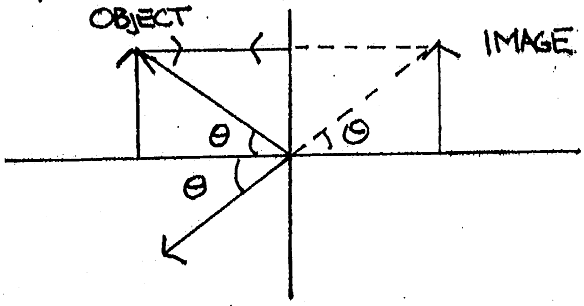
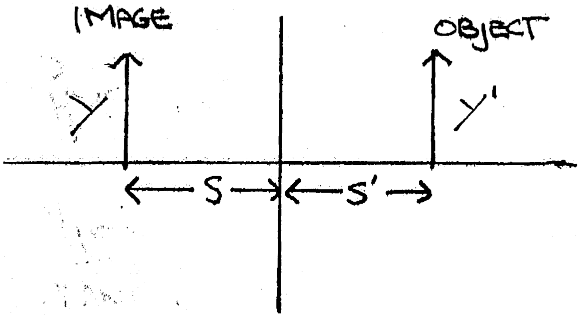
PHYS 262 – GEOMETRICAL OPTICS, CHAPTER 34

MIRRORS – CREATE IMAGES BECAUSE OF LAW REFLECTION.

PLANE MIRROR – FLAT MIRROR



WE SEE AN IMAGE IN THE MIRROR BECAUSE OUR BRAIN FOLLOWS THE REFLECTED LIGHT BACK ON A STRAIGHT LINE.



S = OBJECT DISTANCE. y = OBJECT HEIGHT

S' = IMAGE DISTANCE. y' = IMAGE HEIGHT

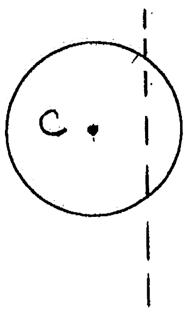
FROM SIMPLE GEOMETRY, $\boxed{S' = S}$

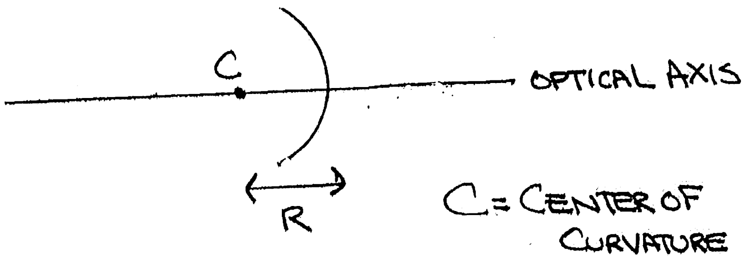
WHICH IN TURN TELLS US $\boxed{y' = y}$.

MAGNIFICATION: $\boxed{m = y'/y}$ FOR A PLANE MIRROR, $m = 1$

PLANE MIRRORS FLIP LEFT AND RIGHT THOUGH YOU HAVE TO BE CAREFUL. LEFT AND RIGHT ARE NOT GOOD PHYSICS DIRECTIONS. WE SWITCH THESE DIRECTIONS IN OUR BRAINS. AN OBJECT POINTING WEST HAS ITS IMAGE POINTING WEST.

SPHERICAL MIRRORS – A MIRROR WHOSE SHAPE IS PART OF A SPHERE.

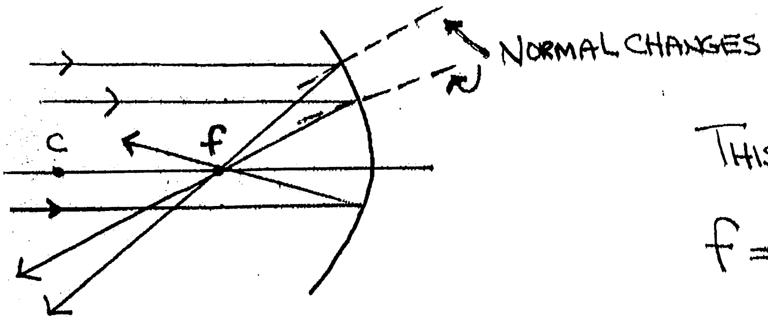




C = CENTER OF CURVATURE

R = RADIUS OF CURVATURE

LAW OF REFLECTION GIVES PATH OF LIGHT. FOR RAYS PARALLEL TO OPTICAL AXIS:

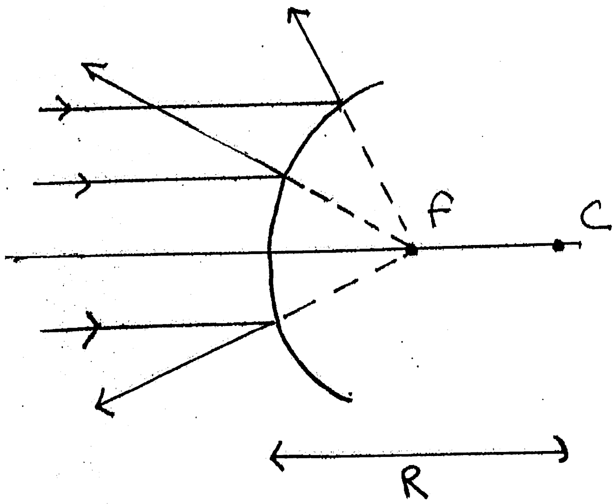


THIS IS CALLED A CONVERGING MIRROR.

f = FOCAL LENGTH

USING GEOMETRY AND LAW OF REFLECTION, IT IS NOT TOO HARD TO SHOW THAT

$$f = \frac{1}{2}R$$



DIVERGING MIRROR

WE CALL ANY DISTANCE TO THE RIGHT OF THE MIRROR NEGATIVE ⇒

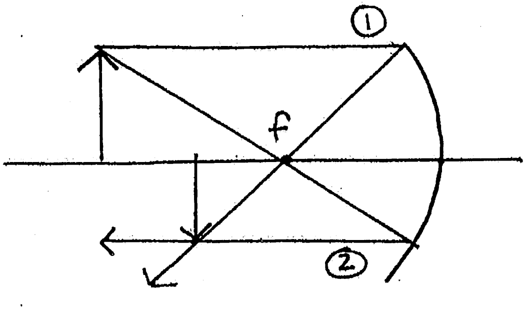
$$f = -\frac{1}{2}R$$

RAY TRACING: WE CAN DETERMINE THE ORIENTATION, AND SIZE, AND LOCATION OF AN IMAGE BY USING CAREFULLY SELECTED RAYS.

PRINCIPLE RAYS:

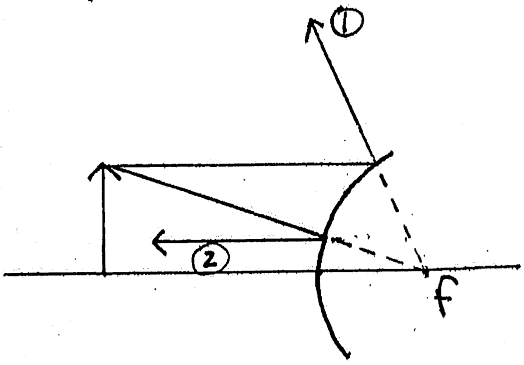
1) A RAY PARALLEL TO THE OPTICAL AXIS IS REFLECTED THROUGH/AWAY FROM THE FOCAL POINT.
2) A RAY PASSING THROUGH/TOWARDS THE FOCAL POINT REFLECTS PARALLEL TO THE OPTICAL AXIS.
3) A RAY PASSING THROUGH/TOWARDS THE CENTER OF CURVATURE REFLECTS ALONG THE RAY IT CAME IN ON.

YOUR BOOK GIVES A FOURTH PRINCIPLE RAY, BUT ONLY ① AND ② ARE USUALLY NEEDED.

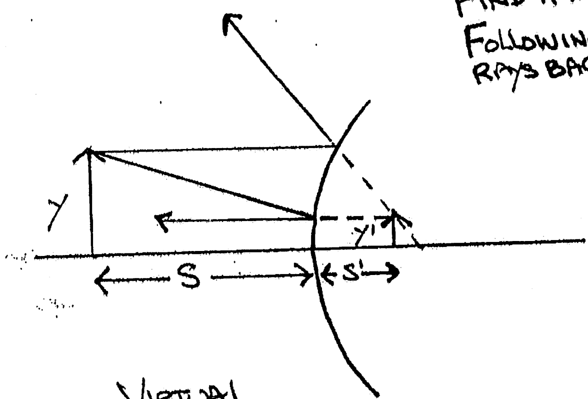


REAL IMAGE

THE IMAGE IS THE POINT WHERE THE RAYS INTERSECT. PHYSICALLY, A PIECE OF PAPER PLACED AT THE IMAGE LOCATION WOULD PRODUCE AN IN-FOCUS, UPSIDE DOWN, ALTERED HEIGHT COPY OF THE OBJECT.



