King Saud University
College of Applied Studies
and Community Service
Department of Natural Sciences

The Reflection of Light

General Physics II
PHYS 111

Nouf Alkathran
nalkathran@ksu.edu.sa

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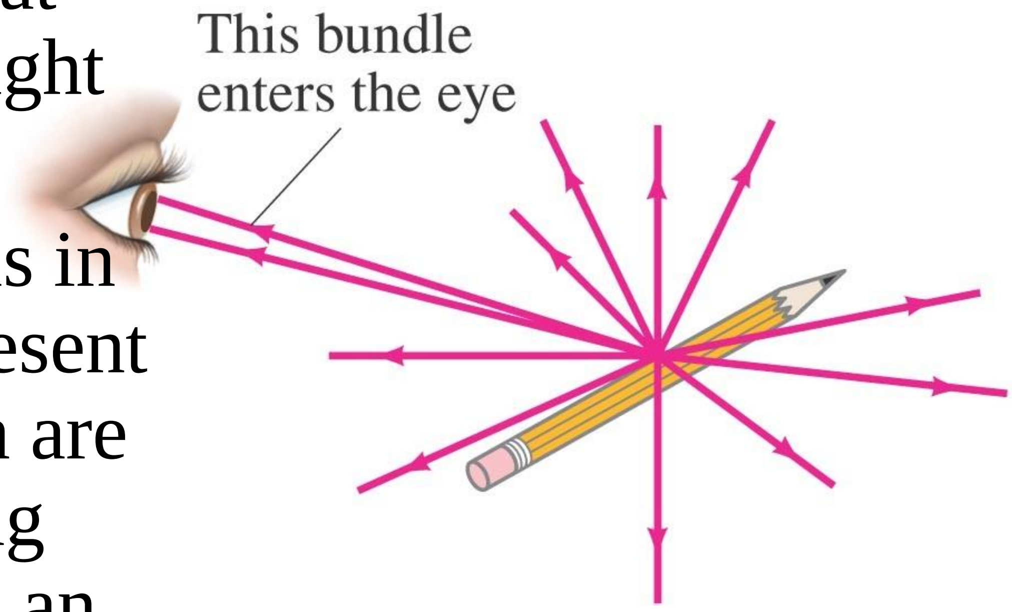
Introduction

- All substances absorb at least some incoming light and reflect the rest.
- Light very often travels in straight lines. We represent light using rays, which are straight lines emanating from an object. This is an idealization, but is very useful for geometric optics.

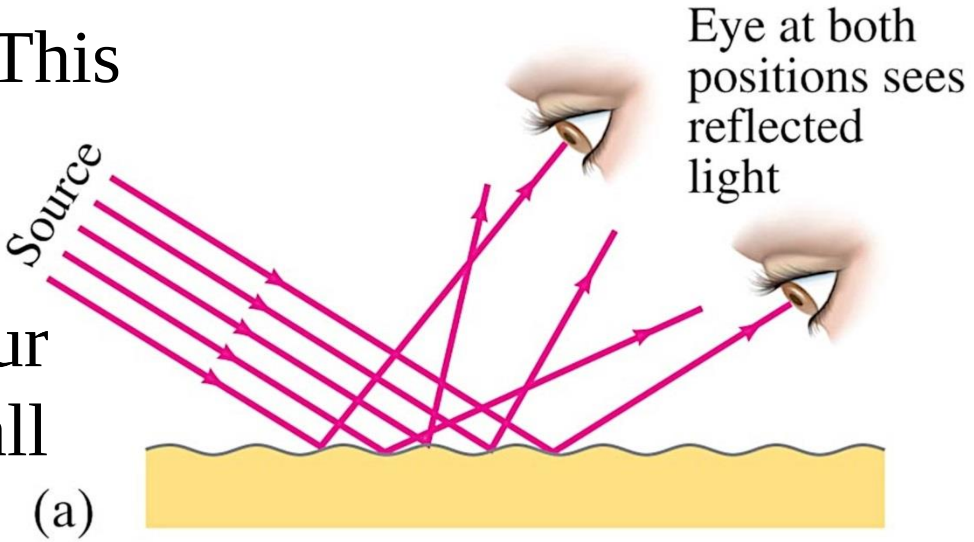


The Texture of a Surface Affects How it Reflects Light

- The manner in which light is reflected from a surface depends on the surface’s smoothness.
- diffuse reflection
- specular reflection

