL's**) are a special kind of gas discharge tube that contain **mercury** vapour and **argon**, an inert gas. The inside of the bulb is coated with a powder called **phosphor**. They work
    1. **Electrical energy charges the electrodes causing the emission of electrons**
    2. **Electrons travel through gas and excite electrons in mercury atoms**
    3. **Excited mercury electrons, return to ground state releasing the energy in the form of ultra violet light (which we cannot see)**
    4. **Ultra violet light is absorbed by phosphor on the walls of the tube exciting the phosphor electrons**
    5. **The phosphor electrons return to gas state releasing the excess energy in form of visible light**

    - Visible light that is emitted in this way is called "**fluorescence**"

- A CFL (Compact Fluorescent Lightbulb) is **20% efficient** so they use **less electricity**, and they **last much longer** than incandescent bulbs.

Properties of Light and Reflection

Using the example on page 409 as a guide, make a labeled diagram of the electromagnetic scale.



The electromagnetic spectrum shows all of the different forms of **energy** and their **wavelengths**, including visible light. Visible light is the only form of energy we can perceive with our **eyes**, but all the forms of energy can be used by or effect humans.

Light travels very fast (**3.00×10^{8} m/s**) and in **straight lines (rectilinear propagation)**.

Light will travel in a straight line as long as it is moving through the same **medium** (**substance**). Light waves **reflect** (**change direction**) when they reach a surface and bounce off of it.

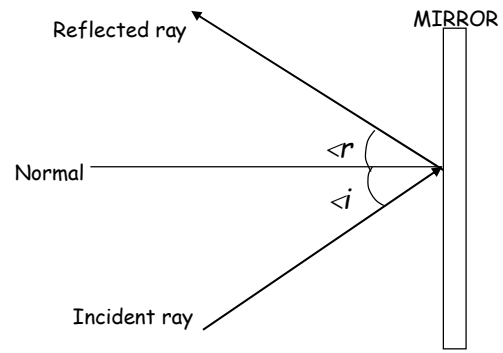
We can use a **ray** to model the **movement of a light wave**. A ray is a **straight line** with an **arrowhead** that shows the **direction** that light is traveling. We can use rays to predict how light **travels**, **creates shadows**, **reflects**, and **refracts**.

Fermat's Principle:

- Light follows the path that will take the **least time**.
- When light reflects off of a surface and remains in one medium, its speed is **constant**, so the path that takes the least time is the shortest path (**a straight line**). This principle leads to the **Laws of Reflection**.

Reflection Vocabulary:

- **Incident ray:** a ray of light coming toward a surface
- **Angle of incidence:** measured between the incident ray and the normal
- **Normal:** a perpendicular line drawn from the point of contact of the incident ray at the surface
- **Reflected ray:** a ray of light starting at the point of contact and moving away from the surface
- **Angle of reflection:** measured between the reflected ray and the normal



Laws of Reflection:

1. The incident ray, reflected ray, and the normal always lie on the **same plane**.
2. The angle of reflection ($\angle r$) is **equal** to the angle of incidence, ($\angle i$).

Images in Plane Mirrors

We can apply the laws of reflection to predict where an object's image will be and what the image will look like in a mirror (the **characteristics** of the image).

An image has 4 characteristics:

- **Location** (closer, farther, or same distance as the object to the mirror)
- **Orientation** (upright or inverted)
- **Size** (same size, larger, or smaller than the object)
- **Type** (real image or virtual image)

The image in a plane (flat) mirror is called a **virtual image**. We see the image of the object in the mirror, but there are **no actual light rays** coming from the image itself – it only appears that way. The rays behind the mirror **do not actually exist,** we only perceive that they exist because our **brain** assumes light travels in **straight lines**

We can predict the characteristics of an object's image by using a **ray diagram**

Characteristics of an image in a plane mirror:

- **Same distance**
- **Upright**
- **Same size**
- **Virtual image**
- Images in plane mirrors are also **laterally inverted**. For example, words in a mirror appear to be written **backwards**.

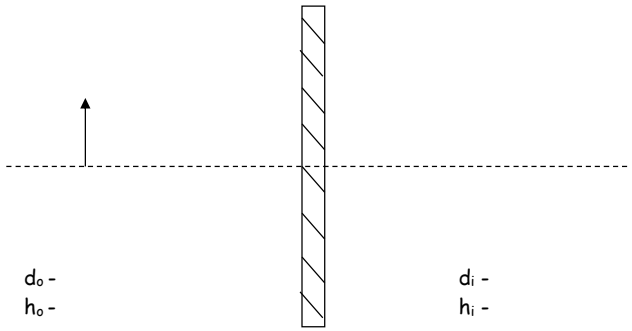
Steps in Locating Images in Plane Mirrors

1. Measure the **perpendicular** distance from the mirror to the object. The image will be located at the **same** distance **behind** the mirror.
2. Use another ray to demonstrate that images are formed where light rays **converge**. You may need to do this for more than one point on the object.

To Demonstrate How the Eye Perceives an Image

1. Draw lines from the **image** to the **eye**, using **dotted** lines behind mirror and **solid** lines in front. (**REFLECTED RAYS**)
2. Draw lines from the intersection of mirror and reflected rays to the object. (**INCIDENT RAYS**)

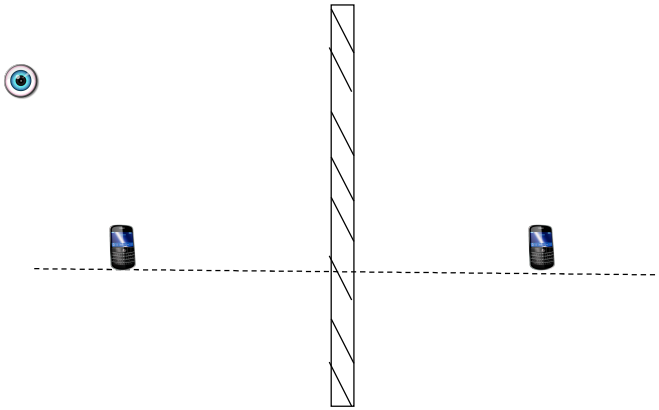
Let's find and analyze the image below:



Characteristics of an image in a plane mirror:

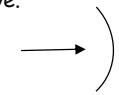
- L -
- O -
- S -
- T -

How your eye perceives an image in a plane mirror

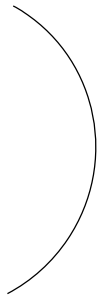


Properties of Concave Mirrors

Concave Mirror – A mirror whose reflecting surface curves inwards, like the inside surface of a basketball. You can remember it because the surface of the mirror forms a cave.



Centre of Curvature (C) – The centre of curvature is the centre of the circle formed by the surface of the mirror. If you took a _____ line at each point on the mirror, they would meet at the centre of curvature.

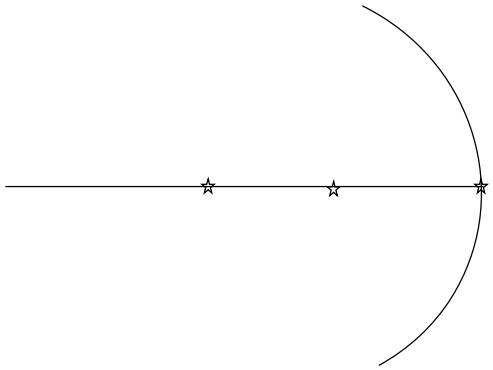


You can also find "C"
because C = 2f
or C = 2 x focal point

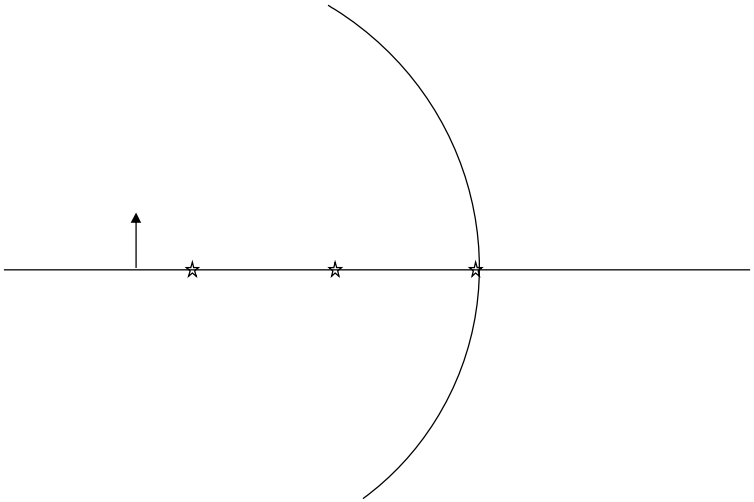
Principle Axis – With a concave mirror the principle axis is a line that passes from a point on the mirror through the centre of curvature. For our purposes we will always draw it in the middle of the mirror

Vertex – The Vertex is where the principle axis strikes the mirror.

