

Module 10: Optics

Topic 4 Content: Spherical Lenses Presentation Notes

Introduction

Convex Lenses

Introduction

Biconvex Plano-convex Convex-concave Meniscus Plano-concave Biconcave

Converging Types Diverging Types

Lenses come in many different shapes. Each shape is designed to have a specific effect on the light that passes through the lens. The drawings show a side view of some examples of lens shapes. Lenses are used in cameras, eyeglasses, telescopes, microscopes and many other optical devices. Spherical lenses are classified as either converging and diverging. In general, converging

Conve r...

Convex Lens Explained

Refraction

Parallel Ray Focal Ray Center Ray

Lenses come in many different shapes. Each shape is designed to have a specific effect on the light that passes through the lens. The drawings show a side view of some examples of lens shapes. Lenses are used in cameras, eyeglasses, telescopes, microscopes and many other optical devices. Spherical lenses are classified as either converging and diverging. In general, converging lenses are wider at the center than at the edges and diverging lenses are wider at the edges than in the center. In this topic, you will learn how each type of lens works. Our studies will focus on the biconvex and biconcave lens shapes. For simplicity we will refer to these two types as simply convex and concave.

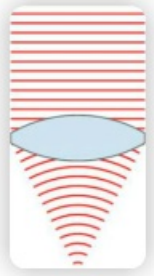
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Topic 4 Content: Spherical Lenses Presentation Notes

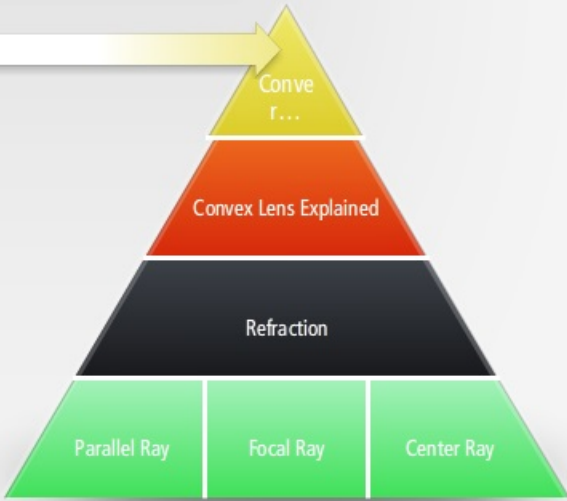
Converging Lens

Convex Lenses

Converging Lens



This image is a view of a converging lens. A converging lens is wider in the center than at the edges. The picture shows how the lens converges light.



Conve
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Convex Lens Explained

Refraction

Parallel Ray Focal Ray Center Ray

This image is a view of a converging lens. A converging lens is wider in the center than at the edges. The picture shows how the lens converges light.

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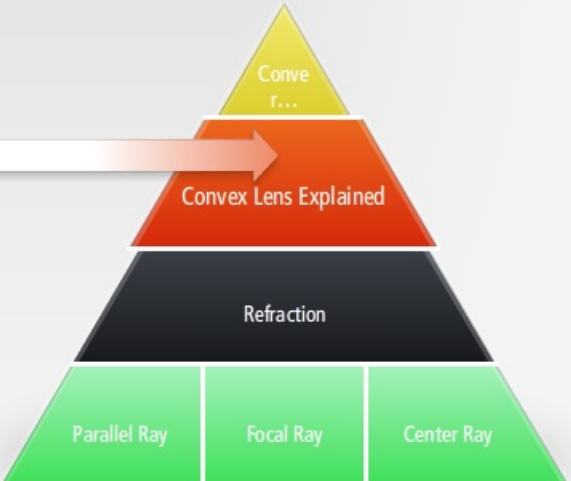
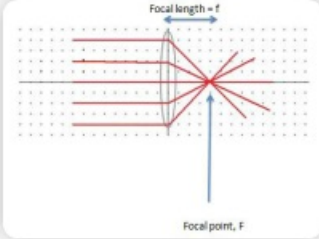
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Convex Lens Explained

Convex Lenses

Convex Lens Explained

When parallel light rays strike a convex lens, the refracted rays will all intersect at one point. This point is called the focal point of the lens. Label it f . Because parallel light rays are converged to a point, this type of lens is classified as a converging lens. The distance from the lens to the focal point is called the



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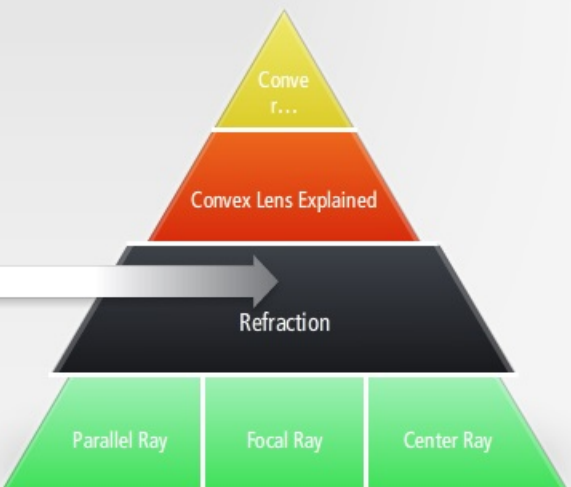
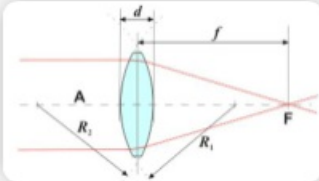
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Refraction

Convex Lenses

Refraction

This diagram shows more detail about how the refraction actually occurs. You should notice that the light bends when it goes from air to lens and again when it goes from lens to air. The previous drawing simplified this process. You will draw the simplified versions in your ray tracing diagrams although, it is actually a little more complicated than that.



