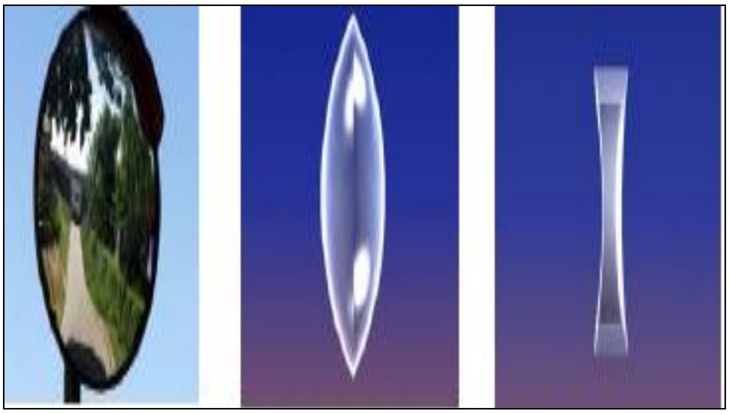
Kirk uk University
Science College
Physics Department

Lectures of GEOMETRIC OPTICS Lecture – 3 –



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Lecture 3: Spherical Mirrors - Concave Mirror – Part 2

3 – 1 Ray Diagrams - Concave Mirror

Case 1: The object is located *beyond* C

- When the object is located at a location beyond the center of curvature, the image will always be located somewhere in **between the center of curvature and the focal point** , as shown in Fig.(**3-1**) **.**

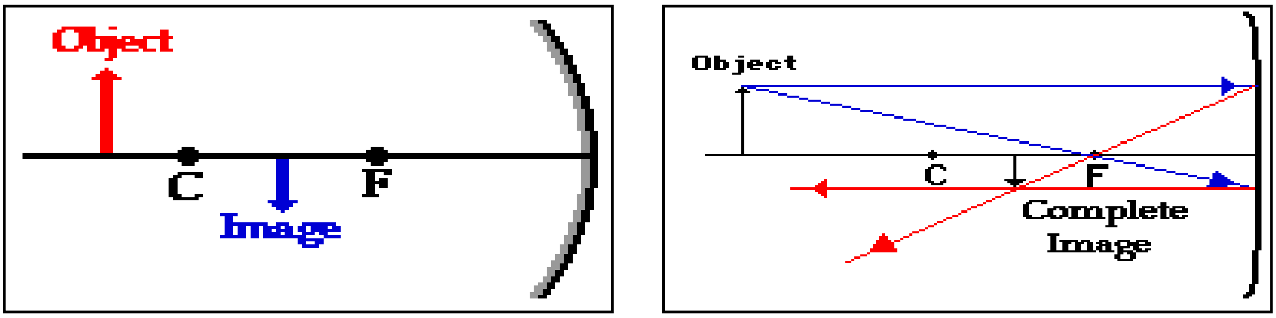


Fig. (3-1): The object is located *beyond* C

- Regardless of exactly where the object is located, the image will be located in the specified region**.**
- In this case, the image will be an **inverted image.**
- In this case, the image is **reduced in size**; in other words, the image dimensions are smaller than the object dimensions**.**
- The term magnification was introduced; the **magnification** is the ratio of the height of the image to the height of the object**.**
- In this case, the absolute value of the magnification is **less than 1.**
- Finally, the image is a **real image.**

Case 2: The object is located at C

- When the object is located at the center of curvature, the image will also be located **at the center of curvature,** as shown in Fig.(**3-2**) and Fig.(**3-4a**) **.**