Focal Point – When a ray travels parallel to the principle axis, it is always reflected through the focal point of the mirror. The distance between the focal point and the surface of the mirror is the _____. This length is ½ the distance to the centre of curvature.



Images always form where _____ from the object _____.



1. Draw a ray parallel to the _____ and the point on the object. It will reflect through the _____.
2. Draw a line through the _____ and the point on the object. It will reflect parallel to the _____.
3. Draw a line through the _____ and the point on the object. It will reflect back on itself.
4. Draw a line through the _____ and the point on the object. Its _____ _____ will be the _____ as the _____.

Don't forget: you can always extend your reflected rays behind the mirror as _____.

You must always report the L.O.S.T. characteristics of every image you form. For the image we just created:

L:

O:

S:

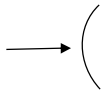
T:

You will notice that the image has formed with _____, as opposed to _____ _____. This means the image formed is _____. Real images can be projected onto a screen.

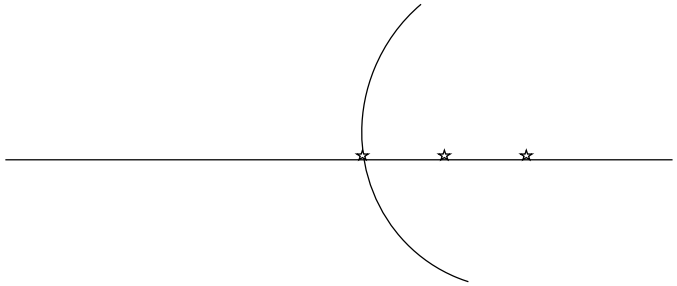
Concave mirrors will create _____ depending on the location of the object. For example: Objects_____ will form images that are _____.

Properties of Convex Mirrors

Convex Mirror – A convex mirror has a reflecting surface that curves outwards like the _____ surface of a ball or sphere.



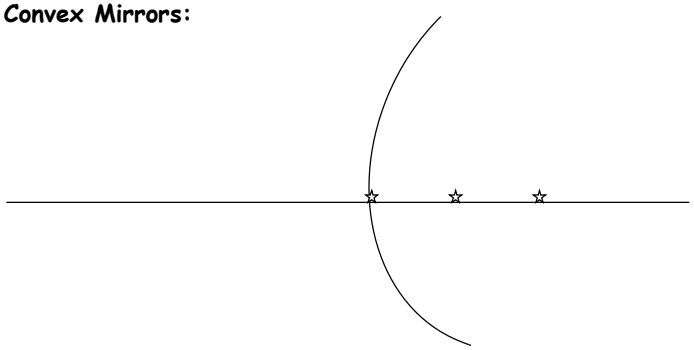
Like concave mirrors, convex mirrors have a focal point and centre of curvature. However, they are both found on the _____ side of the mirror.



In the case of a convex mirror, rays that enter parallel to the principal axis are scattered, with their _____ passing through the _____.

Finding Images in Convex Mirrors:

L	
O	
S	
T	

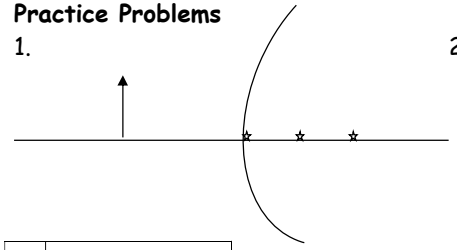


Follow the 4 Rules:

1. Draw a ray parallel to the _____ and the point on the object. It will reflect through the _____.
2. Draw a line through the _____ and the point on the object. It will reflect parallel to the _____.
3. Draw a line through the _____ and the point on the object. It will reflect back on itself.
4. Draw a line through the _____and the point on the object. Its _____ _____ will be the _____ as the _____.

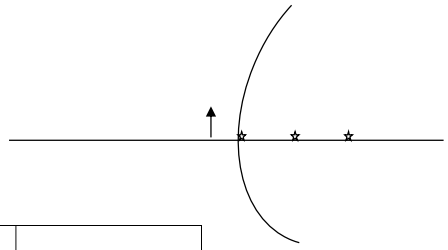
Practice Problems

1.