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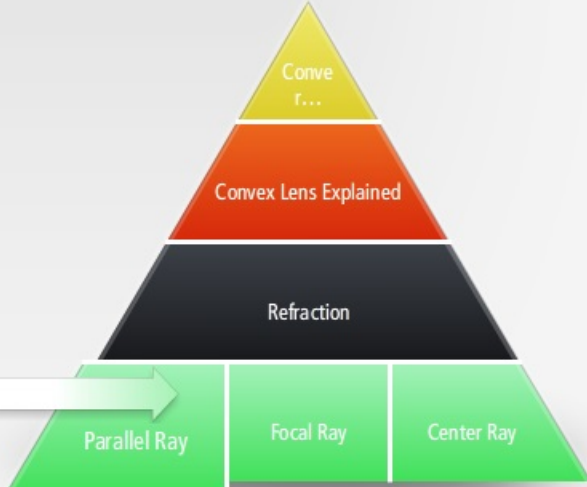

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Parallel Ray

Convex Lenses

Parallel Ray

When images are formed, many light rays go from the object through the lens. To simplify the situation, look at three principal rays to illustrate how the image is formed. The first principal ray is a light ray that travels toward the lens parallel to the principal axis. This light ray will be refracted, so it passes through the focal point. In all the diagrams that follow, the principal ray will be blue.



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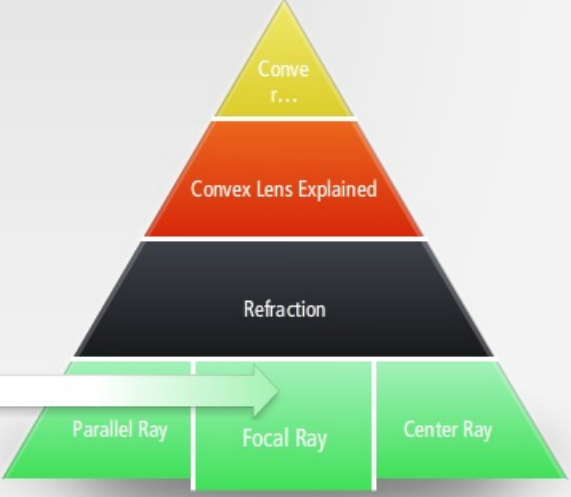
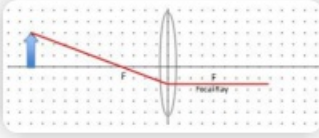
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Focal Ray

Convex Lenses

Focal Ray

The second principal ray is a light ray that passes through the focal point on the way to the lens. This light ray is refracted parallel to the principal axis. In all the diagrams that follow, the focal ray will be red.



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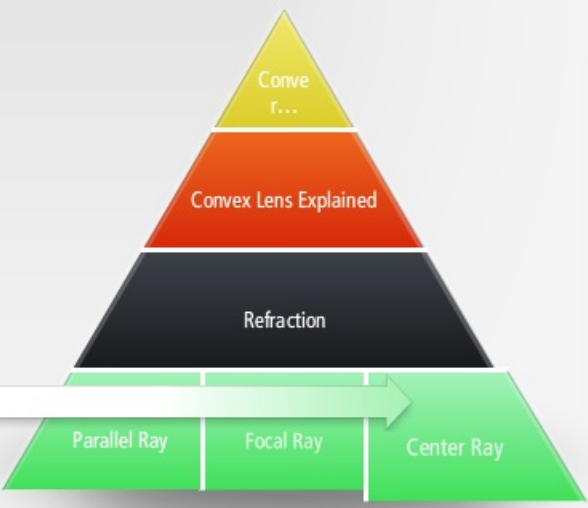
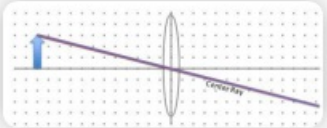
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Center Ray

Convex Lenses

Center Ray

The third principal ray is a ray that strikes the lens at the center, it passes through without changing direction. In all the diagrams that follow, the center ray will be purple. By using these three rays, the location and properties of an image can be determined. Look at what happens when you are using your magnifying glass.



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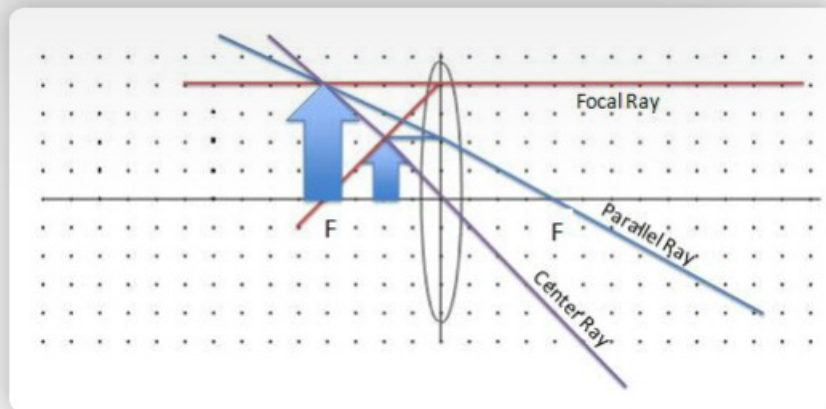
Topic 4 Content: Spherical Lenses Presentation Notes

Object Closer Than Focal Point – Convex

Introduction

Object Closer Than Focal Point - Convex

Introduction



Click each arrow to learn more about convex lenses when the object is placed closer to the lens than the focal point. Click the attachments tab above to download the handout needed for this presentation.

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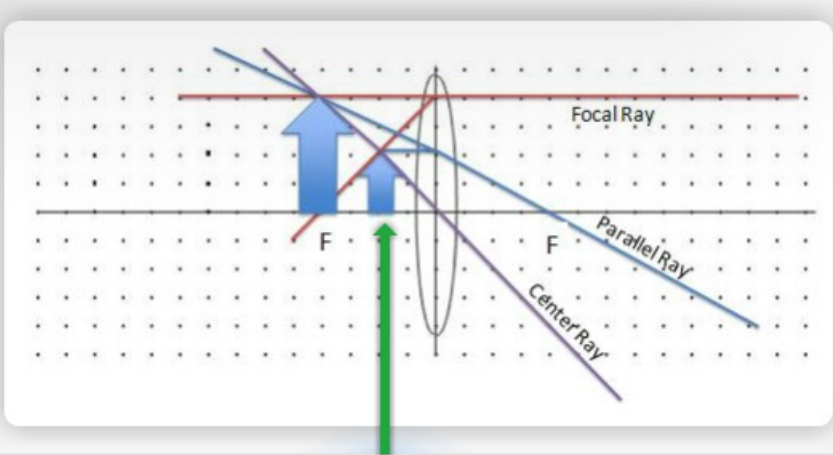
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Topic 4 Content: Spherical Lenses Presentation Notes

