

Multiple Optics Algorithm for Physics 8B

1. Draw a picture!
2. Set up an origin on the optics axis, call this “ $x = 0$ ”. The x -positions of things will all be in reference to this origin point, whereas all object and image distances d_o and d_i will be relative to the optical instrument in question.
3. Set up the grid:

Instrument Number	Instrument Position	Instrument Focal Length	Object Position	Object Distance	Image Distance	Image Position	Magnification
n	x_n	f_n	$x_{o,n}$	$d_{o,n}$	$d_{i,n}$	$x_{i,n}$	M_n
1							
2							
etc.							

4. Fill in instrument properties (labels of the instruments, their x -positions, and their focal lengths).
5. Now, just fill out the objects and images one-by-one!
 - Object Position: The n^{th} object’s x -position. For instrument 1, this is the original object’s position. For all later instruments, the n^{th} object position is the $(n-1)^{\text{th}}$ image position, $x_{o,n} = x_{i,n-1}$.
 - Object Distance: The distance from the object to the instrument (remember the sign conventions!), $d_{o,n} = x_n - x_{o,n}$.
 - Image Distance: Use the normal lens/mirror formula, $\frac{1}{f_n} = \frac{1}{d_{o,n}} + \frac{1}{d_{i,n}}$.
 - Image Position: The n^{th} image’s x -position. The sign conventions are important here and the picture will tell you whether you want your answer to be positive or negative! For a lens, $x_{i,n} = x_n + d_{i,n}$. For a mirror, $x_{i,n} = x_n - d_{i,n}$.
 - Magnification: The magnification factor for the n^{th} instrument, $M_n = -\frac{d_{i,n}}{d_{o,n}}$.

6. Total magnification is found by multiplying together all of the instrument magnifications, $M = M_1 M_2 \dots$.

Tada!

Here is an example, taken from Problem 1 of Physics 8B Worksheet 14:

A 12 cm tall candle is at $x = 0$ cm. There is a lens, $f_1 = +10$ cm, at $x = 30$ cm. There is another lens, $f_2 = +6$ cm, located at $x = 60$ cm.

The grid for this problem, filled with the information given, is:

Instrument Number	Instrument Position	Instrument Focal Length	Object Position	Object Distance	Image Distance	Image Position	Magnification
n	x_n	f_n	$x_{o,n}$	$d_{o,n}$	$d_{i,n}$	$x_{i,n}$	M_n
1	30	+10	0			*	
2	60	+6	*				

(the stars are a reminder that the first image position is the second object position!)

Filling in the rest of the grid gives,

Instrument Number	Instrument Position	Instrument Focal Length	Object Position	Object Distance	Image Distance	Image Position	Magnification
n	x_n	f_n	$x_{o,n}$	$d_{o,n}$	$d_{i,n}$	$x_{i,n}$	M_n
1	30	+10	0	+30	+15	45	-1/2
2	60	+6	45	+15	+10	70	-2/3
							+1/3

The final image will be at $x = 70$ cm, and the total magnification is +1/3, so the image is erect with a height of 4 cm.

Here is a ray diagram, showing an array of rays from start to finish:

