Images in Curved Mirrors

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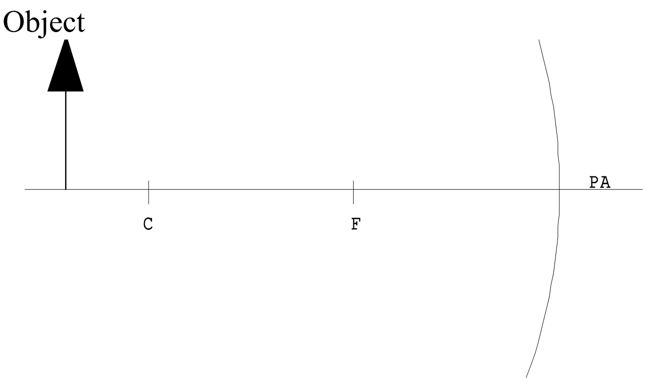
Mirrors can be curved in almost any shape.
There are two classes of curved mirrors depending on their effect on light.

Converging mirrors cause parallel light rays to come to a point, they are also referred to as **concave mirrors** because the *reflecting surface is curved inwards,* (like a bowl).

Diverging mirrors cause parallel light rays to spread apart from a point, they are also called **convex mirrors** because the *reflecting surface is curved outwards*.

Curved Mirror Terminology

Diagram: **Terms associated with converging and diverging mirrors**



The above diagram shows some of the terms associated with curved mirrors.

The **centre of curvature** *C* is the centre of the sphere from which the curved mirror is made; part of the mirror surface that forms the curved mirror.

The **radius of curvature** *R* is the distance from the centre of curvature to the mirror. (R = 2 F)

The middle point of a curved mirror is called the **vertex**, *V*

The **principal axis** *PA* is a line drawn through the vertex, (the middle point), perpendicular to the surface, (i.e. to the centre of curvature).
Because the principal axis goes through the centre of the circle, this axis is a radius of the circle.
This means that the principal axis intersects the mirror at 90^0 and is normal to the surface.

Any light rays that are parallel to the principal axis will be reflected off the mirror through a single point, i.e. parallel light rays meet at a common point.
This point where parallel light rays come, or converge is called the **principal focus** *F*.
Thus parallel light rays converge at principal focus or the **focal point**, *F*.

Note: that the focal point is exactly halfway between the vertex and the centre of curvature.

Because a concave mirror focuses parallel rays at the focal point, F, this type of mirror is thus called a converging mirror.

In the case of a convex mirror, the parallel light rays appear to diverge from F, this type of mirror is thus called a diverging mirror.

The **focal length** *f* is the distance from the vertex to the principal focus measured along the principal axis.

A **real image** is an image formed by light rays that come from the location of the image, the image would appear on a screen if one were placed at the position of the image.
A real image can be caught on a screen since it is formed where real rays intersect.
A real image is drawn as a solid arrow.

A **virtual image** cannot be caught on a screen since it is formed by the intersection of virtual rays. However, a virtual image can be seen by looking into the mirror.
A virtual image is shown using a dotted line.

How to Locate the Images in a Converging (Concave) Mirror

To determine the image of an object in front of a converging mirror, it is usual to draw two incident rays from the top of the object.

These rays will be reflected off the mirror and may or may not cross to form an image.

The geometry of the curved mirror produces the following important rules which can be used to draw the incident and reflected rays:

1. All light rays that are parallel to the principal axis will reflect through the focal point, F.

2. Any rays travelling through the focus, F will reflect back form the mirror parallel to the principal axis.

3. Rays passing through the centre of curvature will reflect back on themselves.
(A line from the centre of curvature to the mirror is normal to the mirror surface)

4. A ray striking the intersection of the principal axis and the mirror surface will reflect back with an angle of reflection equal to the angle of incidence, (as measured from the normal which in this case is the principal axis).

As a convention, the object is always shown as a solid erect arrow.
Any two rays are drawn from the tip of the object:
1. The first ray travels from the tip of the object to the mirror, parallel to the principal axis, the reflected ray will thus pass through the focal point.
2. If the second ray is drawn from the tip of the object through the focal point, then the reflected ray will be parallel to the principal axis.
(A third ray can be drawn through C, the centre of curvature to the mirror, this ray will therefore, from the above rule, will reflect back on itself.)