FIND IMAGE BY FOLLOWING REFLECTED RAYS BACK.



VIRTUAL IMAGE

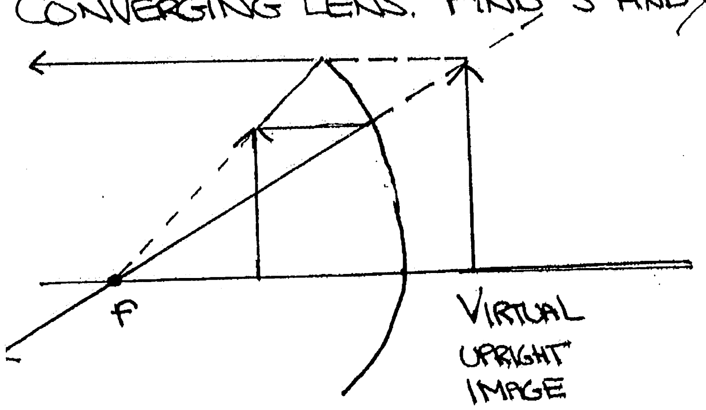
MIRROR EQUATION – USING GEOMETRY, WE CAN SHOW:

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

AND

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

EXAMPLE. A 1cm TALL OBJECT IS PLACED 1cm IN FRONT OF A f = 2cm CONVERGING LENS. FIND s' AND y'.



VIRTUAL UPRIGHT IMAGE

IMAGE ON OTHER SIDE.

$s = 1\text{cm},\ f = 2\text{cm},\ s' = ?$

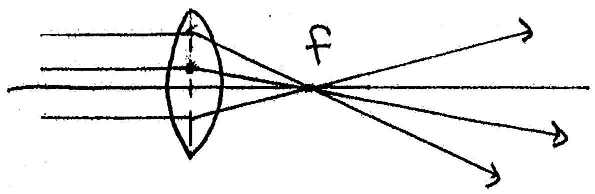
$$\frac{1}{1\text{cm}} + \frac{1}{s'} = \frac{1}{2\text{cm}} \Rightarrow \frac{1}{s'} = \frac{1}{2\text{cm}} - \frac{1}{1\text{cm}} = \frac{-1}{2\text{cm}}$$

$$\Rightarrow s' = -2\text{cm}. \qquad m = \frac{-s'}{s} = -\left(\frac{-2\text{cm}}{1\text{cm}}\right) = 2$$

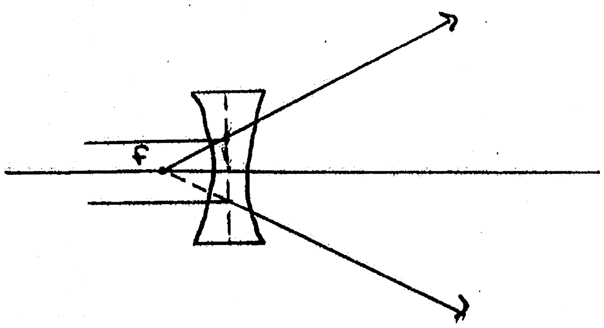
THIN LENSES

LENS - OBJECT WHICH USES REFRACTION TO FOCUS OR DIVERGE LIGHT.

DOUBLE CONVEX - CONVERGING LENS



DOUBLE CONCAVE - DIVERGING LENS



THESE LENSES MUST BE THIN OTHERWISE DISPERSION AND OTHER EFFECTS RUIN FOCUSING.

THIN LENS EQUATION -

AGAIN, SKIPPING THE GEOMETRY, IT IS "EASY" TO SHOW FOR A THIN LENS

$$\boxed{\frac{1}{s}+\frac{1}{s'}=\frac{1}{f}} \qquad \boxed{m=\frac{-s'}{s}}$$

IF WE USE: $f>0$ CONVERGING LENS
$f<0$ DIVERGING LENS
$s'>0$ IMAGES TO THE RIGHT OF LENS (OPPOSITE SIDE OF OBJECT).

$s'>0$ IS CALLED A REAL IMAGE.
$s'<0$ IS CALLED A VIRTUAL IMAGE.

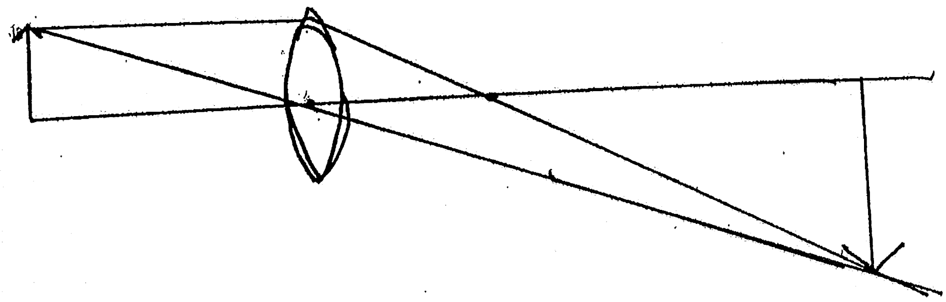
LENS RAY TRACING

① RAYS WHICH ARE PARALLEL REFRACT THROUGH/AWAY FROM THE FOCAL POINT.

② RAYS WHICH PASS THROUGH THE MIDDLE ARE UNBENT

③ RAYS PASSING THROUGH/TOWARDS FOCAL POINT REFRACT PARALLEL.

EXAMPLE: A 1cm TALL OBJECT IS PLACED 3cm IN FRONT OF A CONVERGING LENS WITH $f = 2cm$. WHAT IS IMAGE LOCATION AND MAGNIFICATION?



REAL INVERTED IMAGE

$S = 3cm,\ f = 2cm,\ S' = ?$

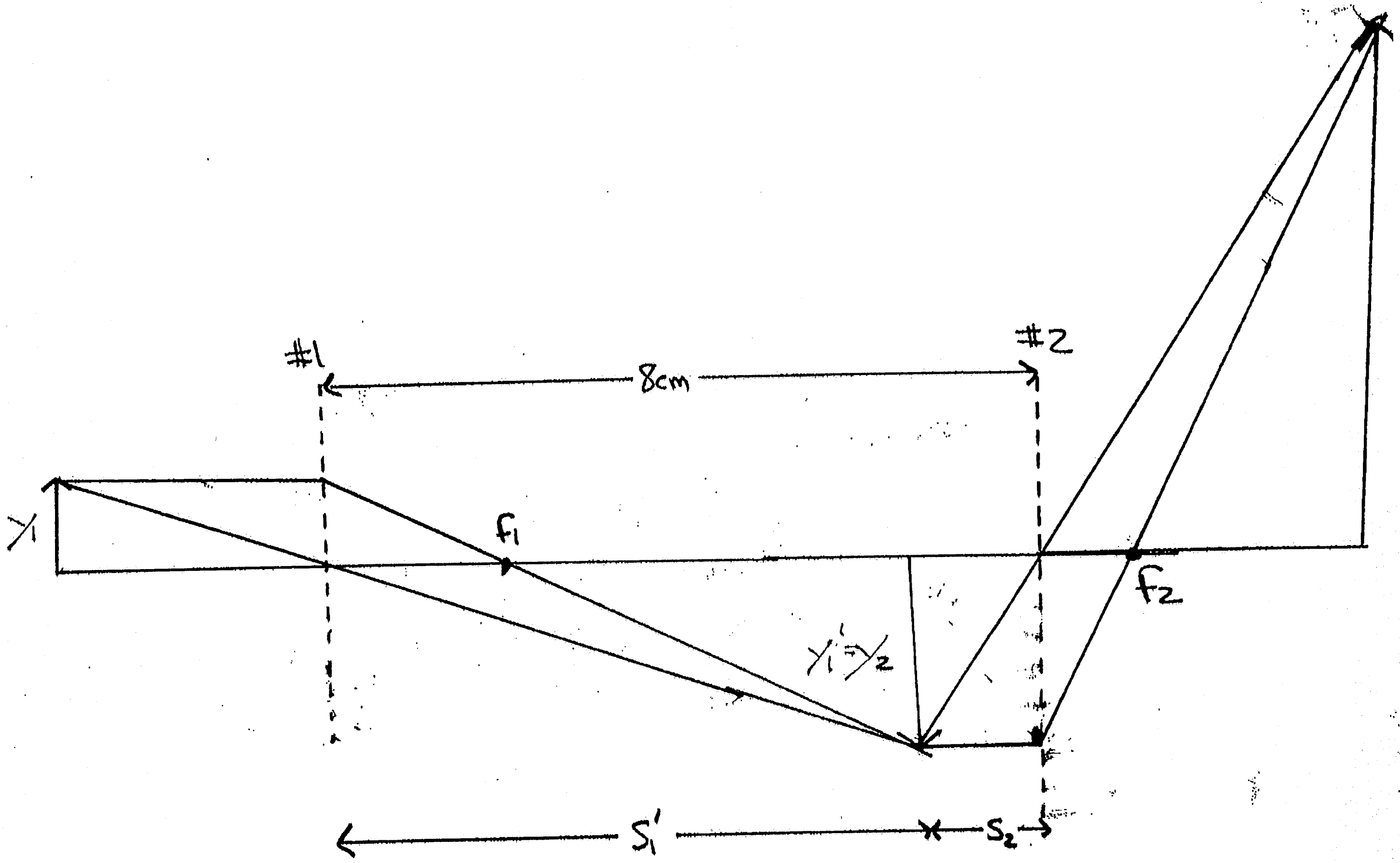
$$\frac{1}{S} + \frac{1}{S'} = \frac{1}{f} \Rightarrow \frac{1}{3cm} + \frac{1}{S'} = \frac{1}{2cm} \Rightarrow \frac{1}{S'} = \frac{1}{2cm} - \frac{1}{3cm} = \frac{3}{6cm} - \frac{2}{6cm} = \frac{1}{6cm} \Rightarrow S' = 6cm$$