Object

Object Closer Than Focal Point - Convex

Object



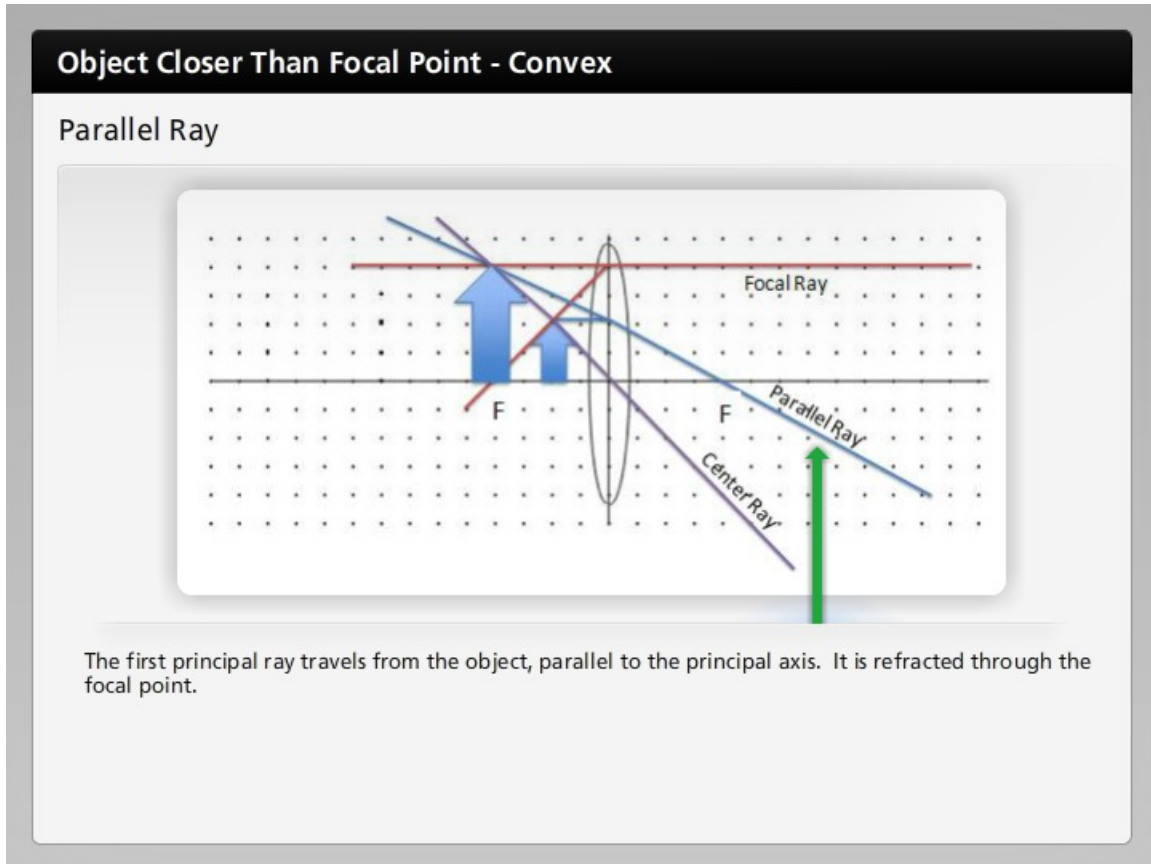
Look at the magnifying glass in more detail. You already know that a magnifying glass can make things look bigger. You should use the handout that you can download from the attachments tab above, a pencil, and a ruler to try to make these diagrams on your own. The object is placed close to the convex lens, closer than the focal point. To find its image, you will trace the three principal rays from the top of the object.

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Topic 4 Content: Spherical Lenses Presentation Notes

Parallel Ray



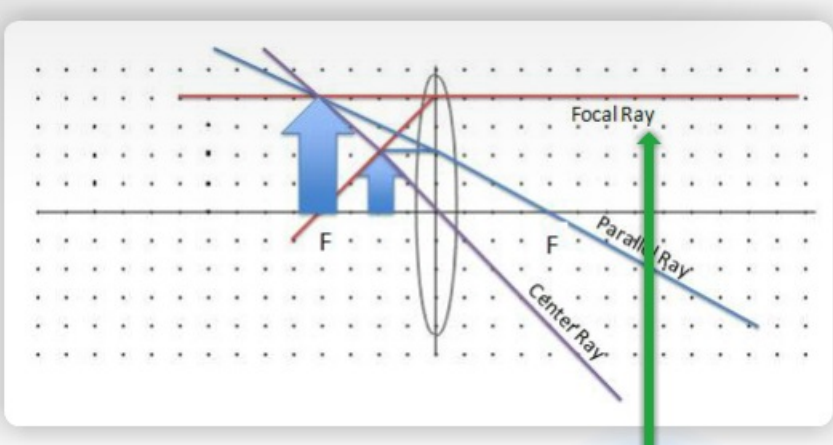
The first principal ray travels from the object, parallel to the principal axis. It is refracted through the focal point.

