Homework 3

Last class we discussed how to construct an image produced by a concave spherical mirror. We learned one most important property of the spherical mirror: if we send the "bundle" of rays parallel to the main optical axis of the mirror (this is the axis of symmetry of the spherical mirror), then, being reflected form the mirror surface, all the rays will intersect in one point which is called "the focal point". The focal point is located on the main optical axis. The distance from the mirror to the focal point is called "the focal length". This property already contains the recipe how to construct the image. It is illustrated in the pictures below (Figure 1):

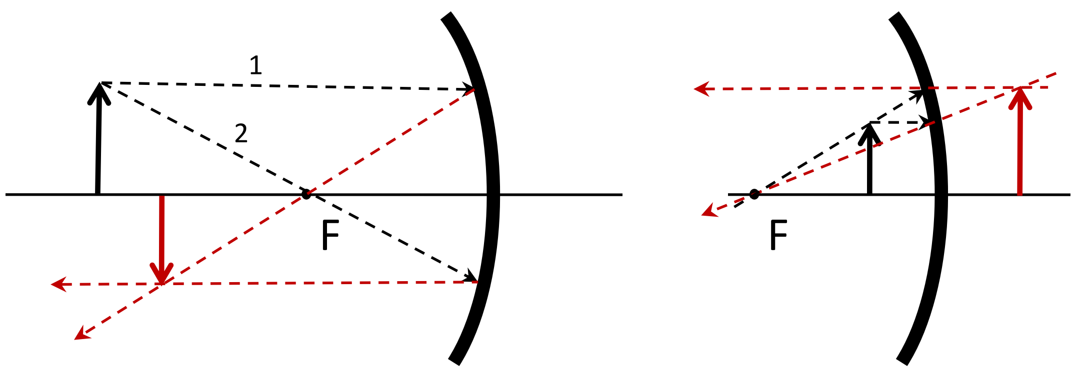

Figure 1.

The black vertical arrow represents the object to be imaged. If we position an object at the distance (from the mirror) which exceeds the focal length, the image will be inverted (upside down) and smaller. This situation is shown in the left part of the figure. To construct the image we have to find the position of the image of the arrow tip. The best way to specify the position of a point is to represent it as intersection of two lines. We will send one beam from the tip of the arrow toward the mirror parallel to the main optical axis. Being reflected it will pass through the focal point. The other beam will be sent from the tip to the mirror through the focal point. This beam will be reflected parallel to the main optical axis. Intersection of these beams will give as the position of the tip of the arrow. Similar procedure will be used for the object positioned between the focal point and the mirror surface (the right part of the Figure 1). The image in this case is not inverted and is magnified. We observed it during the class.

We can choose the two rays by different ways. One of the alternative ways is shown in Figure 2 (we discussed it in the class).

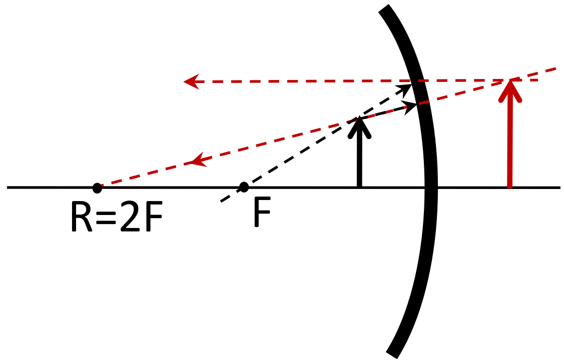

Figure 2.

In this case the second ray passes through the center of curvature of the mirror. This ray will be reflected back along itself, since in this case the incident angle will be zero. Extending both rays to the intersection point behind the mirror we obtain the image.

<u>Magnification.</u>

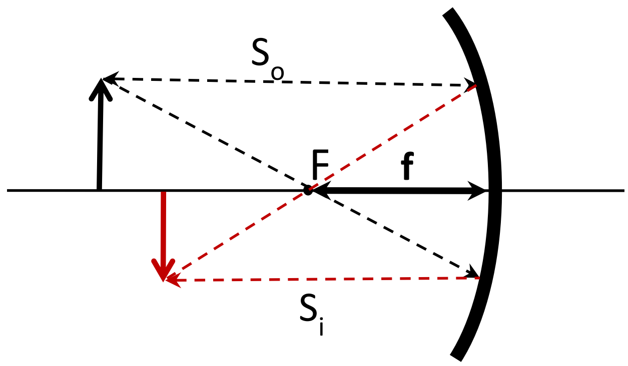

Figure 3 Concave lens.

We derived the expression connecting the distance from the **<u>convex</u>** mirror to the object S_o, the distance from the mirror to the image S_i and the radius of curvature of the mirror R:

$$\frac{1}{S_0} - \frac{1}{S_i} = -\frac{2}{R} \quad (1)$$

Similar equation holds for a **<u>concave</u>** mirror:

$$\frac{1}{S_0} + \frac{1}{S_i} = \frac{2}{R} \quad (2)$$

The equation (2) can be obtained from equation (1) if we will agree on the following sigh rules:

1. We will consider the distance from the mirror to the ***virtual*** image as ***negative***, the distance to the ***real*** image as ***positive***.
2. The radius of curvature of a ***convex*** mirror is ***positive***, for a ***concave*** mirror – ***negative***. That is why in the formula (2) we have 2/R instead of -2/R.
3. The focal distance f=-R/2 for a concave mirror; f=R/2 for a convex mirror.

So the general for of the equations (1) and (2) will be:

$$\frac{1}{S_0} + \frac{1}{S_i} = \frac{1}{f} \quad (3),$$

where the focal distance ***f*** is:

$$f = -\frac{R}{2}\begin{cases} > 0, concave\ mirror \\ < 0, convex\ mirror \end{cases}$$

The parameter *m*

$$m = -\frac{S_i}{S_0} \quad (4)$$

is called ***magnification***. It shows how much times the image is larger than the object (Here we mean “lateral” size, the size in the direction perpendicular to the main optical axis). Please do not be afraid of the negative sign. It just indicates that the image is “flipped” (inverted). In the case of the virtual image (which is not inverted), the magnification will be positive.

1. The object is placed 2 cm away of a concave mirror with the radius of curvature of 8 cm. Find the magnification. Make a picture.

2. The object from problem 1 is moved away from the mirror so the distance is 10 cm now. Find the magnification and make a picture.

3. You have concave mirror. How you can experimentally estimate its focal length?

4. For the case shown in Figure 1 (left) prove that magnification given by the expression (4) gives the ratio of the lengths of the vertical arrows corresponding to the object and the image.