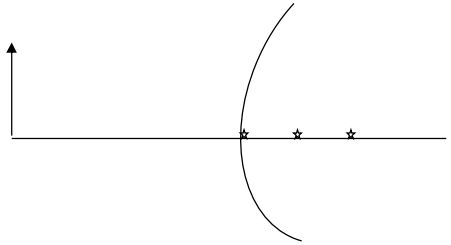
L	
O	
S	
T	

2.



L	
O	
S	
T	

3.



L	
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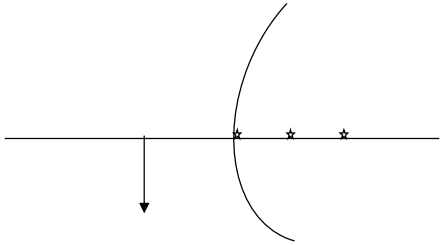
4.

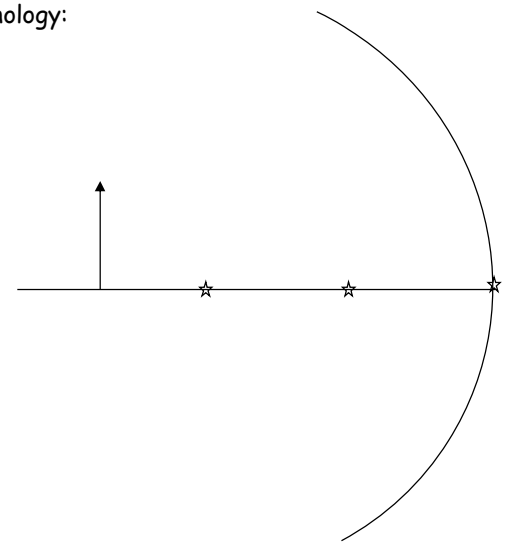


L	
O	
S	
T	

Magnification and Curved Mirror Equations

Figuring out the characteristics of an image in a curved mirror can be accomplished by making _____, but can also be achieved through the use of _____ as well.

Let's review our terminology:



We can also measure these properties:

h_o = d_o =

h_i = d_i =

Remember _____ the PA is "__" height and _____ the PA is "__" height

To the _____ of V is "__" distance to the _____ of V is "__" distance

Magnification Equation

$$m = \frac{hi}{ho} = \frac{-di}{do}$$

Curved Mirror Equation

$$\frac{1}{f} = \frac{1}{do} + \frac{1}{di}$$

1. You are told that an object's image is magnified 1.5 times. You also know that the image is 6 cm high.

   a) What is the height of the object? Is the image upright or inverted?

   b) If the object is 8 cm from the mirror where is the image? Is it real or virtual?

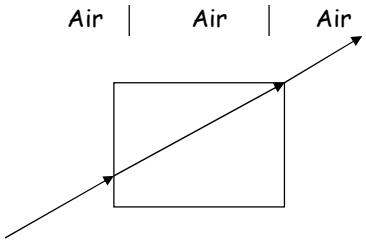
2. A convex security mirror has a focal length of -0.25 m. A person with a height of 1.5 m is 4.0 m from the mirror.

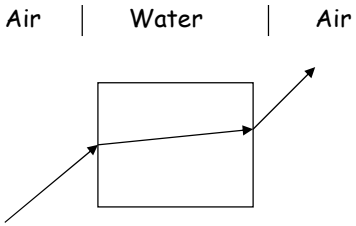
   a) Calculate the image distance

   b) Calculate the image height

Refraction

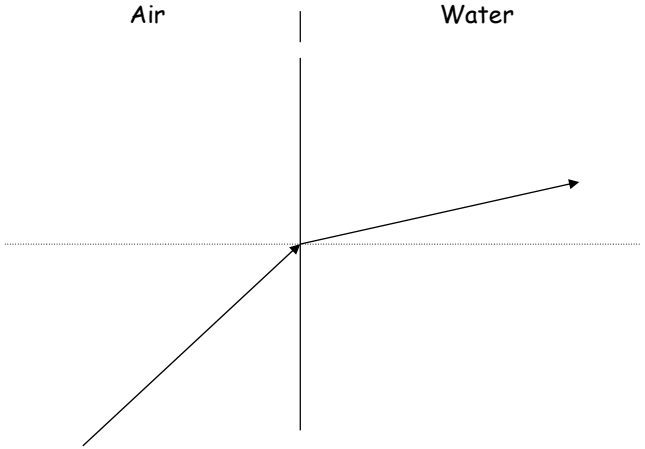
We have discussed how light travels in a straight line as long as it stays in the same medium. But what happens when light moves into a new medium?