Diffuse Reflection

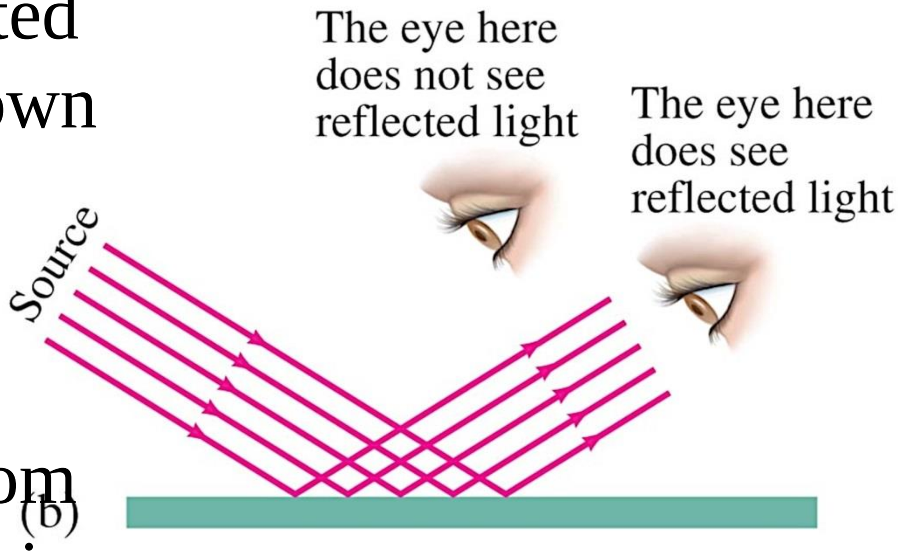
- Light that is reflected from a rough, textured surface, such as paper, cloth, is reflected in many different directions. This type of reflection is called *diffuse reflection.*
- With diffuse reflection, your eye sees reflected light at all angles.



(a)

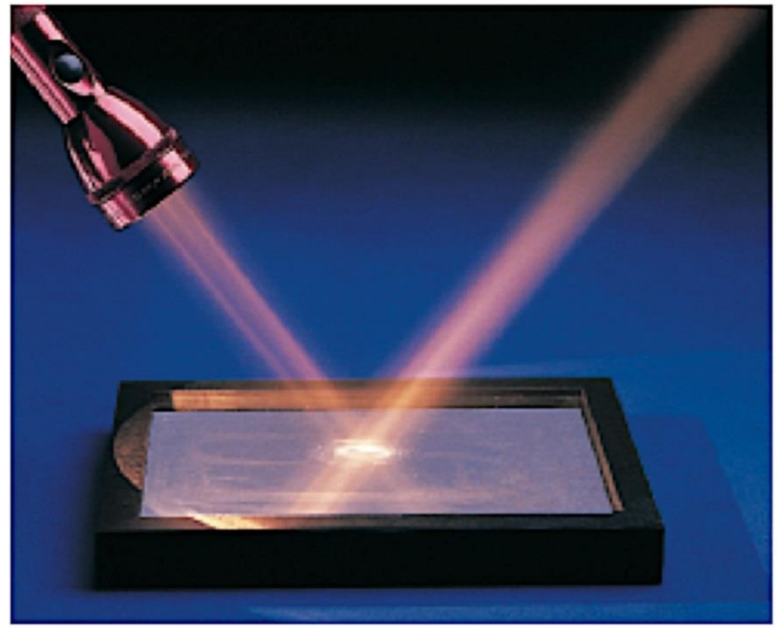
Specular Reflection

- Light reflected from smooth, shiny surfaces, such as a mirror or water in a pond, is reflected in one direction only, as shown in the **Figure .** This type of reflection is called *specular reflection.*
- With specular reflection (from a mirror), your eye must be in the correct position.



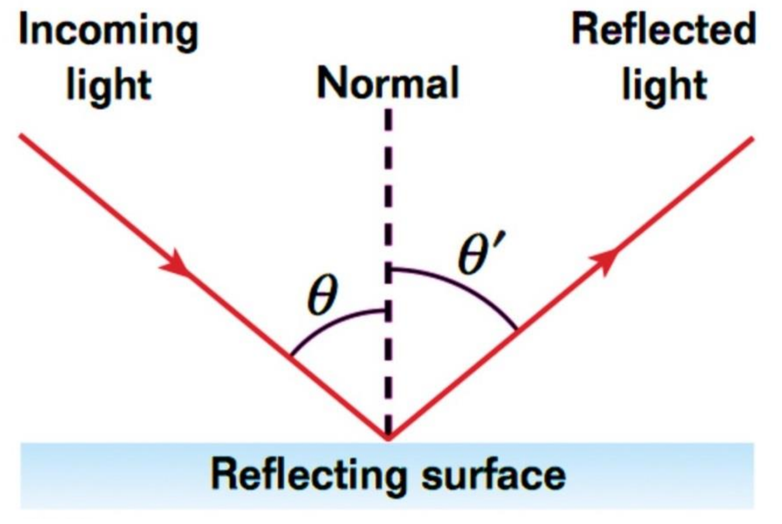
The Law of Reflection

- States that the **incoming and the reflected angles are equal**
- You probably have noticed that when incoming rays of light strike a smooth reflecting surface, such as a polished table or mirror, at an angle close to the surface, the reflected rays are also close to the surface. An example of this similarity between incoming and reflected rays is shown in the Figure.