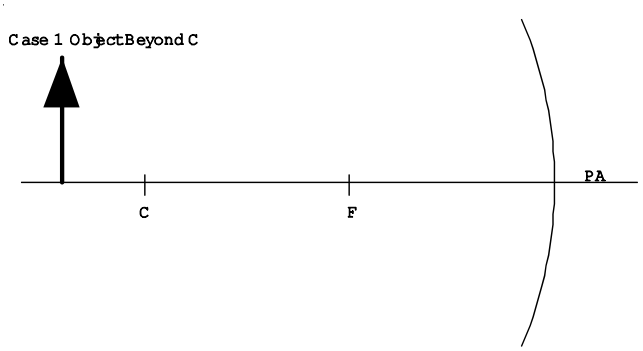
Where the rays intersect after reflection, or appear to do so, gives the location of the tip of the image.

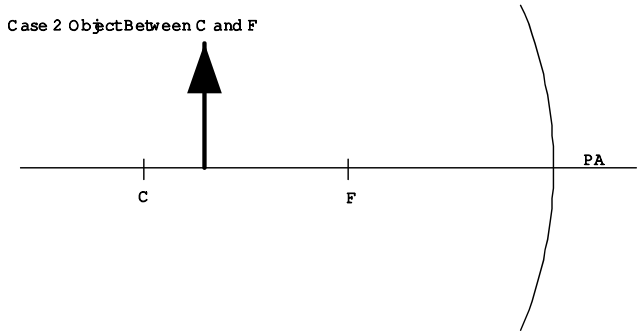
Real rays are drawn as solid lines.

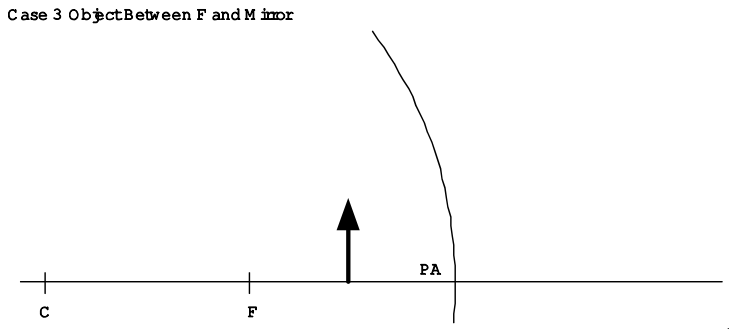
Imaginary or virtual rays, drawn behind the mirror are shown as dotted lines.

Images from a Converging Mirror

Complete the following diagrams that will show the characteristics of images formed by a converging mirror for three object positions:







Fill in the following table after you have completed the above ray diagrams for Case 1, Case 2, and Case 3 and others assigned by your teacher.

Object Location	**S**ize of image	**A**ttitude of Image	**L**ocation of Image	**T**ype of Image
beyond C				
at C				
between C and F				
at F				
inside F				

<u>Summary of Characteristics of Images formed for Converging Mirror:</u>
The image formed by a converging mirror depends on how far the object is from the focal point of the mirror.

If the object is far away from the focal point, then the reflected rays form a smaller, inverted, real image.

The closer the object gets to the focal point, the larger the image becomes.

When the object is exactly at the focal point, all rays that leave the object reverse direction at the mirror and are reflected away from the mirror parallel to each other. In this case, no image is formed.

If the object is between the focal point and the mirror, then the image becomes enlarged, upright and virtual.

Assignment

1. Draw a scale diagram for a converging mirror with a cross-sectional diameter of 4 cm, a focal length of 2 cm and an object height of 1.5 cm, the object is at a distance of 1.0 cm. State the characteristics of the image.

2. Where must the object be placed in front of a converging mirror to form:
a. tiny, real images, b. Large, virtual images?
Draw light ray diagrams to show how each of these images is formed.

3. A converging mirror has a focus fo 75 cm. An object is placed 60 cm in front of the mirror. Describe the image characteristics of this object.

4. A converging mirror has a focal length of 5 cm. An object 2 cm high is 11 cm from the mirror. Draw a ray diagram to determine the image characteristics of this object.

Uses of Converging Mirrors

Car headlights, Flashlight, and Search lights: all use converging reflectors to direct the light from a small light source.
In a searchlight, the light source, (the filament) is at the focus, and the reflected rays form a parallel beam, (see above: if a light source is placed at the focal point, a converging mirror will reflect a parallel beam of light).
Car headlights and most flashlights are designed in a similar way, except that the filament is slightly inside the focus so that the reflected rays spread apart and illuminate a greater area.