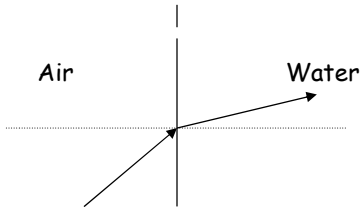
When light crosses a _____ into a new medium it bends changing the ray's direction. When a light ray _____ it is called _____.
Light refracts because when travelling through a more _____ medium it _____. Optical density is a measurement of how much light is slowed down by a medium. Light travels the fastest in a vacuum like in space. The speed of light in a vacuum is _____. In all other mediums it is slower.

First let's review some terminology:

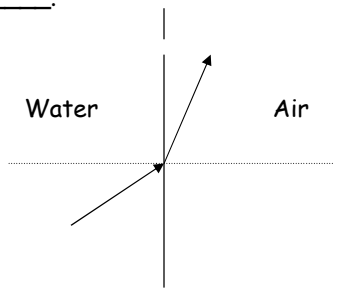


Rules of Refraction

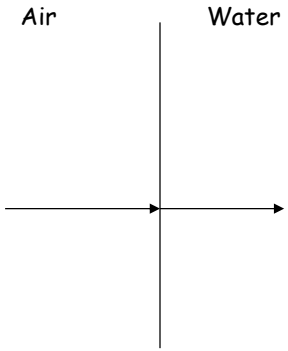
1. When light travels from a less _____ dense medium to a more optically dense medium the refracted ray bends _____ the _____.



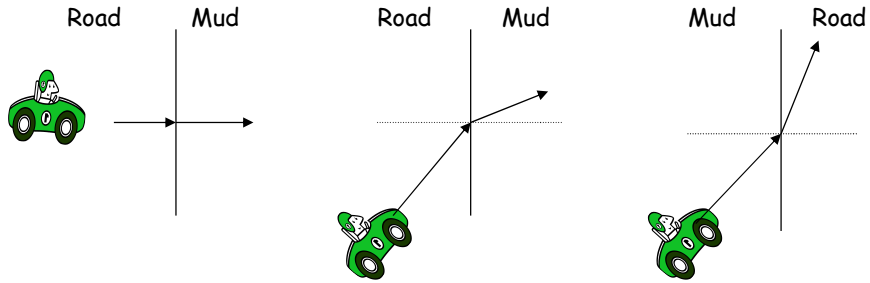
2. When light travels from a more optically dense medium to a less optically dense medium the _____ bends _____ from the _____.



3. When the angle of incidence is 0, no _____ occurs.



Light refracts because of its _____ properties but refracting light can be thought of like a car.



Think of your car as a beam of light. When it comes to a barrier with mud if there is ___ angle it will ____ affect the direction of the car.
If you approach mud on an angle, the tires contacting the mud will _____ while the tires on the road will keep going the same space. This will turn the car into the mud. The opposite will be true for leaving the mud.

Index of refraction

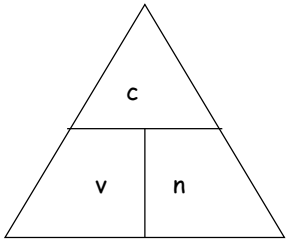
The index of refraction is a measurement of the difference between the speed of light in a medium and the speed of light in a vacuum.

$$n = c/v$$

n =

c =

v =



Some common indices of refraction

Substance	Index of Refraction
Glass	1.5-1.9
Diamond	2.42
Fused quartz	1.46
Quartz crystal	1.54
Glycerin	1.47
Water	1.33

Notice they are all greater than 1.

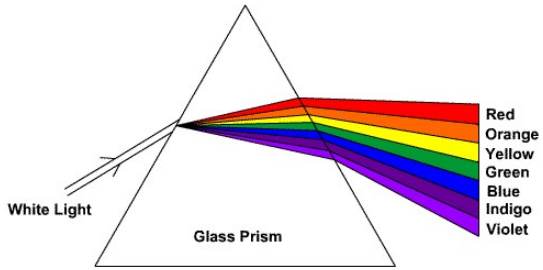
Let's do a practice problem together.