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Topic 4 Content: Spherical Lenses Presentation Notes

Focal Ray

Object Closer Than Focal Point - Convex

Focal Ray



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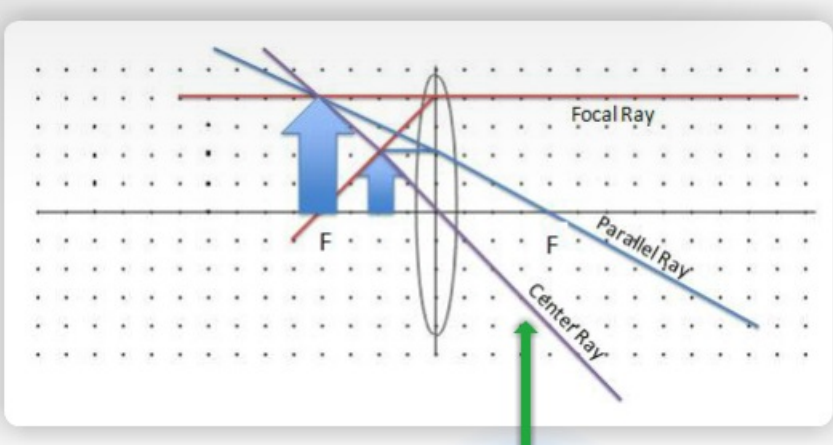
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Center Ray

Object Closer Than Focal Point - Convex

Center Ray



The third principal ray strikes the lens at the center, it passes through the lens without changing direction. Notice that the three light rays will not intersect on the right side of the lens. They spread farther apart.

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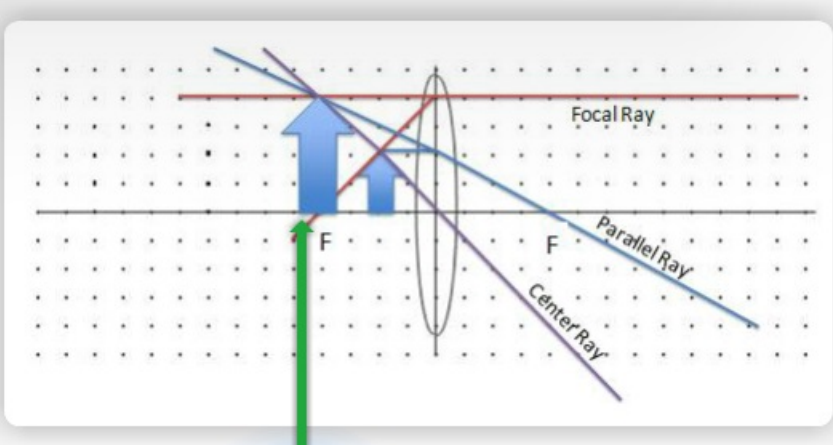
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Topic 4 Content: Spherical Lenses Presentation Notes


Image

Object Closer Than Focal Point - Convex

Image



Remember how you found the virtual image for the mirror? You traced the outgoing light rays behind the mirror. Do the same here. Trace the three refracted rays behind the lens. You should notice that they all appear to come from one point. This is where we see the image of the top of the arrow. Do you remember how to classify the image from our work with mirrors? This image is virtual, upright, and larger than the object. This is how a magnifying glass works. The object must be placed closer to the lens than



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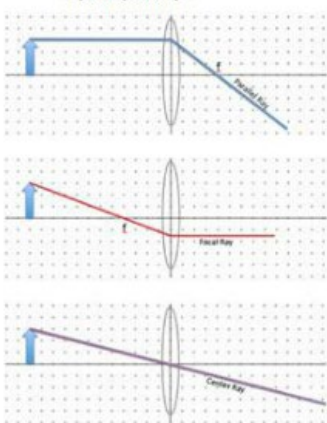
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Topic 4 Content: Spherical Lenses Presentation Notes

Summary of Convex Lenses


Summary of Convex Lenses

- The convex lens can form different types of images.
- Images can be real or virtual.
- Images can be larger, smaller or the same size as the object.
- Images can be upright or inverted.

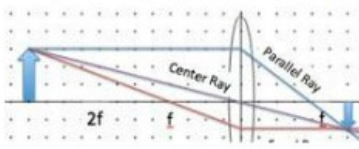
3 principal Rays




Concave Mirrors can form Virtual Images



Concave Mirrors can form Real Images



- The convex lens can form different types of images.
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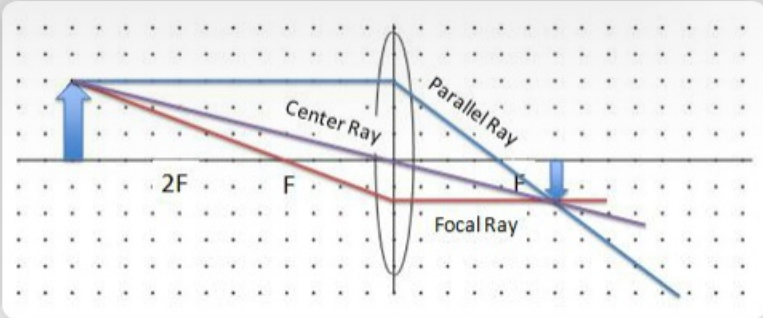
Topic 4 Content: Spherical Lenses Presentation Notes

Object Between F and 2F - Convex

Introduction

Object Between F and 2F - Convex

Introduction



What happens if we move the object further away from the lens? Will the image still be larger than the object? The object is now placed between one and two focal lengths away from the lens. To find its image, you will trace the three principal rays from the top of the object. Click each arrow to see what happens when an object is placed between one and two focal lengths away from the lens.

The diagram shows a convex lens on a grid. A horizontal principal axis passes through the lens's center. Two focal points, labeled 'F', are marked on the axis, one on each side of the lens. A point labeled '2F' is marked on the left side. An object, represented by a blue vertical arrow pointing upwards, is positioned on the left side of the lens, between the 2F and F points. Three rays originate from the top of the object: 1) A blue 'Parallel Ray' that travels parallel to the principal axis and refracts through the focal point 'F' on the right side of the lens. 2) A purple 'Center Ray' that passes straight through the center of the lens without bending. 3) A red 'Focal Ray' that passes through the focal point 'F' on the left side of the lens and refracts parallel to the principal axis. The three rays diverge on the right side of the lens. A blue vertical arrow on the right side of the lens, pointing downwards, indicates the location of a virtual, upright, and magnified image.