The Law of Reflection

- If a straight line is drawn perpendicular to the reflecting surface at the point where the incoming ray strikes the surface, the angle of incidence and the angle of reflection can be defined with respect to the line. Careful measurements of the incident and reflected angles θ and θ', respectively, reveal that the angles are equal, as illustrated in the Figure .



$$\boldsymbol{\theta = \theta'}$$

angle of incoming light ray = angle of reflected light ray

FLAT MIRRORS

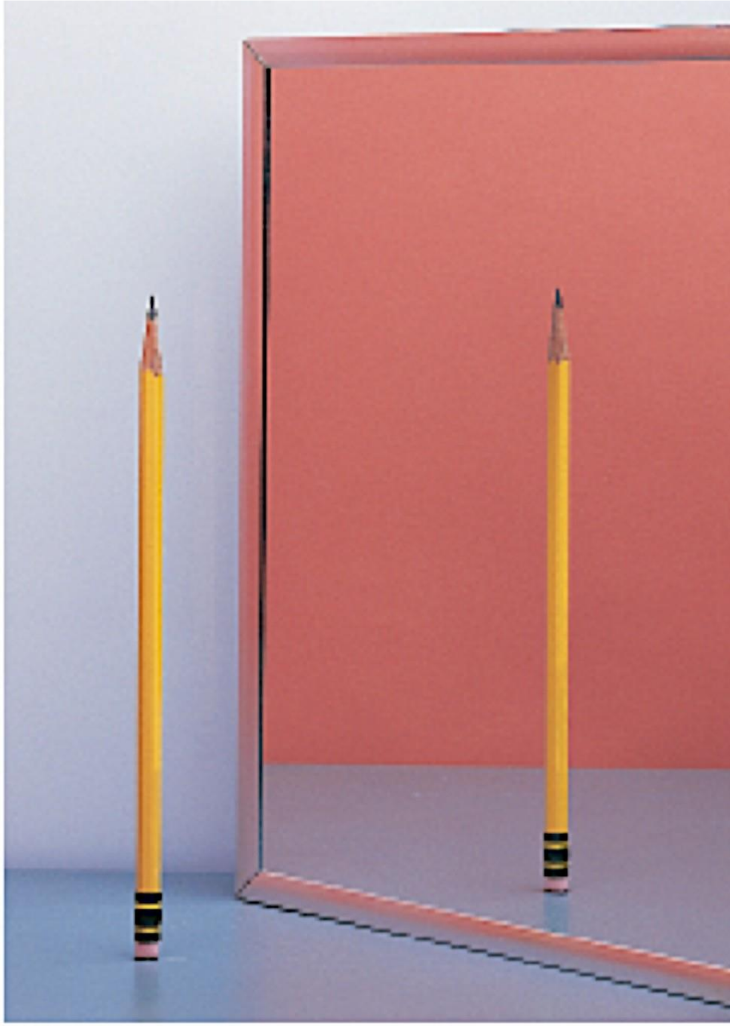
- If an object, such as a pencil, is placed at a distance in front of a flat mirror and light is bounced off the pencil, light rays will spread out from the pencil and reflect from the mirror's surface. To an observer looking at the mirror, these rays appear to come from a location on the other side of the mirror.

FLAT MIRRORS

- As a convention, an object's image is said to be at this location behind the mirror because the light appears to come from that point. The relationship between the *object distance* from the mirror, which is represented as *p*, and the *image distance*, which is represented as *q*, is such that the object and image distances are equal. Similarly, the image of the object is the same size as the object.