You are told that the index of refraction for glass is 1.5. What is the speed of light in glass? (use the G.R.A.S.S. method)

Optical Phenomena in Nature

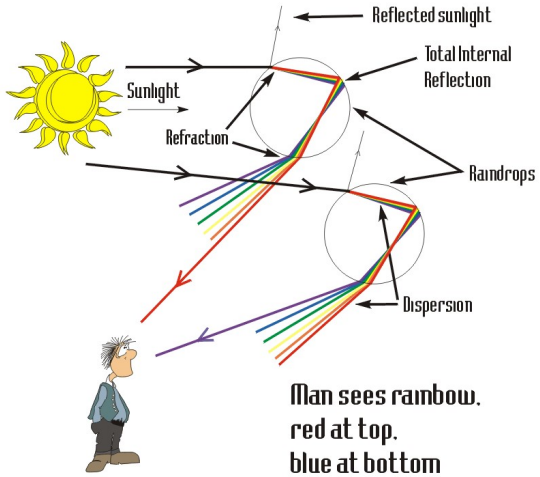
White light is a combination of all the _____ of visible light. When this light is separated into its _____ of colours it is called _____. The colours of visible light in a spectrum can be remembered by _____ (red, orange, yellow, green, blue, indigo and violet).

When white light _____ into a ____ it is _____. It is then _____ a second time when it _____ the prism. Since each colour of light travels at a different ____, each colour of light refracts a _____ creating the separation of coloured _____.



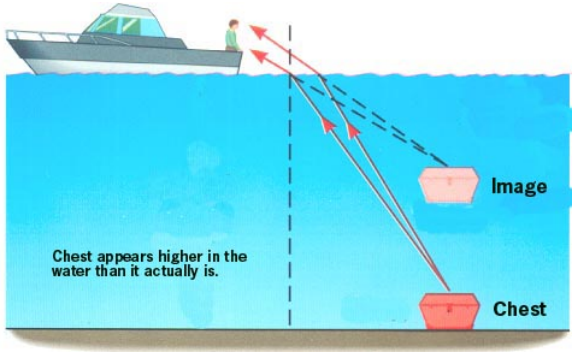
Rainbows

A rainbow is an arc of colours of the visible spectrum appearing opposite the Sun, caused by _____, _____ and _____ of the Sun's rays as they pass through _____.



A rainbow forms when sunlight enters a water droplet and _____, then _____ off the inners surface of the raindrop and then _____ again when leaving the droplet. The two refractions result in the _____ of light. The different colour layers in a rainbow are created by water droplets at different _____ in the sky.

Apparent Depth



Just as real and virtual images can be created by reflected light from a mirror, images are created by refracted rays as well.

For example, an object at the bottom of a lake or pond will create an optical effect in which the image of the object appears _____ than the object. This is called _____.

Some animals such as the _____ or the _____ have found ways to account for the illusion of apparent depth.

Shimmering and Mirages

Shimmering and mirages are caused by the _____ of light in _____ _____. When light travels through air at different temperatures, it refracts because hot air is _____ dense than cooler air. Since there is no distinct _____ between sections of air and the fact that air is constantly _____ the location and amount of _____ is constantly _____.

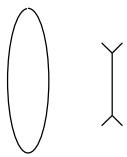
Shimmering is the apparent movement of objects over _____. Metallic surfaces or any other material, like asphalt, that tend to _____ _____ will display shimmering.

A mirage occurs on a much larger scale than shimmering and is typically seen over _____ like the desert. The air over the desert heats up faster than the surrounding air. When sunlight reaches the hot air, the sunlight is _____. You will interpret the origin of the light as being on the _____. An object that appears to be on the ground but is not really there is called a _____.

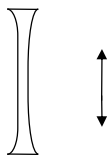
The opposite type of mirage can happen when _____ brings _____ over a very _____ or land mass. This condition is known as a _____ _____. When this type of mirage occurs, people will think they are seeing an object in the _____.

Lenses

A lens is a device that _____ light. Lenses come in all _____ and _____.