A concave mirror is also used in a reflecting telescope, (FYI: the first reflecting telescope was made by Isaac Newton in 1668). In a reflecting telescope, parallel light rays are focused to a sharp image after reflecting off a converging mirror. (See above: very distant objects, such as stars, form tiny images very close to the focal point of the mirror.)

Radio telescopes and satellite dishes are devices that also cause parallel light rays to converge; however in these cases it is the electromagnetic waves that converge and not visible light rays.

Shaving mirrors and Cosmetic mirrors are also used to produce an enlarged image. These converging mirrors typically have a focal length of about 1 m. By placing your face within the focal length, an enlarged, upright, and virtual image is formed by the mirror.

A solar oven, also called a solar cooker, is a device that uses light from the Sun as its energy source. A solar oven transforms sunlight directly into heat that can be used for cooking. A solar oven uses a converging mirror to concentrate the Sun’s rays, converting light to heat through absorption is the interior of the oven is a dark colour, and using a clear cover so that the Sun’s rays can enter but very little heat can leave.

The examination lamp used in a dentist’s office also employs a converging mirror.

Converging mirrors are also used in some lasers to concentrate the light into a fine intense beam.

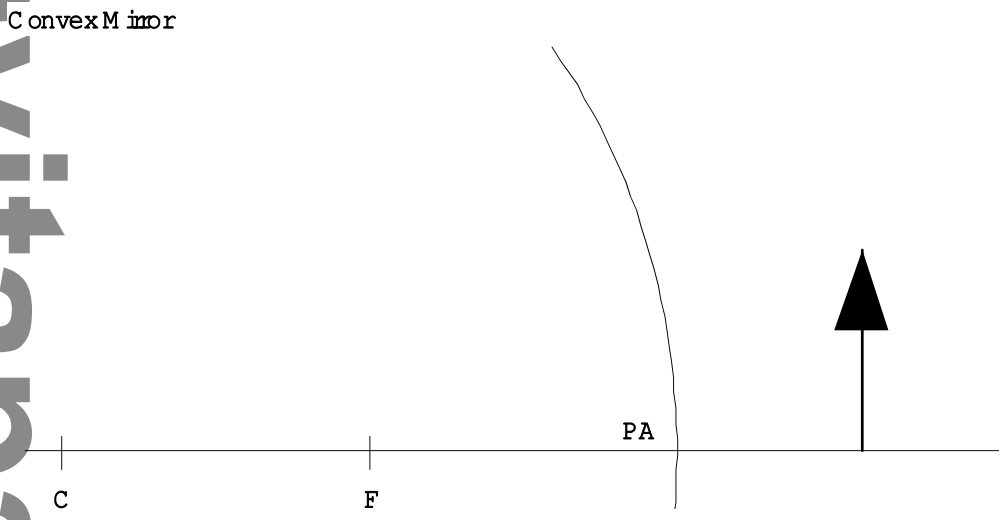
Diverging (Convex) Mirrors

Diverging mirrors, (sometimes called **convex mirrors)** are also curved mirrors and they cause parallel light rays to spread out from a point, they are because the *reflecting surface is curved outwards*.

How to Locate the Image in a Diverging (Convex) Mirror

The parts of a diverging mirror and the imaging rules for a diverging mirror are similar to those for a converging mirror.

The difference is that the focal point, F — now called a virtual focus, (to find F for a diverging mirror, extend the reflected rays backward until they appear to meet behind the mirror); and C — the centre of curvature are behind the mirror and light rays seem to come from an apparent light source behind the mirror, See diagram below:

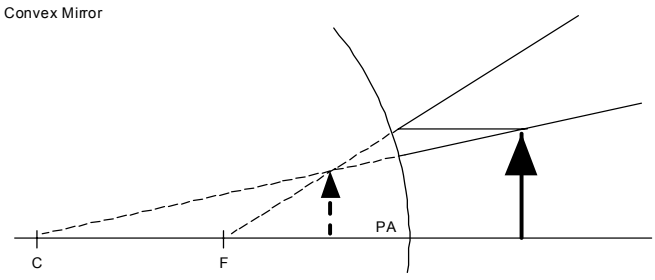


The rays reflected off a convex mirror always diverge, thus convex mirrors are referred correctly as diverging mirrors.

Drawing Ray Diagrams for Diverging Mirror: See Diagram below

The steps to draw a ray diagram for a diverging mirror are the same as those for the converging mirror.