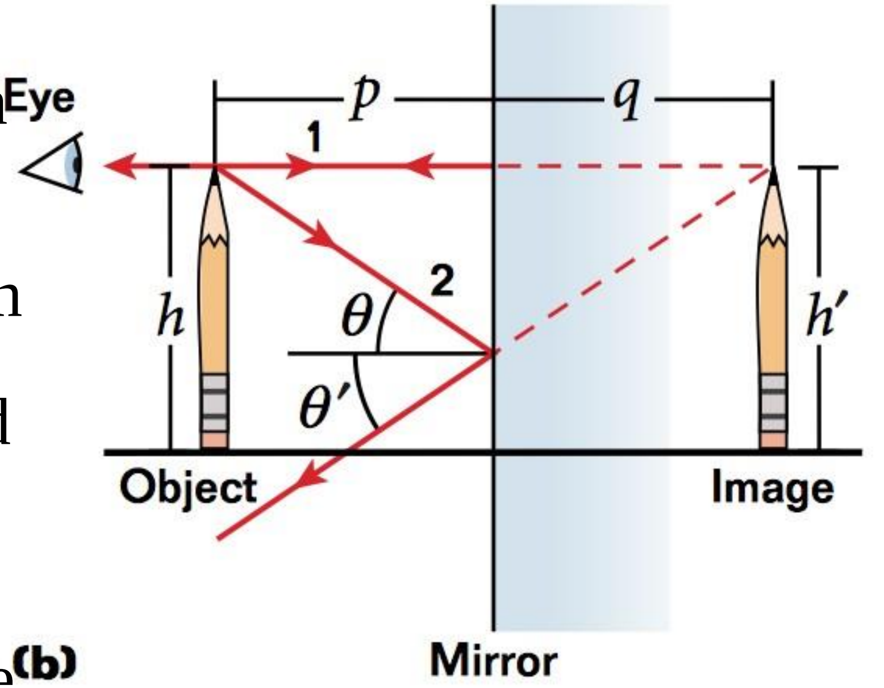
FLAT MIRRORS

- The image formed by rays that appear to come from the image point behind the mirror, but never really do is called a **virtual image.**
- a flat mirror always forms a virtual image, which always appears as if it is behind the surface of the mirror. For this reason, a virtual image can never be displayed on a physical surface.



Ray Diagrams

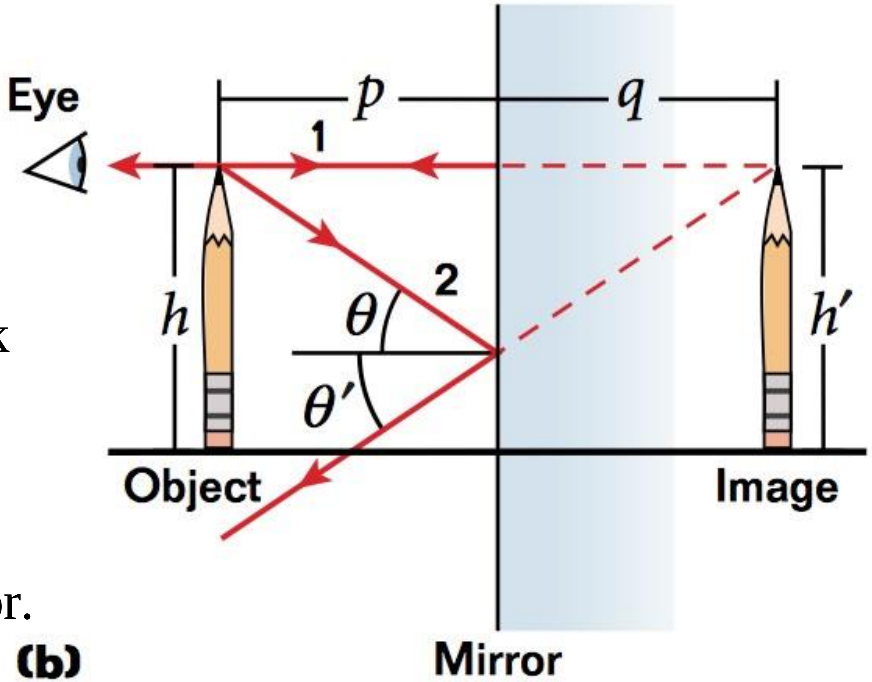
- Suppose you want to make a ray diagram for a pencil placed in front of a flat mirror. First, sketch the situation. Draw the location and arrangement of the mirror and the position of the pencil with respect to the mirror. Construct the drawing so that the object and the image distances (*p* and *q*, respectively) are proportional to their actual sizes. To simplify matters, we will consider only the tip of the pencil.



Ray Diagrams

- To pinpoint the location of the pencil tip's image, draw two rays on your diagram.

1. Draw the first ray from the pencil tip perpendicular to the mirror's surface. Because this ray makes an angle of 0° with a line perpendicular (or *normal*) to the mirror, the angle of reflection also equals 0°, causing the ray to reflect back on itself.
2. Draw the second ray from the tip of the pencil to the mirror, but this time place the ray at an angle that is not perpendicular to the surface of the mirror.
3. Then, draw the reflected ray, keeping in mind that it will reflect away from the surface of the mirror at an angle, ***θ'*** , equal to the angle of incidence, ***θ.***



(b)

Ray Diagrams

4. Next, trace both reflected rays back to the point from which they appear to have originated, that is, behind the mirror. Use dotted lines when drawing these rays that appear to emerge from behind the mirror to distinguish them from the actual rays of light (the solid lines) in front of the mirror. The point at which these dotted lines meet is the image point, which in this case is where the image of the pencil's tip forms.
5. By continuing this process for all of the other parts of the pencil, you can locate the complete virtual image of the pencil.

