11 Mirrors and lenses

The purpose of this experiment is to learn about image formation and detection, and to study the physics of thin lenses and mirrors.

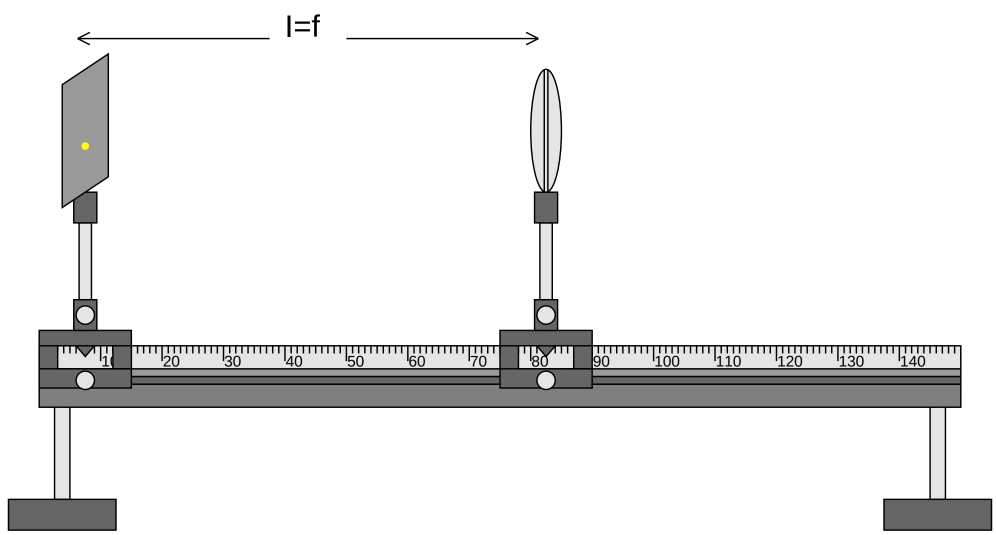
The apparatus consists of the optical bench, illuminated images, and a variety of lenses and mirrors.

11.1 Part 1. Finding f

To establish the focal length of a thin lens or mirror, place the illuminated object lamp on another lab table as far from your optical bench as possible. Place a converging lens in a lens holder on the bench, and a projection screen at the other end. "Aim" your bench at the object, with the lens between the distant lamp and your screen. Now move the lens around until a sharp, inverted (and probably very small) image of the illuminated object forms on the screen. If $O >> I$, f then

$$\frac{1}{O} + \frac{1}{I} = \frac{1}{f} \approx \frac{1}{I}, \quad I = f$$

and you can determine the focal length of your lens.
Do this with both a lens and a concave mirror. For the mirror you will need to swap with the screen position.

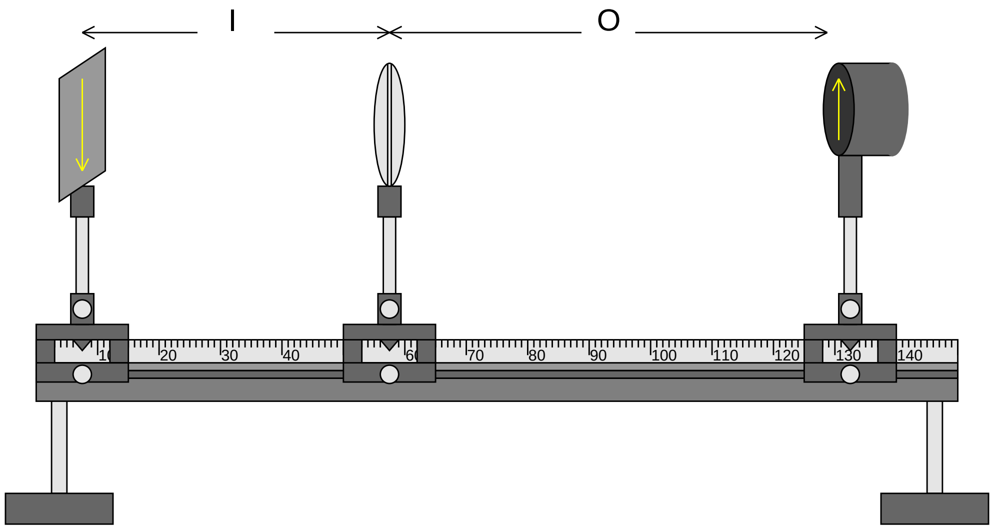


11.2 Part 2. Real images for lenses

Real images are actual convergences of light rays, and so they may be caught on the viewing screen.
place the illuminated object at one end of the bench, the screen at the other, and your converging lens in between. For three lens positions, compute