1. Any ray parallel to the principal axis is reflected as if it had come through the focus, F.
2. A ray aimed at the focus, F, is reflected parallel to the principal axis.
3. A ray aimed at the centre of curvature, C, is reflected back upon itself.
4. Draw the virtual image where the reflected rays appear to intersect.



The reflected rays spread out instead of the prays being collected as in the case of the converging mirror.

The reflected rays from an object never cross in front of the mirror to form a real image.

The human brain extrapolates these rays behind the mirror to where they appear to converge.

This results in the diverging, (convex) mirror producing a smaller, upright and virtual image of the object.

Summary of Images formed by a Diverging Mirror

Distance of object from mirror	**S**ize of image	**A**ttitude of Image	**L**ocation of Image	**T**ype of Image
All distances in front of the mirror				

Diverging mirrors are used when people need to see over a very large area. Because if its curved surface, a diverging (convex) mirror can reflect light from all parts of a room to a person's eyes.

This property of a diverging mirror to produce a virtual image that is upright and smaller than the object enables diverging mirrors to be used for security cameras in stores.
A diverging mirror allows one to view a large region of the store from one location.

Diverging security mirrors are sometimes used on public transportation buses, as well as on roads with sharp curves on some countries.

At truck inspection stations and border crossings, security guards often need to see the underside of large semitrailers and other vehicles. To do this, a diverging mirror is attached to the end of a long handle at an angle, this enables a security guard to see the underside of a vehicle without crawling under it.

For the same reason, diverging mirrors are used in vehicles as side view mirrors and rear-view mirrors.

However, if one looks in a diverging mirror, it appears as if the image is originating from a smaller point behind the mirror. Because of these smaller images, diverging mirrors on cars often have a warning such as 'the objects in the mirror are closer than they appear'.

Diverging mirrors are also used in some automatic teller machines and computers.
A diverging mirror allows the machine users to see what is happening behind them while they are facing the machine screen.

Many camera phones include a diverging mirror so that the user can accurately aim the camera to take a self-portrait.

Assignment: CONCEPT REVIEW

1. Describe the law of reflection as a relationship between the angle of incidence, the angle of reflection, and the normal.

2. Describe the kinds of images that can be formed by plane mirrors.

3. List the energy transformation steps that occur in an electric discharge tube. That is, what form of energy is transformed into what other form of energy until the energy becomes light?

4. a. What two properties do all electromagnetic waves have in common?
   b. If light is a form of energy, explain how light can be different colours.

5. What is meant when the image is said to be behind the mirror? What do you call this type of image?

6. Explain how you would find the focal point of a diverging (convex) mirror.

7. a. What is a real image? b. What is a virtual image?

8. Describe what kind of mirror you would use if you needed to view a large, spread out area in a small mirror.

9. What kinds of images do diverging (convex) mirrors form?

10. A lighted object is placed at the focal point of a converging (concave) mirror. Describe the light rays reflecting off the mirror.

11. Using a ray diagram with five rays to show how a car headlight uses a converging mirror to direct light.

12. Draw ray diagrams for a diverging mirror and state the characteristics of the image for the following object positions: a. 1.0 F b. 0.50 F

13. Draw a ray diagram to determine the position of an image formed by a converging mirror that has a focal length of 3.0 cm and a 2.0 cm height object is positioned at 6.0 cm from the mirror. Measure the height and the distance from the focal length of the image.

14. Sometimes, on a sunny day, campers start a campfire using a small mirror to light paper or dry grass. What shape of mirror would they use ? What is happening to the sunlight when they do this? Draw a ray diagram to illustrate your answer.

15. You are looking at your image in a cosmetic or a shaving mirror. Where is your head located with respect to the focus?

16. Why are diverging mirrors placed on sharp turns in parking spaces?
17. Where must an object be located in order for a converging mirror to form:
    (a) a real image ? (b) a virtual image ?
18. A photograph is covered with non-glare glass. The surface of this glass is rougher than regular glass. How would this feature contribute to it being non-glare glass?
19. a. Explain why most cars have both a plane and a diverging (convex) rear-view mirror.
    b. What safety problems can occur when using diverging mirrors?
20. In a funhouse you see a strange distorted image of yourself in a curved mirror. Your face and the upper half of your body appear shrunken, while your lower half is enlarged and inverted. Describe the shape of the mirror.