- Note that the pencil's image appears as far behind the mirror as the pencil is in front of the mirror ($p = q$). Likewise, the object height, h, equals the image height, h'.

Apparent Left-Right Image Reversal

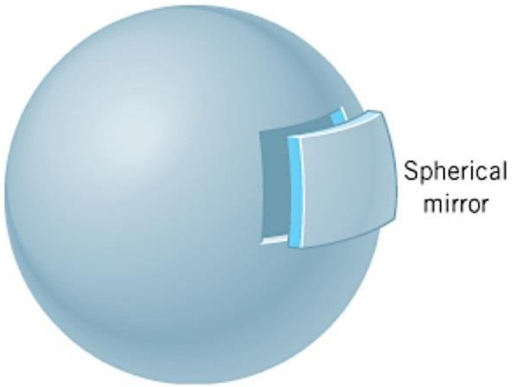
- The image formed by a flat mirror appears reversed to an observer in front of the mirror. You can easily observe this effect by placing a piece of writing in front of a mirror, In the mirror, each of the letters is reversed. You may also notice that the angle the word and its reflection make with respect to the mirror is the same.
- Emergency vehicles are usually reverse-lettered so the lettering appears normal in the rear view mirror of a car.

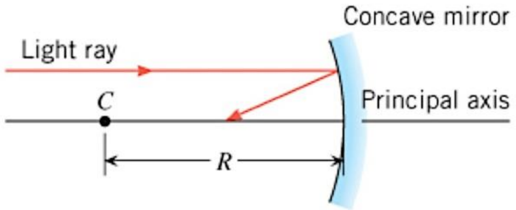
Image Characteristics for flat Mirrors

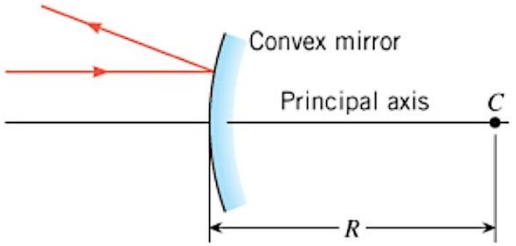
1. Creating a virtual image
2. Apparent Left-Right Image Reversal
3. Object Distance and Image Distance are equal
4. Relative Size of Image and Object are the same

Curved Mirrors

- CONCAVE SPHERICAL MIRRORS
- CONVEX SPHERICAL MIRRORS
- If the *inside* surface of the **spherical mirror** is polished, it is a ***concave mirror.*** If the *outside* surface is polished, is it a ***convex mirror. R*** is the radius of curvature of the mirror.
- The ***principal axis*** of the mirror is a straight line drawn through the ***center of curvature C*** and the midpoint of the mirror.







CONCAVE SPHERICAL MIRRORS

- The images for objects close to the mirror are larger than the object and it is a virtual image Figure (a).

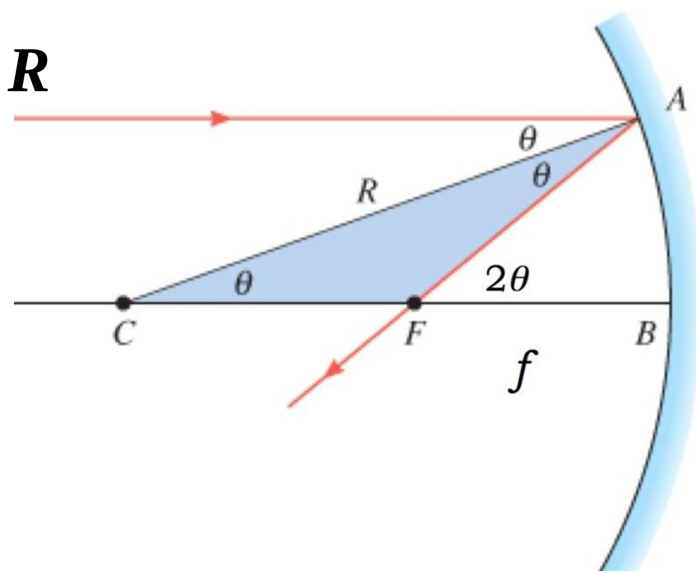
- whereas the images of objects far from the mirror are smaller and upside down and it is a real image Figure (b).