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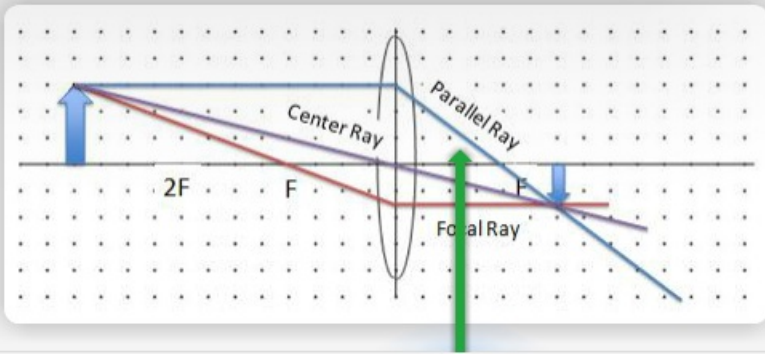
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Parallel Ray

Object Between F and 2F - Convex

Parallel Ray



The first principal ray travels from the object, parallel to the principal axis. It is refracted through the focal point.

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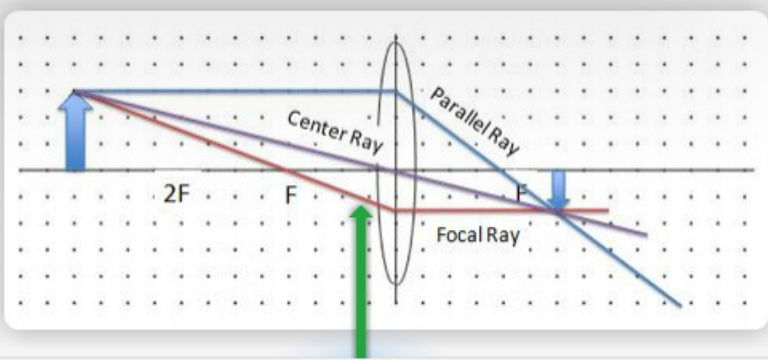
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Focal Ray

Object Between F and 2F - Convex

Focal Ray



The diagram illustrates the formation of a real, inverted, and magnified image by a convex lens when the object is placed between the focal point (F) and twice the focal length (2F). Three principal rays are shown: 1) A parallel ray (blue) that travels parallel to the principal axis and refracts through the far focal point (F). 2) A center ray (blue) that passes straight through the optical center of the lens. 3) A focal ray (red) that travels through the near focal point (F) and refracts parallel to the principal axis. The intersection of these rays forms the image. A green arrow points to the focal ray.

The second principal ray travels through the focal point on the way to the lens. It is refracted parallel to the principal axis.

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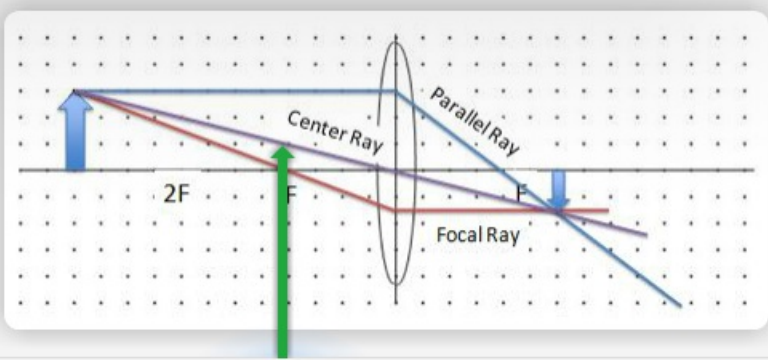
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Center Ray

Object Between F and 2F - Convex

Center Ray



The diagram illustrates a ray diagram for a convex lens. An object, represented by a blue arrow pointing up, is positioned between the focal point (F) and the twice-focal point (2F) on the left side of the lens. Three principal rays are shown: 1) A parallel ray (blue) that starts from the top of the object and travels parallel to the principal axis, refracting through the focal point (F) on the right. 2) A focal ray (red) that starts from the top of the object and passes through the focal point (F) on the left, refracting parallel to the principal axis. 3) A center ray (purple) that starts from the top of the object and passes straight through the center of the lens without changing direction. The intersection of these three rays on the left side of the lens indicates the location of a real, inverted, and magnified image. The focal point (F) and twice-focal point (2F) are marked on the principal axis.

The third principal ray strikes the lens at the center. It passes through without changing direction. Notice that the three light rays intersect on the left side of the lens. This means a real image will be formed of the tip of the arrow at that location. The image is real, inverted and larger than the object.

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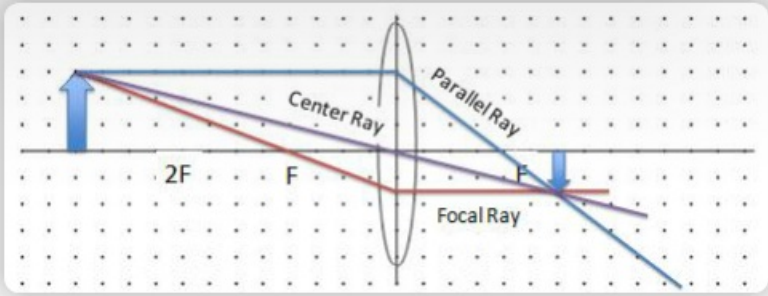
Topic 4 Content: Spherical Lenses Presentation Notes

Object Beyond 2F - Convex

Introduction

Object Beyond 2F - Convex

Introduction



What happens if we move the object further away from the lens? The object is now placed farther away than two focal lengths. To find its image, you will trace the three principal rays from the top of the object. Click the arrows to see what happens when an object is placed farther than two focal lengths.

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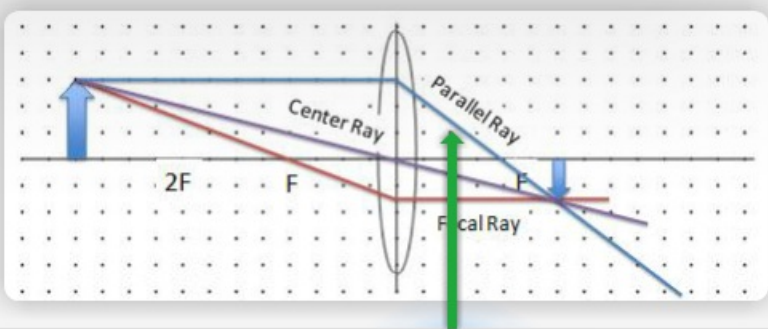
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Parallel Ray

Object Beyond 2F - Convex

Parallel Ray



The first principal ray travels from the object, parallel to the principal axis. It is refracted through the focal point.