$$\frac{1}{O} + \frac{1}{I}$$

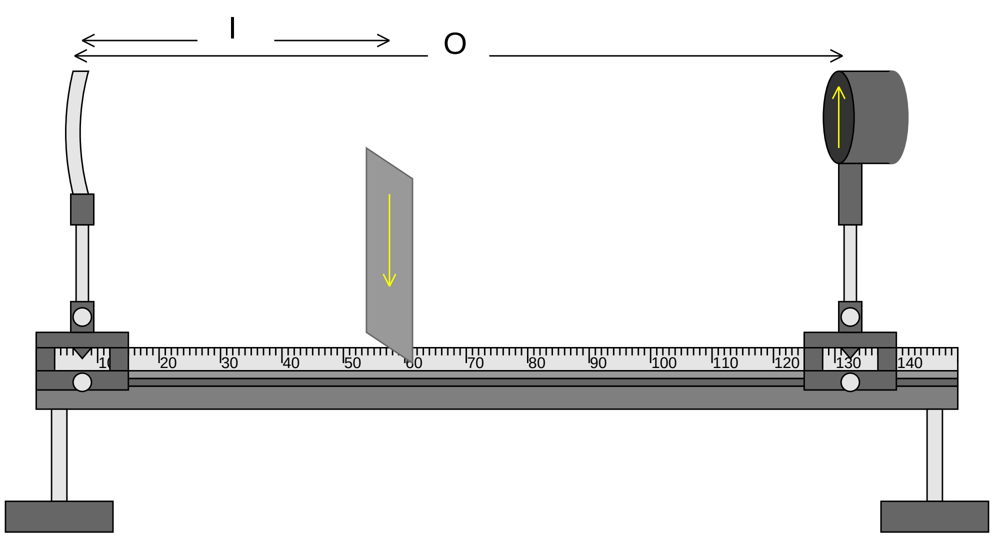
and compare it to $\frac{1}{f}$. You will have to move both the screen and lens to get three measurements.



The positions of the optical elements can be read off of the pointer/scales on the benches. For example in the figure above, the screen is at $x_{screen} = 7\,cm$, the lens is at $x_{lens} = 57\,cm$ and the object is at $x_{obj} = 132\,cm$, so that $O = x_{obj} - x_{lens} = 132 - 57 = 65\,cm$, and $I = x_{lens} - x_{screen} = 50\,cm$.

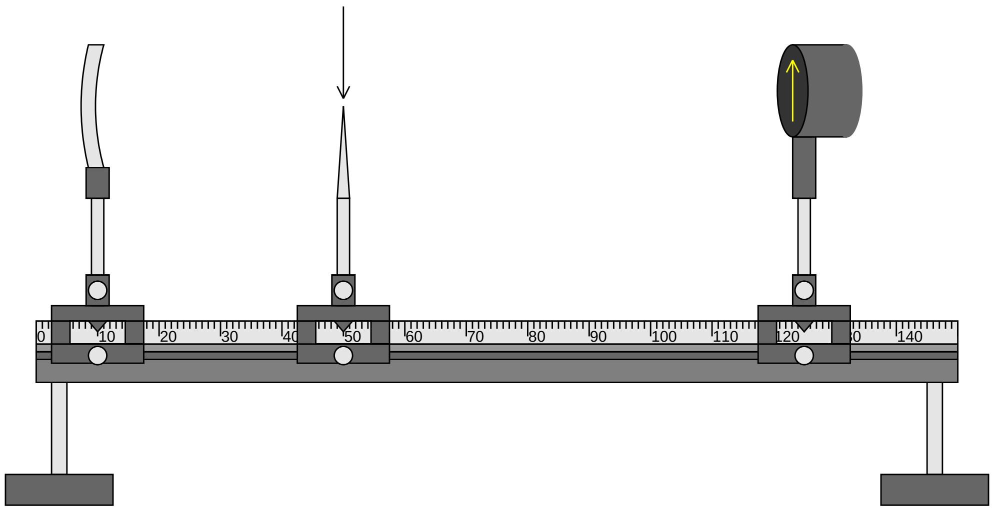
11.3 Part 3. Real images of mirrors

There are two ways to locate the real image formed by a concave mirror. The first is to aim the mirror a little up, or a little down, and use a card between the mirror and object upon which the image will be cast.