Concave Spherical Mirror

- A spherical mirror with light reflecting from its silvered, concave surface (that is, the inner surface of a sphere) is called a **concave spherical mirror.**

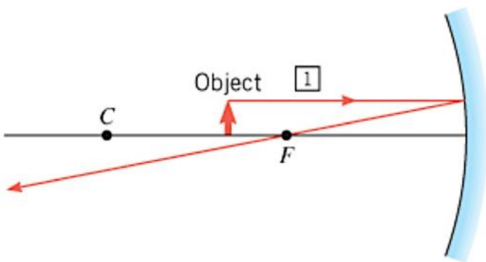
- The focal point *F* of a concave mirror is halfway between the center of curvature of the mirror *C* and the mirror at *B*.

$$f = (1/2)\,R$$

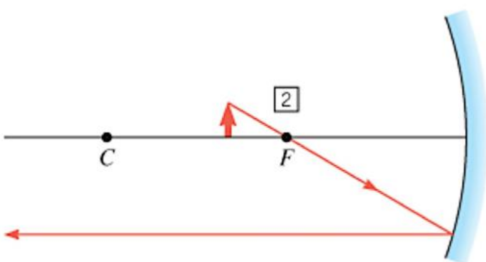


IMAGING WITH CONCAVE MIRRORS

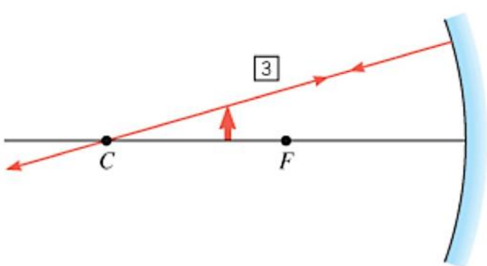
- To find the image of an object placed in front of a concave mirror, there are several types of rays which are particularly useful ➔➔ ray tracing



This ray is initially parallel to the principal axis and passes through the focal point.



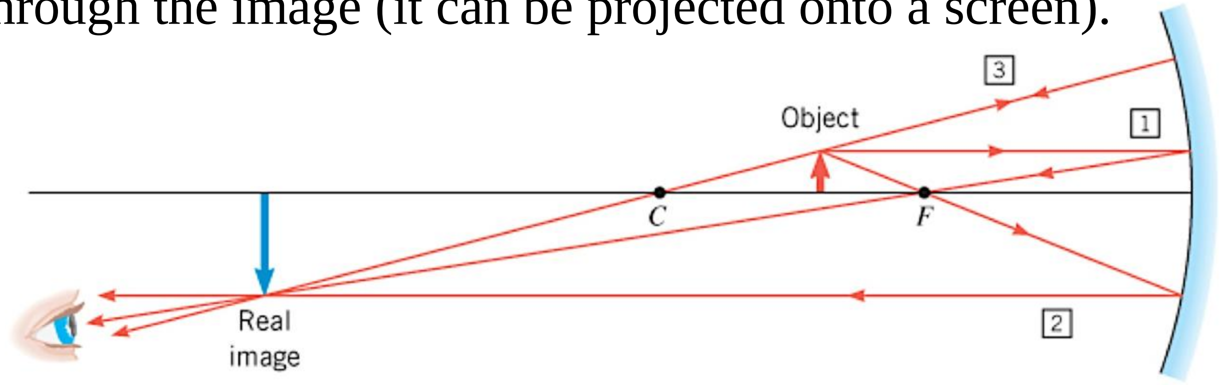
This ray initially passes through the focal point, then emerges parallel to the principal axis.



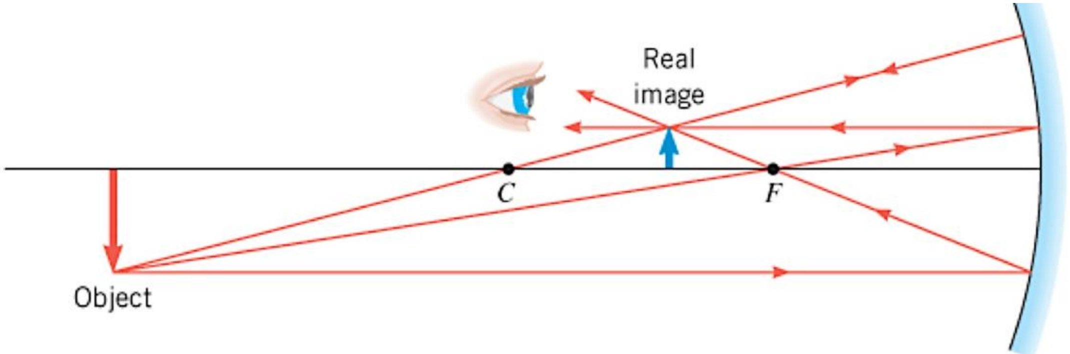
This ray travels along a line that passes through the center and so reflects back on itself.

