2.1: Introduction to Lens and Mirror Calculations

The equation that relates object distance p, image distance q and focal length f is

$$\frac{1}{p}+\frac{1}{q}=\frac{1}{f}. \tag{2.1.1}$$

Or is it? Should that not be a minus sign on the left hand side? Or should it be a plus sign for mirrors and minus for lenses? ("**M**ore for a **M**irror; **L**ess for a **L**ens."?)

As all who have ever tried lens and mirror calculations know, the biggest difficulty we have to face is that of the dreaded *sign conventions*. It seems that no two professors or teachers or books use the same convention. No sooner have we mastered one than we encounter a professor who insists upon another. Each professor thinks that his is far superior to anyone else's, or is even seemingly unaware that there could be any convention other than his own. We rapidly become discouraged. Indeed, when we try to use Equation 2.1.1 there is just one chance in eight that we choose the correct sign for all three symbols. In fact the situation is even worse than that. You might choose the signs correctly for all the symbols and get the right answer, −15 cm, according to your own convention, yet your professor, who uses a different convention, marks it wrong. You might be perfectly clear in your own mind that, since the image is a virtual image, the answer must be minus fifteen. But your professor may interpret the minus sign as meaning that the image is to the left of the lens, or on the opposite side of the lens from the object, or is inverted, and he consequently marks it wrong.

Truly, of course, an answer "−15 cm" means nothing unless we are all certain as to exactly what it meant by the minus sign. I therefore suggest that you do not leave the "answer" is this ambiguous form. If you are asked where the image is and what is its magnification, be very explicit and make it clear, in words (not just by plus or minus signs) whether the image

1. is on the same side of the lens as the object is, or on the opposite side;
2. is real or virtual;
3. is erect or inverted;
4. is magnified or diminished.

In this chapter I shall, needless to say, introduce my own sign convention, and needless to say my own convention is vastly superior to anyone else's and quite different from any that you may already be used to or that your own teacher uses, or that you have ever seen in any book. Worse, I am not going to make use of Equation 2.1.1 at all. Instead, I am going to use a technique referred to as the *convergence method*. At first, you are not going to like it at all, and you may give up impatiently after just a few minutes. I hope, however, that you will persist. Let us look, for example, at the following problem:

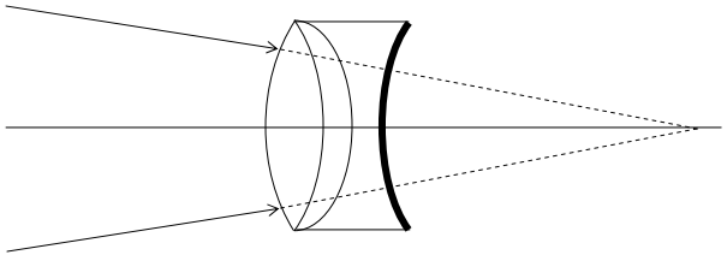

FIGURE II.1

The three lenses all have different refractive indices, all radii of curvature are different, the whole thing is immersed in water, the last surface is a mirror, and the object is a virtual object. Perhaps you are asked to find the image. Or you may be told where the image is and asked to find one of the radii of curvature, or one of the refractive indices. At present, this looks like a hopelessly difficult problem to be avoided before all others in an examination. There is scarcely any chance of getting the right answer.

However, I now assert that, if you take a few minutes to understand the convergence method, you will be limited in your ability to solve problems like these, correctly, *solely by the speed at which you can write*. As soon as you see the problem you will immediately and confidently know how to do it. You just have to make sure that you know where to find the $1/x$ button on your calculator.