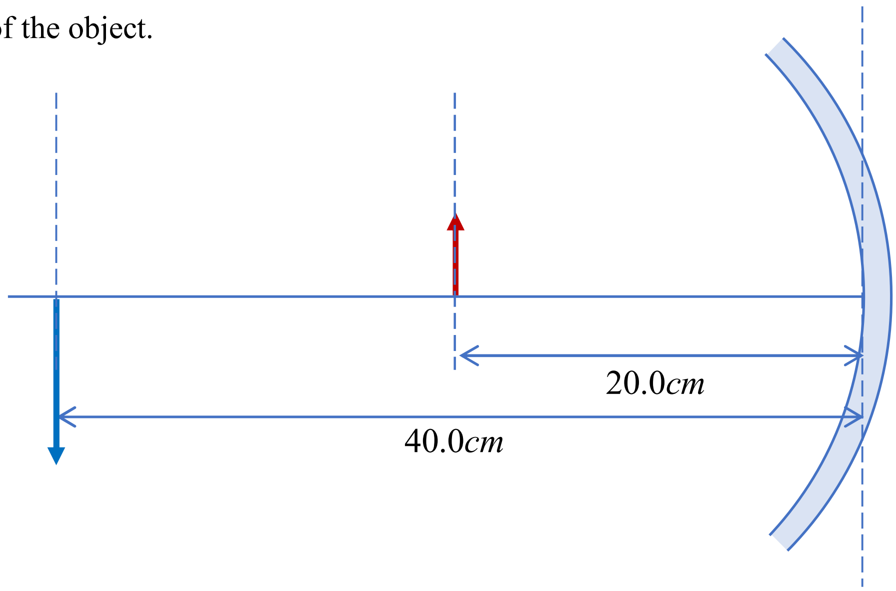
Chapter 34: Geometric Optics

Group Members:

1. An object (red arrow) is placed $20.0cm$ to the left of a concave mirror. The image (blue arrow) produced is also to the left of the mirror and it is inverted and is two times the size of the object.



a. What is the image position?

We are given the object distance $s = 20.0cm$ and the lateral magnification (inverted and double) is $m = -2$. Solving the following equation for s'

$$m = -\frac{s'}{s} = -2$$

We have the image distance as $s' = 2s = 40.0cm$.

b. Is the image real or virtual?

With s' being positive, the image is real.

c. What is the focal length and radius of curvature of the concave mirror?

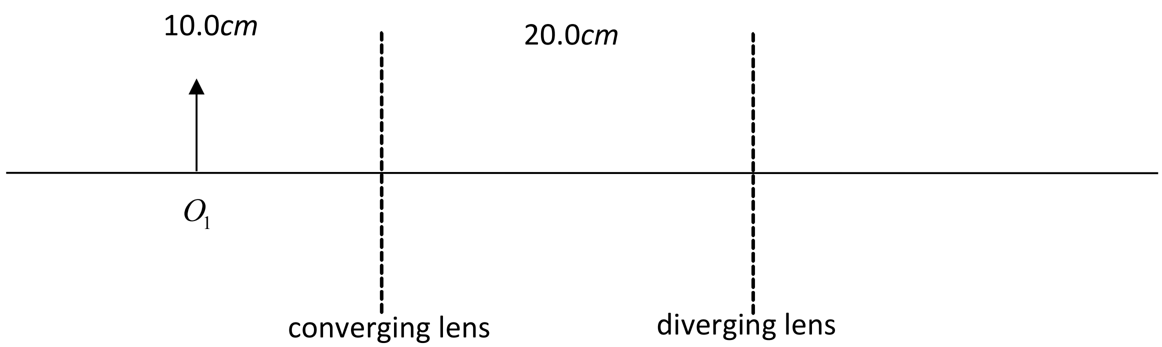
Now, we can use the mirror equation to find the focal length.

$$\frac{1}{f}=\frac{1}{s}+\frac{1}{s'}$$
$$\frac{1}{f}=\frac{1}{20.0cm}+\frac{1}{40.0cm}=\frac{2+1}{40.0cm}$$
$$f=13.3cm$$

For a spherical mirror, $f=\frac{R}{2}$.

Thus, the radius of the concave mirror is $R=2f=26.7cm$.

2. A thin converging lens with focal length $20.0cm$ and a thin diverging lens with focal length $10.0cm$ are separated by $20.0cm$. An object O_1 is placed at a distance of $10.0cm$ to the left of the converging lens.



a) Find the position of the image I_1 produces by the converging lens.

For a first lens, we have $\frac{1}{s_1^{'}} = \frac{1}{f_1} - \frac{1}{s_1}$

By our sign convention, $f_1 = 20.0cm$ is positive since the first lens is converging. Using the equation above, we have

$$\frac{1}{s_1^{'}} = \frac{1}{20} - \frac{1}{10} = -\frac{1}{20} \quad \rightarrow \quad s_1^{'} = -20cm.$$

b) Is the image I_1 real or virtual with respect to the converging lens? Will I_1 be on the incoming (left) or outgoing (right) side of light wrt the converging lens?

$s_1^{'}$ is negative so the image producing by the converging lens is virtual and I_1 being virtual needs to be on the incoming side of light. In this case, it will be located to the left of the converging lens.

c) Now consider this intermediate image I_1 as the object O_2 for the diverging lens. With respect to the diverging lens, Is the location of O_2 be on the incoming side (real) or outgoing side (virtual) of the diverging lens?

O_2 is to the left (incoming side of light) of the diverging lens so by convention, O_2 is real and s_2 will be positive.

d) Now, calculate the object distance s_2 of O_2 wrt the diverging lens?

Since O_2 is $20.0cm$ to the left of the first converging lens the converging lens is another $20.0cm$ to the left of the diverging lens, s_2 is positive and has the value of,

$$s_2 = 20.0cm + 20.0cm = 40.0cm$$

e) Now, with s_2 know, find the position of the final image produced the diverging lens.

For a diverging lens, $f_2 = -10.0cm$ by convention is negative and applying the lens' equation, we can solve for the final image distance s_2' produced by the diverging lens,

$$\frac{1}{s_2'} = \frac{1}{f_2} - \frac{1}{s_2} = \frac{1}{-10} - \frac{1}{40} = -\frac{5}{40} \quad \rightarrow \quad s_2' = -8.00cm.$$

The final image is **virtual** as indicated by the negative sign and is located 8cm (to the left) of the diverging lens.

f) What is the total lateral magnification of the final image? $[m_{tot} = m_1 m_2]$

$$M = m_1 m_2 = \left(-\frac{-20cm}{10cm}\right)\left(-\frac{-8cm}{40cm}\right) = +\frac{2}{5} = +0.4$$

Finally, here is the ray tracing diagram for the situation,