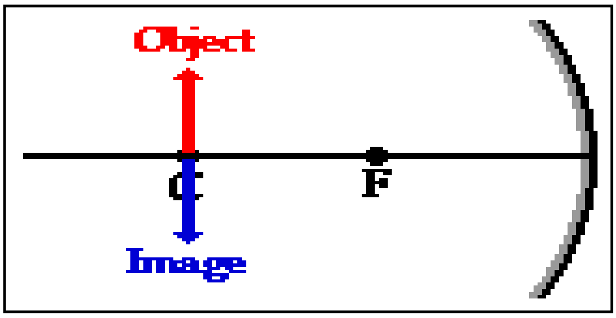


Fig. (3-2): The object is located at C

- In this case, the image will be **inverted.**
- The image dimensions are equal to the object dimensions**.**
- The absolute value of the magnification is **equal to 1.**
- Finally, the image is a **real image.**

Case 3: The object is located between C and F

- When the object is located *in front of* the center of curvature, the image will be located ***beyond* the center of curvature** , as shown in Fig.(**3-3**) and Fig.(**3-4b**) **.**

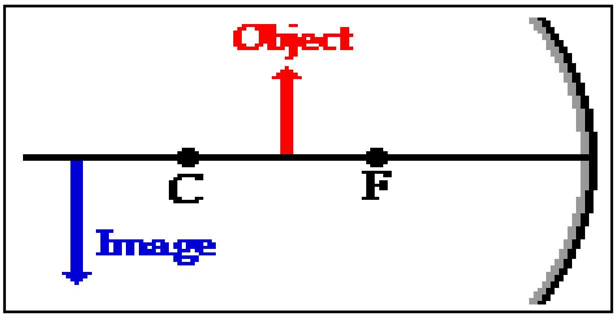
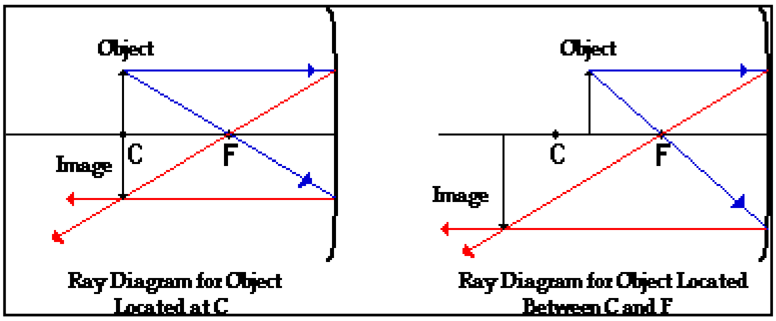


Fig. (3-3): The object is located between C and F

- Regardless of exactly where the object is located between **C** and **F**, the image will be located somewhere *beyond* the center of curvature**.**
- In this case, the image will be **inverted.**
- The image dimensions are larger than the object dimensions**.**
- The absolute value of the magnification is **greater than 1.**
- Finally, the image is a **real image.**



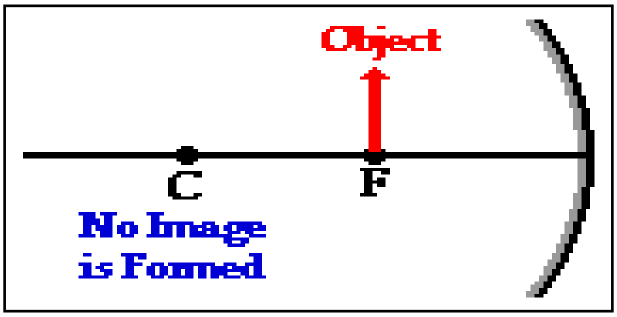
(**3-4a**) (**3-4b**)

(3-4a) :The object is located at C

(3-4b) : The object is located between C and F

Case 4: The object is located at F

- When the object is located at the focal point, **no image is formed** as shown in Fig.(**3-5**).