$$m = \frac{-S'}{S} = \frac{-6cm}{3cm} = -2cm \quad (m < 0 \Rightarrow \text{INVERTED})$$

MULTIPLE LENSES – BECAUSE LENSES PASS LIGHT THROUGH THEM IT IS POSSIBLE TO PLACE ONE AFTER THE OTHER. THIS ALLOWS THE IMAGE OF A LENS TO BECOME THE OBJECT FOR THE SUBSEQUENT LENS.

EXAMPLE: A 1cm TALL OBJECT IS PLACED 3cm IN FRONT OF AN $f = 2cm$ CONVERGING LENS. A SECOND $f_2 = 1cm$ CONVERGING LENS IS PLACED 8cm FROM THE FIRST LENS. WHAT IS THE FINAL IMAGE LOCATED AND WHAT IS THE OVERALL MAGNIFICATION?

TO MAKE RAY TRACING EASIER I USUALLY REPLACE LENSES WITH VERTICAL DASHED LINES LOCATED AT LENS'S CENTER



$S_1 = 3cm,\ f_1 = 2cm,\ S_1' = ?\quad \frac{1}{S_1} + \frac{1}{S_1'} = \frac{1}{f_1} \Rightarrow S_1' = 6cm$

S_1' = DISTANCE FROM LENS #1 TO ITS IMAGE

S_2 = DISTANCE FROM LENS #2 TO ITS OBJECT (WHICH IS #1'S IMAGE)

$\Rightarrow S_2 = 8cm - 6cm = 2cm,\quad f_2 = 1cm,\ S_2' = ?\quad \frac{1}{S_2} + \frac{1}{S_2'} = \frac{1}{f_2}$

$\frac{1}{2cm} + \frac{1}{S_2'} = \frac{1}{1cm} \Rightarrow \frac{1}{S_2'} = \frac{1}{1cm} - \frac{1}{2cm} = \frac{1}{2cm} \Rightarrow S_2' = 2cm$

$m_1 = \frac{y_1'}{y_1},\ m_2 = \frac{y_2'}{y_2}\qquad y_2 = y_1' \Rightarrow m_1 m_2 = \frac{y_1' y_2'}{y_1 y_2} = \frac{y_2'}{y_1} = m$ (OVER MAG.)

$\Rightarrow \boxed{m = m_1 m_2}\qquad m_1 = \frac{-S_1'}{S_1} = \frac{-6cm}{3cm} = -2,\quad m_2 = \frac{-S_2'}{S_2} = \frac{-2cm}{2cm} = -1$

$\Rightarrow m = 2$ (SOMETHING WENT VERY WRONG w/ THE DIAGRAM!)