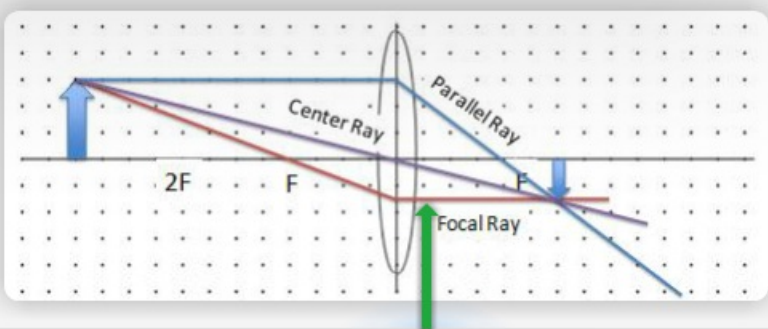
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Focal Ray

Object Beyond 2F - Convex

Focal Ray



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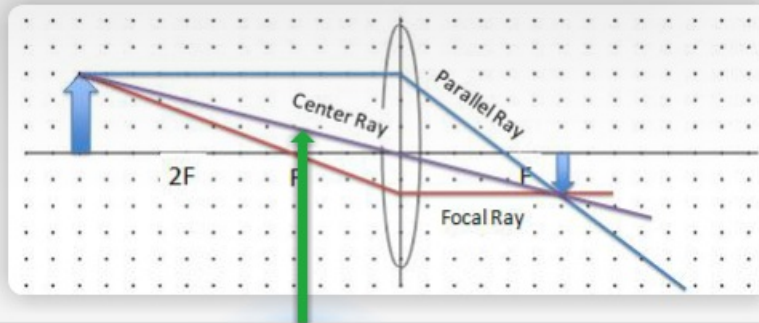
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Center Ray

Object Beyond 2F - Convex

Center Ray



The third principal ray strikes the lens at the center. It passes through without changing direction. Notice that the three light rays intersect on the right side of the lens. This means a real image will be formed of the tip of the arrow at that location. The image is real, inverted and smaller than the object. This is how the inverted, smaller image of the plant was made.

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Concave Lenses

Introduction

Concave Lenses

- Concave Lens Has a Virtual Focus
- Parallel Ray
- Focal Ray
- Center Ray

Introduction



Do you have perfect 20/20 vision? If not, you are not alone. About 75% of Americans need vision correction. The most common vision problem for young people is myopia or nearsightedness. People with myopia can see well up close, but need corrective lenses for seeing far away. Concave lenses are used to correct myopia. A concave lens is thicker at the edges than in the center. If you look closely at the eyeglasses in this photo, you can see that the edges of the lenses are thick, protruding from the frame. Click the tabs to learn more about concave lenses.

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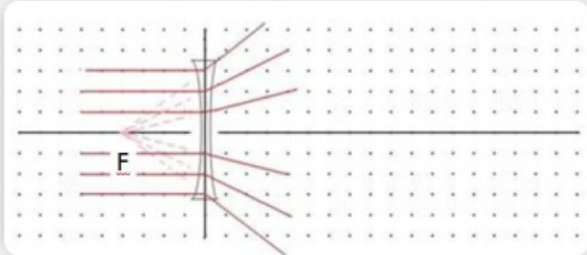
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Concave Lens Has A Virtual Focus

Concave Lenses

Concave Lens Has a Virtual Focus

Concave Lens Has a Virtual Focus



When parallel rays hit a concave lens, the refracted rays diverge, or spread apart. They do not intersect on the right side of the lens. You may notice that the rays all appear to come from a common point on the left side of the lens. This point is called the focal point. You can think of this as a virtual focal point, since the light rays do not actually intersect. Since the concave lens makes parallel light rays diverge, it is classified as a diverging lens.

Parallel Ray

Focal Ray

Center Ray

When parallel rays hit a concave lens, the refracted rays diverge, or spread apart. They do not intersect on the right side of the lens. You may notice that the rays all appear to come from a common point on the left side of the lens. This point is called the focal point. You can think of this as a virtual focal point, since the light rays do not actually intersect. Since the concave lens makes parallel light rays diverge, it is classified as a diverging lens.

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Parallel Ray

Concave Lenses

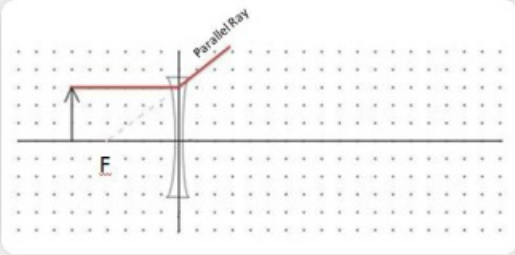
Concave Lens Has a Virtual Focus

Parallel Ray

Focal Ray

Center Ray

Parallel Ray



When a light ray hits the concave lens parallel to the principal axis, it refracts as if it were coming from the virtual focal point.

The diagram shows a concave lens on a grid. A horizontal principal axis passes through the center of the lens. A vertical dashed line represents the optical axis. A red line labeled 'Parallel Ray' is horizontal and parallel to the principal axis. It hits the lens and refracts away from the axis. A dashed line is drawn from the point where the ray hits the lens, extending back to a point labeled 'F' on the principal axis to the left of the lens, representing the virtual focal point.

When a light ray hits the concave lens parallel to the principal axis, it refracts as if it were coming from the virtual focal point.