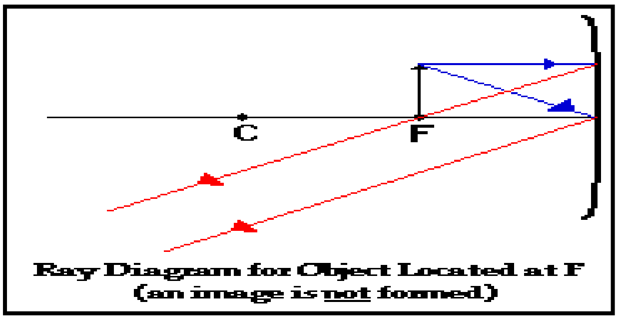


Fig. (3-5): The object is located at F

- Light rays from the same point on the object will reflect off the mirror and neither converge nor diverge.
- After reflecting, the light rays are traveling parallel to each other and do not result in the formation of an image.

Case 5: The object is located *in front of* F

- When the object is located at a location in front of the focal point, the image will always be located somewhere **on the opposite side of the mirror** , as shown in Fig.(**3-6**)**.**

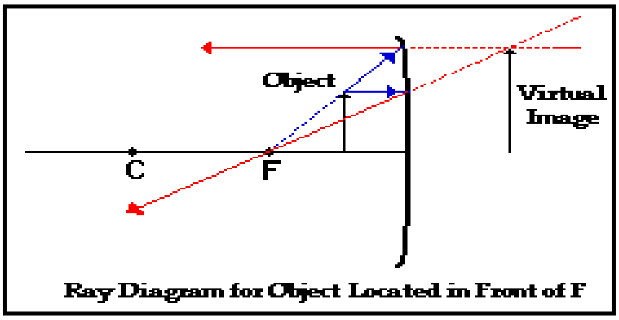


Fig. (3-6): The object is located in front of F

- Regardless of exactly where in front of **F** the object is located, the image will always be located behind the mirror**.**
- In this case, the image will be an **upright image.**
- In this case, the image is **magnified**; in other words, the image dimensions are greater than the object dimensions**.**
- The magnification is **greater than 1.**
- Finally, the image is a **virtual image.**

3 – 2 The Mirror Equation - Concave Mirror

- Ray diagrams can be used to determine the image location, size, orientation and type of image formed of objects when placed at a given location in front of a concave mirror.
- Ray diagrams provide useful information about object-image relationships, yet fail to provide the information in a quantitative form.
- While a ray diagram may help one determine the approximate location and size of the image, it will not provide numerical information about image distance and image size.
- To obtain this type of numerical information, it is necessary to use the **Mirror Equation** and the **Magnification Equation.**

- The mirror equation expresses the quantitative relationship between the object distance ($d_\circ$), the image distance (d_i), and the focal length (f).
- The equation is stated as follows that shown in Fig.(3-7):

$$\frac{1}{f}=\frac{1}{d_\circ}+\frac{1}{d_i}\quad...(3-1a)\qquad \text{or} \qquad \frac{2}{R}=\frac{1}{d_\circ}+\frac{1}{d_i}\quad...(3-1b)$$

