The Lens / Mirror Chart

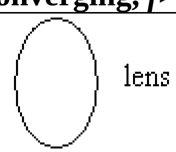
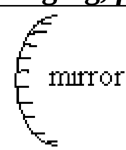
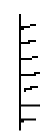
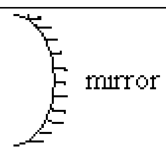
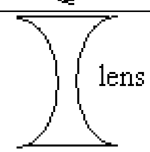
i=f m =0	inverted, m<0 real, i>0 shrunk, $\dot{m}$ <1	inverted, m<0 real, i>0 same size, $\dot{m}$ =1	inverted, m<0 real, i>0 magnified, $\dot{m}$ >1	$i=\infty$ $m=\infty$	upright, m>0 virtual, i<0 magnified, $\dot{m}$ >1	upright, m>0 virtual, i<0 same size, $\dot{m}$ =1	upright, m>0 virtual, i<0 shrunk, $\dot{m}$ <1	i=f m =0
∞		2f		f		location of lens or mirror		∞
		converging lens or mirror , f>0					diverging lens or mirror, f<0	

This chart describes the possible properties of the *image*, not of the object;
but the horizontal positions in the chart represent the possible locations of the *object*, not of the image.

sign conventions

	positive	**negative**
object distance ***o* or *s***	object on same side as incoming light (always the case for a single lens or mirror)	object on opposite side to incoming light (possible with multiple lenses or mirrors only)
focal point distance ***f***	converging lens or mirror (convex lens or concave mirror)	diverging lens or mirror (concave lens or convex mirror)
image distance ***i* or *s*'**	real image (image on same side as outgoing light)	virtual image (image on opposite side to outgoing light)
magnification, *m*	upright (image has same orientation to axis as object) $\dot{m}$ <1 means "shrunk" (image is smaller than object) $\dot{m}$ >1 means "magnified" (image is bigger than object)	inverted (image has opposite orientation to axis as object)
height **h_o and h_i**	pointing up from principal axis	pointing down from principal axis

converging vs. diverging, convex vs. concave

	converging, *f*>0	**diverging, *f*<0**	**f=∞**
convex			 plane mirror i=-o, so the image will be virtual, upright, and the same size as the object.
concave			

ray tracing

incoming	**outgoing**
parallel to axis (P)	converging: *through* focal point on same side as outgoing light diverging: *in line with* focal point on opposite side as outgoing light plane mirror: parallel to axis, since focal point is at ∞
to middle of lens or mirror (M)	out from middle of lens along same line as incoming ray reflected from middle of mirror at same angle as incoming ray
converging: *through* focal point on same side as incoming light (F) diverging: *in line with* focal point on opposite side to incoming light	parallel to axis

The image is located where the outgoing light rays converge (real image), or where their "tracebacks" converge (virtual image).
Only two rays are necessary to locate the image; usually P and M rays are most convenient.

equations

$$\frac{1}{f} = \frac{1}{o} + \frac{1}{i}$$ the lens/mirror equation

$$m = -\frac{i}{o} = \frac{h_i}{h_o}$$ the magnification equation

$\dot{i} < \dot{o}$ means image is shrunk (i.e., image is smaller than object)
$\dot{i} = \dot{o}$ means image is same size as object
$\dot{i} > \dot{o}$ means image is magnified (i.e., image is larger than object)

$\dot{R} = 2\dot{f}$ for mirrors only

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$ for lenses only ("lens-maker's equation")

A surface that is convex toward the object has positive *R*; a surface concave toward the object has negative *R*.
Some textbooks use a different form of the lens-maker's equation, with different sign conventions for the *R*'s.

lens power = $\frac{1}{f}$, unit = diopter = $\frac{1}{\mathrm{m}}$

special situations for lenses and mirrors

object location	infinity	focal point
incoming rays	all parallel to each other and to principal axis	all pass through focal point
outgoing rays	all pass through focal point	all parallel to each other and to principal axis
image location	focal point	infinity (i.e., no image)
magnification	m=0 (i.e., image is shrunk to a point)	$m = \infty$ (i.e., no image)