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Focal Ray

Concave Lenses

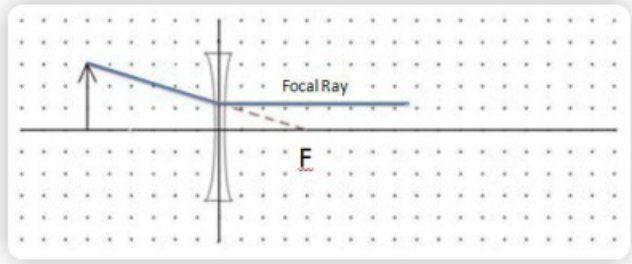
Concave Lens Has a Virtual Focus

Parallel Ray

Focal Ray

Center Ray

Focal Ray



When a light ray hits the concave lens as if it were going to the focal point, it is reflected parallel to the principal axis.

When a light ray hits the concave lens as if it were going to the focal point, it is reflected parallel to the principal axis.

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Center Ray

Concave Lenses

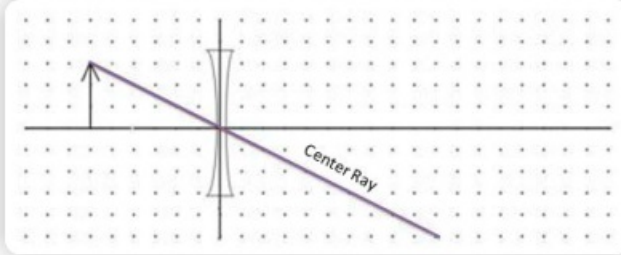
Concave Lens Has a Virtual Focus

Parallel Ray

Focal Ray

Center Ray

Center Ray



A ray that hits the concave lens at the center passes through without a change in direction. You will use the three principal rays to show how a concave lens forms an image.

The diagram shows a concave lens (biconcave shape) on a grid. A horizontal line represents the principal axis. A vertical line represents the optical axis. A ray, labeled 'Center Ray', is shown as a straight line passing through the center of the lens and the intersection of the principal and optical axes. The ray is labeled 'Center Ray' at its end on the right side.

A ray that hits the concave lens at the center passes through without a change in direction. You will use the three principal rays to show how a concave lens forms an image.

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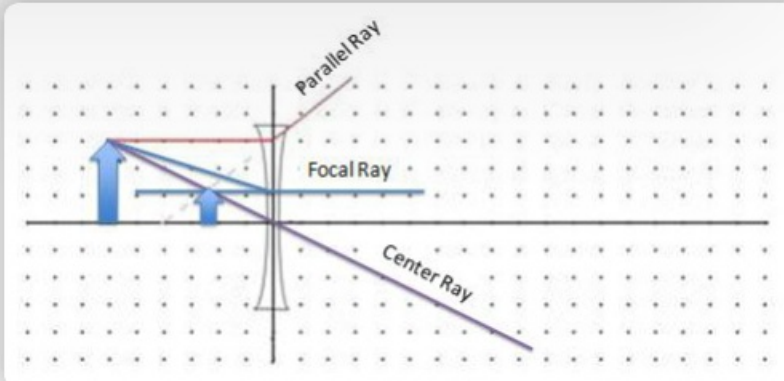
Topic 4 Content: Spherical Lenses Presentation Notes

Concave Lens Example

Introduction

Concave Lens Example

Introduction



Click the arrows to see how an image is formed when an object is placed near a concave lens.

The diagram illustrates the ray paths for a concave lens. A vertical line represents the lens, and a horizontal line represents the principal axis. Three rays are shown: a red 'Parallel Ray' that diverges from the principal axis, a blue 'Focal Ray' that appears to originate from the focal point on the same side as the object, and a purple 'Center Ray' that passes straight through the lens. A blue arrow on the left indicates the direction of light travel from left to right. A small blue arrow below the lens indicates the direction of an interactive element.

Click the arrows to see how an image is formed when an object is placed near a concave lens.

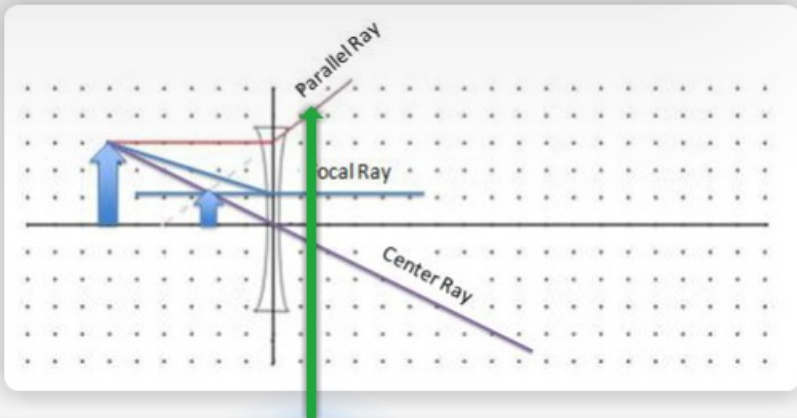
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Topic 4 Content: Spherical Lenses Presentation Notes

Parallel Ray

Concave Lens Example

Parallel Ray



The diagram illustrates the refraction of three principal rays through a concave lens. A vertical line represents the lens, and a horizontal line represents the principal axis. A blue arrow representing an object is placed to the left of the lens. Three rays originate from the top of the object: 1) A red 'Parallel Ray' that is parallel to the principal axis and refracts away from the principal axis as if it came from the focal point on the left. 2) A blue 'Focal Ray' that is directed towards the focal point on the left and refracts parallel to the principal axis. 3) A purple 'Center Ray' that passes straight through the center of the lens. The intersection of these rays on the left side of the lens forms a virtual, upright, and magnified image.

An object is placed near a concave lens. You will show how the image is formed using the three principal rays. The first ray is the parallel ray, it is refracted as if it were coming from the focal point.