The second method, **parallax**, is somewhat better. We use a spike to locate the image. Stand just behind the illuminate object, and look into the mirror. Locate the image of the object in the mirror. Now place a spike on the bench and move it around until the parallax disappears. This will happen when the spike is at the **same** location as the image.

Parallax is the apparent motion of an object relative to the location of a more distant object. If you hold up your index fingers in front of your face, one a few centimeters away, the other at arm's length, and move your head from side to side (left to right), your near finger appears to move relative to the distant finger. Hold them up at the same distance from your eyes, and move your head from side to side; there is no apparent motion.



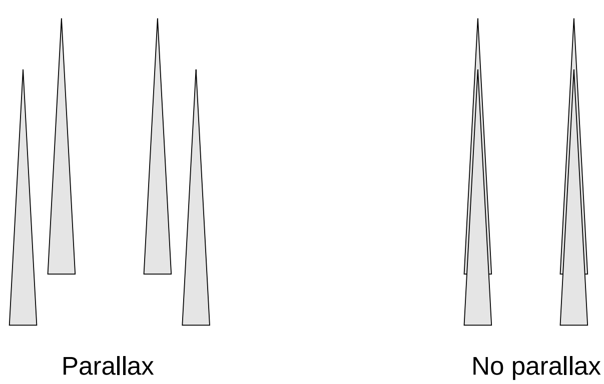
Use one method or the other to measure I and O for three mirror locations, and verify that

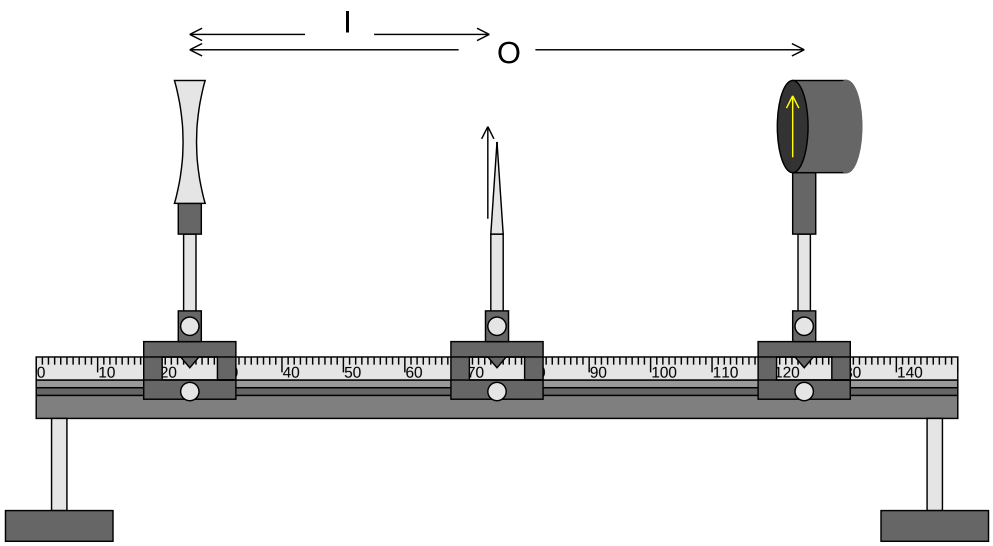
$$\frac{1}{O} + \frac{1}{I}$$

agrees well with $\frac{1}{f}$.

11.4 Part 4. Virtual images

Parallax is the only means of measuring a virtual image distance. Pick a diverging lens, and place the illuminated object on a distant table. Mount the lens on the bench, and put a spike on the bench between the lens and object. Look through the lens at the light source, and adjust the spike position until there is no parallax between it and the image of the source as seen through the lens. Compute the focal length of the lens.