Converging lens (Biconvex)

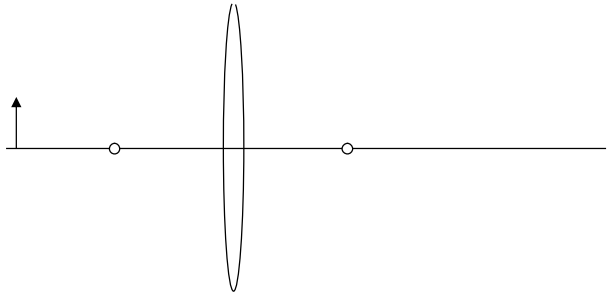


Diverging Lens (Biconcave)

Ray Diagrams for Converging Lenses

RULES FOR DRAWING RAY DIAGRAMS FOR CONVERGING LENSES:

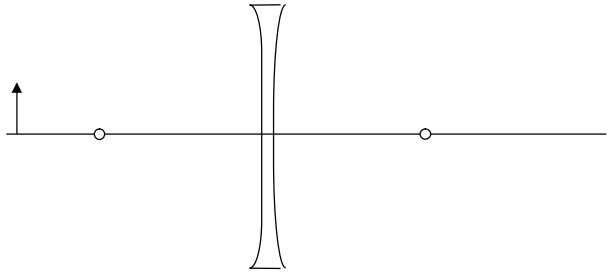
Step 1	Step 2	Step 3	Step 4	Step 5
· Draw principal axis and vertical line through lens · Draw focal points on both sides of the lens at the same distance of the lens · Add an object that is farther from the lens than the focal point	· Draw the 1st ray parallel to the principal axis until it reaches the axis of symmetry · From there, the ray goes through the focal point on the opposite side	· Draw the 2nd ray from the top of the object through the centre of the lens · The centre of the lens acts like a flat piece of glass, so rays leave going the same direction that they enter	· Draw the 3rd ray through the focal point on the same side of the lens as the object to the axis of symmetry · From the axis of symmetry, continue ray until it meets the other 2 rays.	· Draw the real image · The top of the image is at the point where the three rays meet · The bottom of the image is on the principal axis



Ray Diagrams for Diverging Lenses

RULES FOR DRAWING RAY DIAGRAMS FOR DIVERGING LENSES:

Step 1	Step 2	Step 3	Step 4	Step 5
· Draw principal axis and vertical line through lens · Draw focal points on both sides of the lens at the same distance of the lens · Add an object that is farther from the lens than the focal point	· Draw the 1st ray parallel to the principal axis until it reaches the axis of symmetry · From there, the ray leaves as though it were coming from the virtual focal point on the object side	· Draw the 2nd ray from the top of the object through the centre of the lens ·The centre of the lens acts like a flat piece of glass, so rays leave going the same direction that they enter	· Draw the 3rd ray going from the top of the object to the focal point on the opposite side of the lens. STOP at the axis of symmetry and then draw it PARALLEL to the principal axis	· Because the rays do NOT meet, extend RAY 2 and RAY 3 · The top of the image is at the point where the three rays meet · The bottom of the image is on the principal axis



Images created by lenses can also be determined mathematically.

Thin Lens Equation

$$\frac{1}{f} = \frac{1}{di} + \frac{1}{do}$$

Magnification Equation

$$m = \frac{hi}{ho} = \frac{-di}{do}$$

An object is 8.5 cm high is placed 28 cm from a converging lens. The focal length is 12 cm.

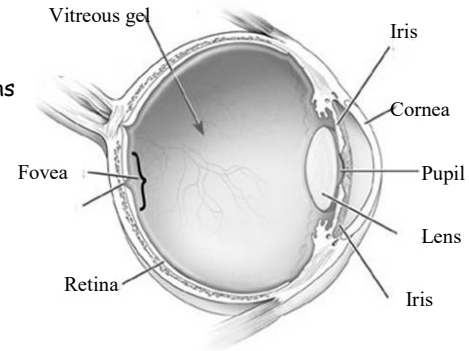
a. Calculate the image distance, di

b. Calculate the image height, hi.

The Human Eye

- Vision is the act or power of **sensing with the eyes**.
- The eyes receive **visual stimuli (light)** from the environment.
- Eyes can convert light into **electrical impulses** that travel to the brain via your nervous system (neurons) and our brain perceives this information as what we call vision.
- Eyes resemble simple cameras –a **diaphragm** (iris) that controls the amount of light, an **aperture** (pupil) that the light enters through, a **converging lens** (lens and cornea) that causes light to converge on the film (retina).
- The eyes sit in the **eye sockets** (orbits), an opening in the back allows for the attachment of the **optic nerve**.

Parts of the Eye



Lens: the lens is responsible for helping to _____ the focus of the eye. The lens changes _____ to allow clear vision both for _____ and for _____.

Ciliary Muscles & Suspensory Ligaments: control the _____ of the lens.