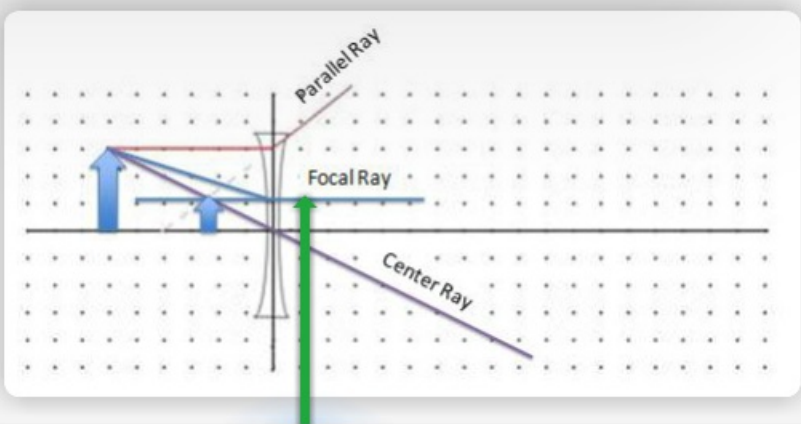
An object is placed near a concave lens. You will show how the image is formed using the three principal rays. The first ray is the parallel ray, it is refracted as if it were coming from the focal point.

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Focal Ray

Concave Lens Example

Focal Ray



The ray that strikes the concave lens as if it is going toward the focal point is refracted parallel to the principal axis.

The ray that strikes the concave lens as if it is going toward the focal point is refracted parallel to the principal axis.

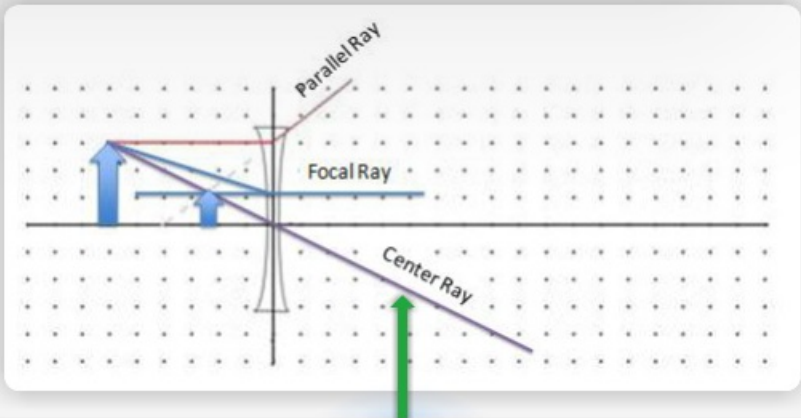
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Center Ray

Concave Lens Example

Center Ray



The diagram shows a concave lens on a grid. A horizontal principal axis passes through the center of the lens. A vertical line represents the lens. A blue arrow on the left represents an object. Three rays are shown: a red 'Parallel Ray' that is parallel to the principal axis and refracts as if it came from the focal point on the left; a blue 'Focal Ray' that is parallel to the principal axis and refracts as if it came from the focal point on the right; and a green 'Center Ray' that passes through the center of the lens without changing direction. The rays are traced back to the left side of the lens to form a virtual image.

The ray that strikes the concave lens at the center passes through without changing direction. You probably noticed that the light rays that come out of the lens do not intersect. You must trace them back to the other side of the lens to find the virtual image.

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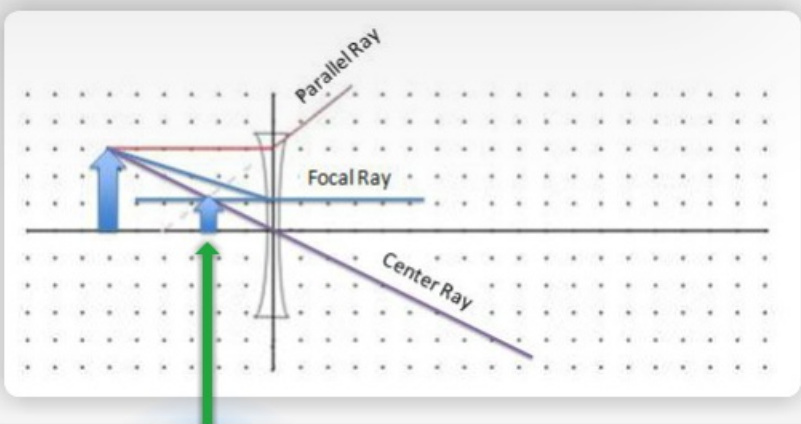
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Image Formed

Concave Lens Example

Image Formed



The diagram illustrates the ray tracing for a concave lens. A vertical line represents the lens, and a horizontal line represents the principal axis. A blue arrow representing the object is placed to the left of the lens. Three rays are shown: a red 'Parallel Ray' that diverges from the lens, a blue 'Focal Ray' that appears to originate from the focal point on the same side as the object, and a purple 'Center Ray' that passes straight through the lens. The intersection of the back-projections of the parallel and focal rays forms a smaller, upright blue arrow representing the virtual image. A green arrow points upwards from the principal axis to the image.

The image formed by the concave lens is virtual, upright and smaller than the object.

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Summary of Concave Lenses

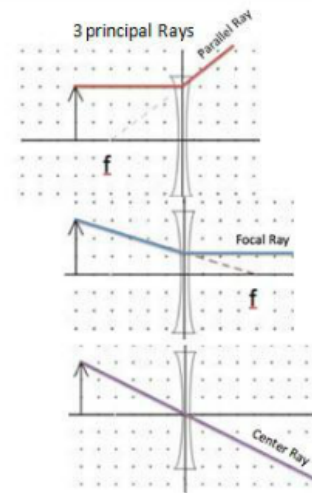
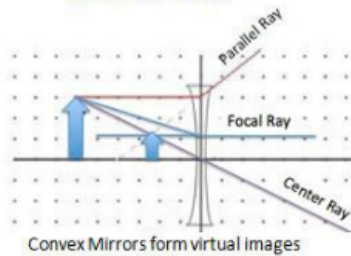
Summary of Concave Lenses

- Images can be located using three principal rays:

- Parallel ray refracts as if it is coming from the focal point.
- Focal ray is refracted parallel.
- Center ray passes through without changing direction

- Drawing these three rays from one point on the object locates the image of that part of the object.

- Images are always:
 - Virtual
 - Upright
 - Smaller
 - In front of the lens



- Images can be located using three principal rays:
 - Parallel ray refracts as if it is coming from the focal point.
 - Focal ray is refracted parallel.
 - Center ray passes through without changing direction.
 - Drawing these three rays from one point on the object locates the image of that part of the object.