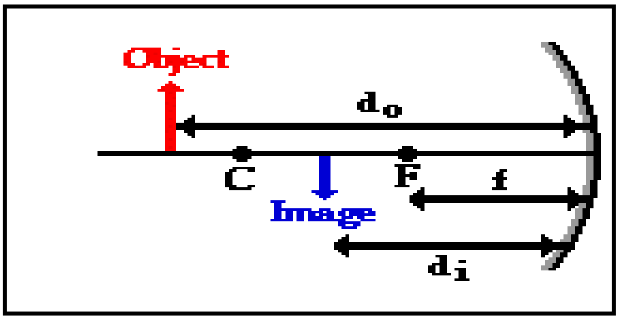


Fig. (3-7): The Variables of Mirror Equation – Concave Mirror

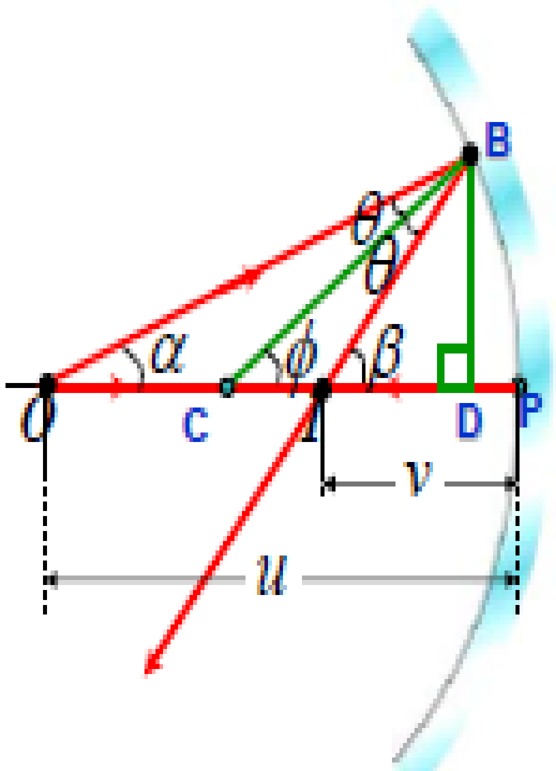
- The magnification equation relates the ratio of the image distance (d_i) and object distance (d_o) to the ratio of the image height (h_i) and object height ($h_\circ$).
- The magnification equation is stated as follows:

$$M=\frac{h_i}{h_\circ}=-\frac{d_i}{d_\circ}\quad...(3-2)$$

- These two equations can be combined to yield information about the image distance and image height if the object distance, object height, and focal length are known.
- As a demonstration of the effectiveness of the mirror equation and magnification equation, consider the examples and its solution in the next lecture.

3 – 3 Derivation of Spherical mirror equation-Concave Mirror

- Figure below shows an object O at a distance u and on the principal axis of a concave mirror. A ray from the object O is incident at a point B which is close to the pole P of the mirror.



- From the figure,

$\triangle BOC \Rightarrow \phi = \alpha + \theta$ ——(1)

$\triangle BCI \Rightarrow \beta = \phi + \theta$ ——(2)

then, eq. (1)-(2) :

$$\phi - \beta = \alpha - \phi$$

$$\alpha + \beta = 2\phi \quad \text{——(3)}$$

By using $\triangle BOD$, $\triangle BCD$ and $\triangle BID$ thus

$$\tan\alpha = \frac{BD}{OD}\,;\ \tan\phi = \frac{BD}{CD}\,;\ \tan\beta = \frac{BD}{ID}$$

- By considering point B very close to the pole P, hence

$$\tan\alpha \approx \alpha\,;\ \tan\phi \approx \phi\,;\ \tan\beta \approx \beta$$

$$OD \approx OP = u\,;\ CD \approx CP = r\,;\ ID \approx IP = v$$

then

$$\alpha = \frac{BD}{u}\ ;\ \phi = \frac{BD}{r}\ ;\ \beta = \frac{BD}{v}$$

Substituting this value in eq. (3) 26

therefore

$$\frac{BD}{u} + \frac{BD}{v} = 2\left(\frac{BD}{r}\right)$$

$$\frac{1}{u} + \frac{1}{v} = \frac{2}{r} \quad \text{where } r = 2f$$

$$\boxed{\frac{1}{f} = \frac{1}{u} + \frac{1}{v}}$$

Equation (formula) of spherical mirror

3 – 4 The +/- Sign Conventions – Concave Mirror

- The sign conventions for the given quantities in the mirror equation and magnification equations are as follows**:-**

- (f) is $(+)$ if the mirror is a (concave mirror)**.**
- (d_i) is $(+)$ if the image is a real image and located on the object's side of the mirror**.**
- (d_i) is $(-)$ if the image is a virtual image and located behind the mirror**.**
- (h_i) is $(+)$ if the image is an upright image (and therefore, also virtual)**.**
- (h_i) is $(-)$ if the image an inverted image (and therefore, also real)**.**
- (R) is $(+)$ if center of curvature is in front of mirror (concave mirror)**.**
- (M) is $(+)$, image is **upright.**
- (M) is $(-)$, image is **inverted.**