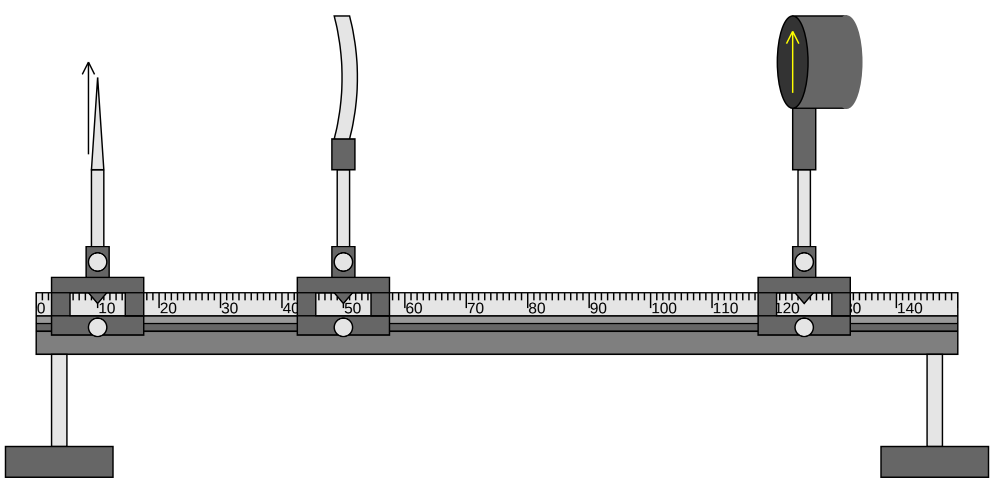
Now mount a source/object on the bench, and for three locations of the lens relative to the object, measure O and I and verify that

$$\frac{1}{O} + \frac{1}{I}$$

agrees well with $\frac{1}{f}$.

11.5 Part 5. Virtual images of a diverging mirror

Again you will find that the only way to locate a virtual image created by a convex mirror is by parallax. Set up a diverging mirror, lamp and spike as illustrated. You will need to stand behind the lamp/object, and look into the mirror to see the virtual image (formed behind the mirror). You will probably need to get the spike point up above the mirror so that it is not blocked.



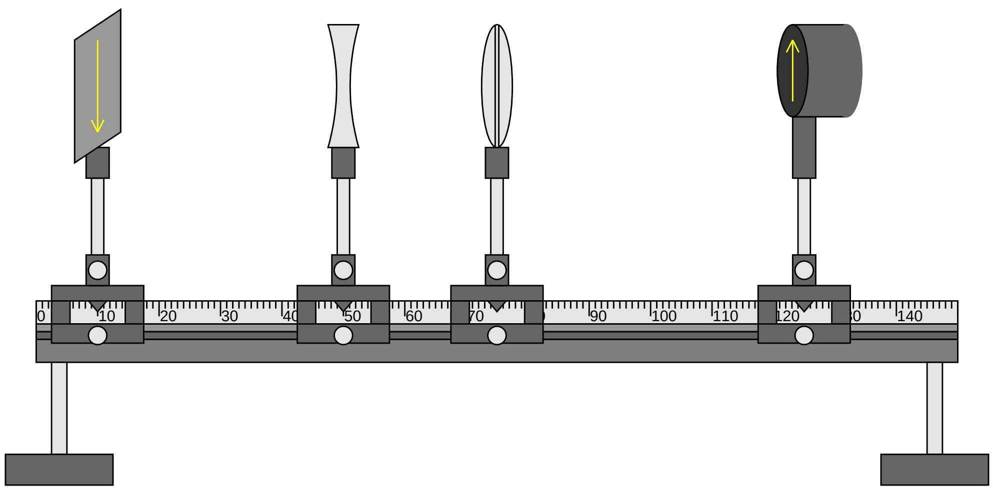
For three different mirror locations relative to the lamp/object, measure both I and O, and compute the focal length of the mirror. Compute an average as well.

11.6 Part 6. Focal length of a diverging lens

If your measurements of the focal length of your converging lens were precise, you can use it to re-measure the focal length of the diverging lens by using the pair to create a real image. Set the bench up as in the figure. Let d be the distance between the two lenses. Let O be the distance from the lamp/object to the converging lens, and I be the distance from the screen to the diverging lens. The intermediate image I_{con} formed by the converging lens becomes the virtual object for the diverging lens. Measure I, O and d, and use

$$\frac{1}{O} + \frac{1}{I_{con}} = \frac{1}{f_{con}}, \qquad \frac{1}{d - I_{con}} + \frac{1}{I} = \frac{1}{f_{div}}$$

to determine f_{div}. How well does it agree with your earlier measurements? Is the image erect or inverted?