A Real Image

- If the object is placed between *F* and *C*, the image is ***real, inverted and magnified***.
- If the object is placed at a distance greater than *C* from the mirror, the image is ***real, inverted and reduced in size***. A ***real image*** is one where light is actually passing through the image (it can be projected onto a screen).

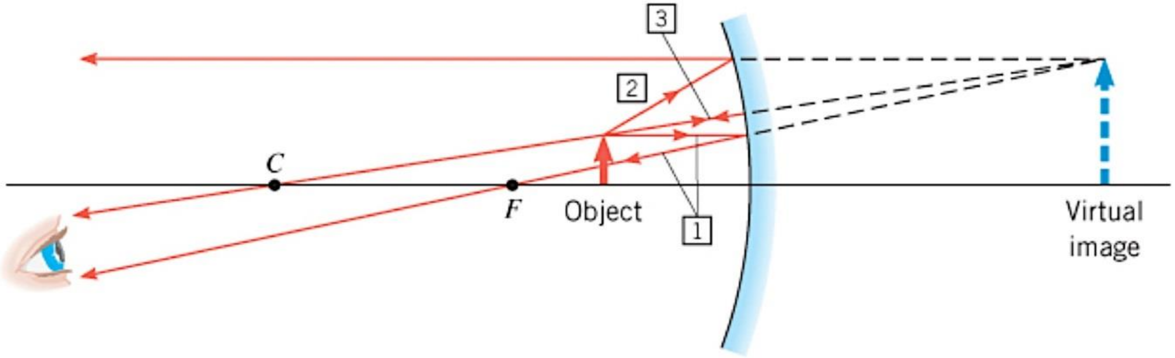


(*a*)



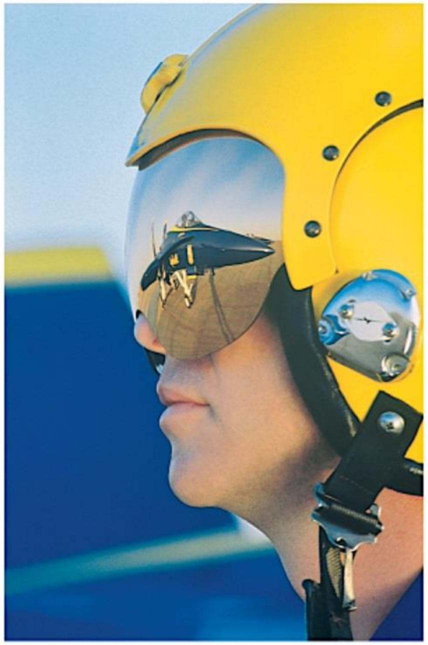
A Virtual Image

- When an object is placed between the focal point *F* and a concave mirror, The image is ***virtual, upright, and magnified*** (as in the case of images from flat mirrors, a virtual image is one from which light appears to be emanating but through which light does not pass, e.g. it cannot be projected onto a screen).