Aqueous Humour: a _____ important for nourishing the lens and cornea.

Vitreous Humour: a _____ substance that fills the back portion of the eye behind the lens and helps the eye keep its shape.

Cornea: a dome-shaped structure at the front of the eye. It is transparent, allowing light to enter the eye, and together with the _____ helps focus and direct light onto the _____.

Sclera: the _____, _____ outer layer of the eyeball that forms the _____ of your eyes.

Iris: the _____ part of the eye that _____ and _____ to let varying amounts of light in.

Pupil: the _____ in the centre of the iris through which _____ the eye.

Retina: a thin film of tissue where images are brought into _____, it lines the _____ _____ of the eyeball and is covered by specialized cells called _____ (_____ and _____) and _____ (_____).

Fovea: located on the retina and is responsible for _____ vision, which is necessary in humans for reading, watching television or movies, driving etc…

Blind spot: the place in the visual field where there is ___ light-detecting photoreceptor cells due to the _____ passing through it.

Optic Nerve: transmits visual information from the _____ to the _____.

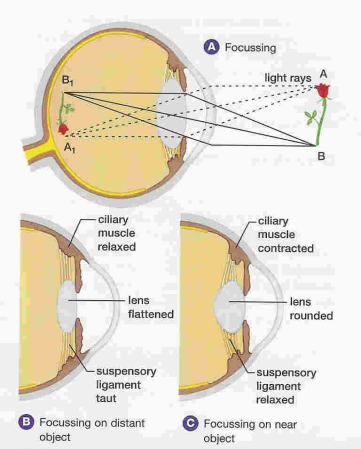
Humans have **binocular vision**. Binocular vision is vision in which **both eyes** are used together. The word binocular comes from two Latin roots, *bin* for **two**, and *oculus* for **eye**. Having two eyes confers at least four advantages over having one:

1. It gives a creature a _____ eye in case one is damaged
2. It gives a wider field of view. For example, a human has a horizontal field of view with one eye of about ___ degrees and with two eyes of about __ degrees
3. It gives binocular _____ in which the ability to detect faint objects is enhanced
4. Having two different positions on the head allows for more precise _____ perception

The eye is a sensitive organ that must be protected from the environment:

- Eyebrows prevent moisture, mostly _____ and rain, from flowing into the eye
- Eyelids protect the eye from _____ light _____
- Eyelashes protect the eye from _____
- Lacrimal glands secrete _____ to flush the eye

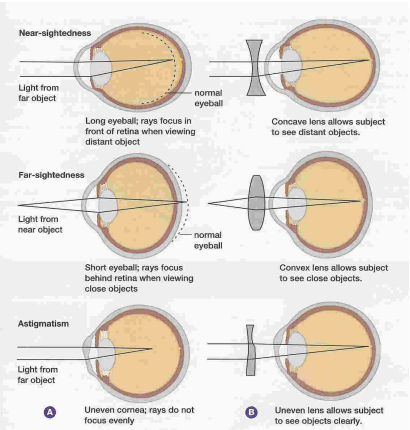
How the eye Functions



As light enters the eye, the **pupil dilates** if there is **insufficient** light or **constricts** if there is **too much** light; this action is controlled by the **iris**.
The shape of the **lens** can be altered as the **distance** from the object being viewed changes; this action is controlled by the **ciliary muscle** and **suspensory ligament**.

When focusing on **distant** objects, the lens is **flat** because the ciliary muscle is **relaxed** and the suspensory ligament is **tight**. When focusing on a **near** object, the lens becomes **rounded** because the ciliary muscles **contract**, thus causing the suspensory ligament to **relax**. These adjustments are referred to as **accommodation**.
When light rays enter the eyes, the object's rays are **refracted** by the **cornea** and the **lens** in such a way that an **inverted** and **reversed** image of the object forms.

Disorders of the Visual System



Near-sightedness (myopia) is a condition in which the person has difficulty seeing things that are **far** away. It usually occurs when the eyeball is **too long** or the ciliary muscle is **too strong**. When this occurs, the image is focused **in front** of the retina.

Far-sightedness (hyperopia) is a condition in which a person has difficulty seeing things **close up**. It usually occurs when the eyeball is **too short** or the ciliary muscle is **too weak**. When this occurs, the image is focused **behind** the retina.

Astigmatism is when there is an abnormal shape of the **cornea** or **lens** that results in **uneven focus**.