11.7 Pre-lab questions

1. A lens produces an image whose magnification is $m = -0.5$ of an object placed $O = 100\,cm$ away. Determine the focal distance of the lens using

$$\frac{1}{O} + \frac{1}{I} = \frac{1}{f}, \qquad m = -\frac{I}{O}$$

Draw a ray diagram illustrating image formation.

2. A lens produces an image whose magnification is $m = 0.5$ of an object placed $O = 100\,cm$ away. Determine the focal distance of the lens and draw a ray diagram illustrating image formation.

3. You look at a spherical mirror and see an image of yourself that is $\%50$ life-size, and rightside up. Your face is $20.0\,cm$ from the mirror. Determine its radius of curvature, and draw a ray diagram to scale illustrating the image formation.

4. If you look into a highly polished steel bowl of spherical section, you see an image of yourself $33.3\,cm$ **behind** the bowl. If you flip the bowl over and look into it, you see an image of your face $50\,cm$ **behind** the bowl. Compute the magnitude of the bowl's radius of curvature, and the distance of your face from the center of the bowls surface (O).

11.8 Lab report

Mirrors and lenses

Experimenter 1 ____________________ **Experimenter 2** ____________________

Experimenter 3 ____________________ **Experimenter 4** ____________________

Part 1a. Finding f for a converging lens

I = ____________________ (m) **f =** ____________________ (m)

Draw your ray diagram below

Part 1b. Finding f for a concave mirror

I = ____________________ (m) **f =** ____________________ (m)

Draw your ray diagram below

Part 2. Real images for lenses

O = ______________ (m) **I** = ______________ (m) $\frac{OI}{O+I} = f =$ ______________ (m)

O = ______________ (m) **I** = ______________ (m) $\frac{OI}{O+I} = f =$ ______________ (m)

O = ______________ (m) **I** = ______________ (m) $\frac{OI}{O+I} = f =$ ______________ (m)

Draw a ray diagram below for one of your cases

Average $f = f_{conv}$ and standard deviation

Part 3. Real images for mirrors

O = ______________ (m) **I** = ______________ (m) $\frac{OI}{O+I} = f =$ ______________ (m)

O = ______________ (m) **I** = ______________ (m) $\frac{OI}{O+I} = f =$ ______________ (m)

O = ______________ (m) **I** = ______________ (m) $\frac{OI}{O+I} = f =$ ______________ (m)

Draw a ray diagram below for one of your cases

Part 4a. Finding f for a diverging lens by parallax

I = ______________________ (m) **f =** ______________________ (m)

Draw your ray diagram below

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Part 4b. Virtual images for lenses by parallax

O = ______________ (m) **I =** ______________ (m) $\frac{OI}{O+I} = f =$ ______________ (m)

O = ______________ (m) **I =** ______________ (m) $\frac{OI}{O+I} = f =$ ______________ (m)

O = ______________ (m) **I =** ______________ (m) $\frac{OI}{O+I} = f =$ ______________ (m)

Draw a ray diagram below for one of your cases

____

Average $f = f_{div}$ and standard deviation

Part 5. Virtual images for convex mirrors by parallax

O = ____________ (m) **I** = ____________ (m) $\frac{OI}{O+I} = f =$ ____________ (m)

O = ____________ (m) **I** = ____________ (m) $\frac{OI}{O+I} = f =$ ____________ (m)

O = ____________ (m) **I** = ____________ (m) $\frac{OI}{O+I} = f =$ ____________ (m)

Draw a ray diagram below for one of your cases

Part 6. Focal length of a diverging lens

Measured distances

$x_{screen} =$ ____________ (m) $x_{div} =$ ____________ (m)

$x_{conv} =$ ____________ (m) $x_{obj} =$ ____________ (m)

$O =$ ____________ (m) $I =$ ____________ (m)

$^*f_{con} =$ ____________ (m) $d =$ ____________ (m)

Calculated distances

$I_{con} =$ ____________ (m) $f_{div} =$ ____________ (m)

* Use your previously measured average value.

Compare this f_{div} with that from parts 4a and 4b