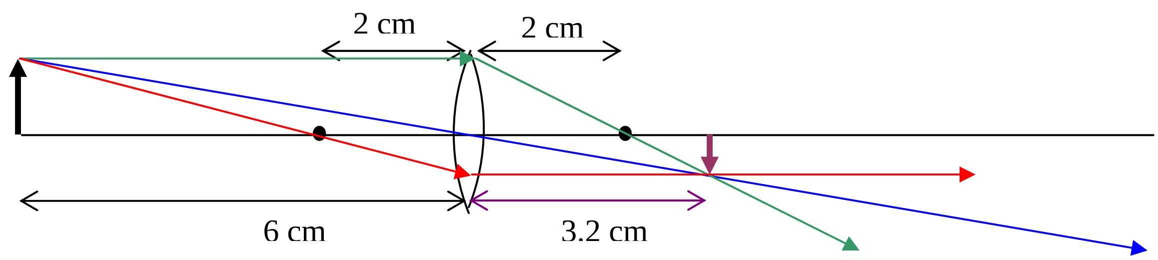
1. An object 1 cm tall stands 6 cm in front of a lens with a focal length of +2 cm.

- **a) Draw a ray diagram showing the image formed by this lens. The two foci of the lens have been drawn in. From your ray diagram, estimate the magnification (including sign) and the approximate distance of the image from the lens**
- b) **Now calculate these quantities. How well did you do?**



Three rays are always pretty easy to draw, for a converging lens like this one: A ray passing through the focus, parallel to the optic axis, or passing through the vertex. The one passing through the vertex goes straight through (blue lines). The one coming in parallel to the optic axis will be refracted to pass through the far focus (green lines), and the one passing through the near focus will exit parallel to the optic axis (red lines). As you can see, they meet very well at a single point to make an inverted image.

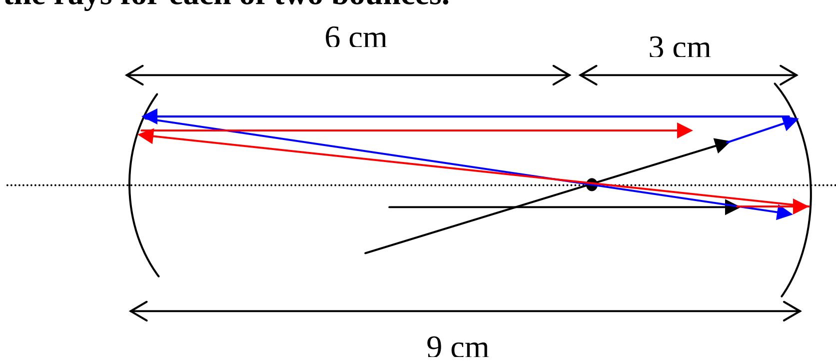
The image is at a distance of about 3.2 cm, by direct measurement. The image is about 0.53 cm tall. Since the object is almost exactly 1 cm tall, the magnification is 0.53/1 = 0.53, except since it's inverted, it is – 0.53

The exact distance to the image can be calculated using

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f}, \quad \text{so} \quad \frac{1}{q}=\frac{1}{f}-\frac{1}{p}=\frac{1}{2\text{ cm}}-\frac{1}{6\text{ cm}}=\frac{1}{3\text{ cm}}$$

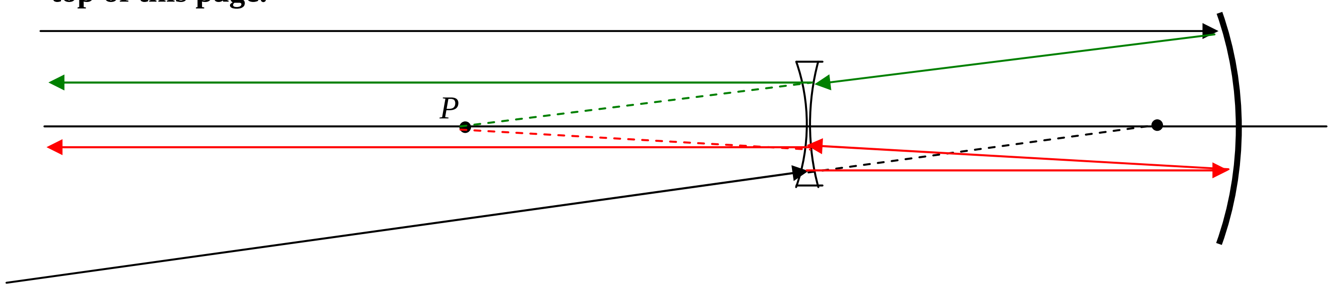
So the object distance is q = 3 cm, or about 7% less than we estimated. The magnification can be found from $M = -q/p = -3/6 = -0.50$, or about 6% less than we estimated. These errors are probably related, but they are pretty close, so nothing to be concerned about.

2. A pair of mirrors have focal lengths of 3 cm and 6 cm respectively. The mirrors are exactly 9 cm apart, so they have a common focal point as drawn. The optic axis is drawn in as a dashed line. Twobv different incoming light rays are drawn. For each of these incoming rays, show how the light is reflected after it bounces off of each mirror. In other words, show as accurately as possible the direction of the rays for each of two bounces.



To do this problem, simply remember that a light ray through the focus of a mirror is reflected parallel to the optic axis, and a light ray parallel to the optic axis is reflected parallel. Hence the upper ray is reflected first parallel, and then back through the focus (blue line), while the lower one is reflected first through the focus and then back parallel (red line).

3. A diverging lens and a curved mirror are arranged such that the focal point of the mirror (*P*) coincides with one of the focal points of the diverging lens. One incoming ray is parallel to the optic axis. It misses the lens, bounces off of the mirror, and then passes through the lens. Show how its direction changes at each step. The other one is headed straight for the far focus of the diverging lens. It passes through the lens, bounces off of the mirror, and then passes back through the lens. Show how its direction changes at each step. You may write your answer directly on the test, but if so, make sure you write your name at the top of this page.



This is a straightforward ray tracing problem. The trick is to remember how ray tracing works with a diverging lens. The rule is that any ray headed for the <u>far</u> focus of the lens comes out parallel, and any ray going in parallel looks like it comes out of the other focus. For curved convex mirrors, any ray that goes in parallel comes out headed towards the focus, and any ray passing through the focus comes out parallel.

Let's start with the upper ray. It misses the lens, and then hits the mirror, traveling parallel to the optic axis. It therefore will reflect headed straight for the focal point *P* of the mirror. However, it encounters the lens. Since it is heading for the point *P*, which is also the far focal point of the lens, it will come out of the lens parallel. So it follows the upper path sketched above.

The lower ray is headed for the right focus of the lens. It therefore comes out of the lens parallel to the optic axis. So it goes straight towards the mirror. Since it is now traveling parallel to the optic axis, it reflects headed straight towards the focal point *P*. When it encounters the lens, since it is going towards the point *P*, which is a focal point of this lens, it comes out parallel. So this ray follows the lower path sketched above.