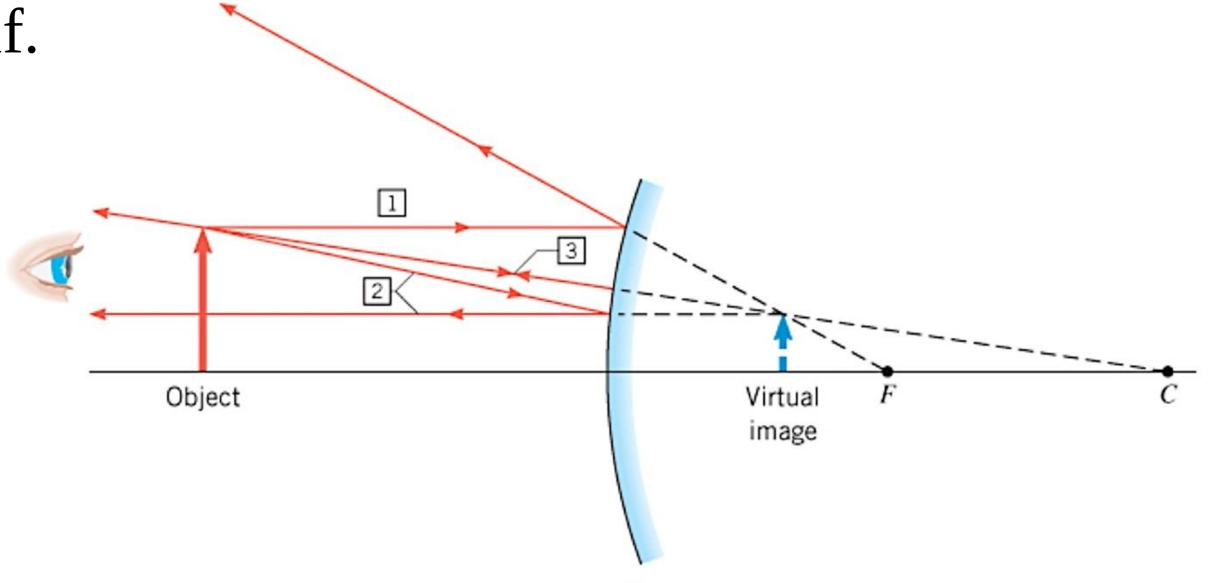
CONVEX SPHERICAL MIRRORS

- A convex spherical mirror is a segment of a sphere that is silvered so that light is reflected from the sphere's outer, convex surface . This type of mirror is called a **convex spherical mirror**
- For convex mirrors the image of an object is **always** ***virtual, upright, and reduced in size.***



IMAGING WITH CONVEX MIRRORS

- Ray 1 is initially parallel to the principal axis and appears to originate from the focal point.
- Ray 2 heads towards the focal point, emerging parallel to the principal axis.
- Ray 3 travels toward the center of curvature and reflects back on itself.



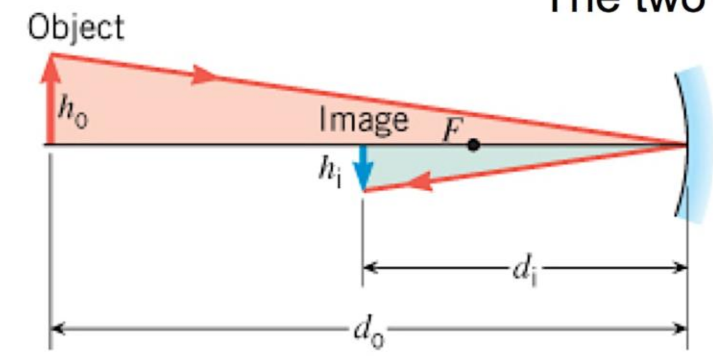
(a)

IMAGING WITH CONVEX MIRRORS

- So far we have discussed concave and convex mirrors qualitatively and graphically. We now want to derive **two simple equations** which provide **quantitative relationships** among the quantities we have defined to describe mirrors, i.e.,
- f =focal length
- p =object distance
- q =image distance
- m = magnification

<u>Magnification and Mirror Equations</u>

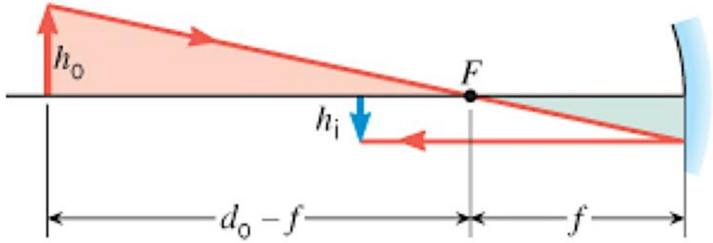
The two right triangles are similar in each case.



(a)

$$\frac{h_o}{-h_i} = \frac{d_0}{d_i}$$ minus since inverted

$$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$ **Magnification equation**



(b)

$$\frac{h_o}{-h_i} = \frac{d_o - f}{f}$$

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$ **Mirror equation**

Both equations are valid for concave and convex mirrors and for real and virtual images.

MIRROR EQUATION

- The following equation relates object distance, *p or* $\boldsymbol{d_0}$, image distance, *q or* ***di***, and the radius of curvature, *R*, is called *the mirror equation*.

MIRROR EQUATION

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$\frac{1}{\text{object distance}} + \frac{1}{\text{image distance}} = \frac{1}{\text{focal length}}$$

The Magnification

- The curved mirrors form images that are not the same size as the object. The measure of how large or small the image is with respect to the original object's size is called the ***magnification*** of the image.

EQUATION FOR MAGNIFICATION

$$M = \frac{h'}{h} = -\frac{q}{p}$$

$$\text{magnification} = \frac{\text{image height}}{\text{object height}} = -\frac{\text{image distance}}{\text{object distance}}$$

Sign Conventions for Spherical Mirrors

- f is + for a concave mirror.
- f is − for a convex mirror.

- p is + if the object is in front of the mirror.
- p is − if the object is behind the mirror.

- q is + if the object is in front of the mirror (real image).
- q is − if the object is behind the mirror (virtual image).

- M is + for an image upright with respect to the object.
- M is - for an image inverted with respect to the object.

Questions

- A 2.0 cm high object is placed 7.10 cm from a concave mirror whose radius of curvature is 10.20 cm. Find the location of the image and its size.

Questions

- A convex mirror is used to reflect light from an object placed 66 cm in front of the mirror. The focal length of the mirror is 46 cm in back of the mirror. Find the location of the image and the magnification.