

## Exploring hand magnifiers – a single positive lens

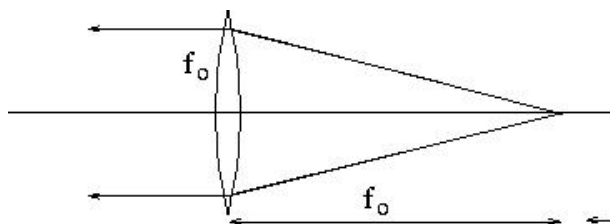


Figure 1 – A single positive lens – curved on both sides

- **Uses – a 20cm or 15cm positive lens from the Keplerian Telescope envelopes. Can use also use a 75cm lens from the Galileian Telescope envelopes, but with more difficulty because of the long focal length.**
- **What kind of big lenses are in your kit?**

If your kit is labeled “Keplerian telescope”, you have two positive lenses. In a positive lens, shown above, both sides of the lens stick-out from the middle. Continue to read on in the next section.

If your kit is labeled “Galileian telescope”, your lens might look a little different. You may have a half-positive – or “plano-convex” – lens. A half-positive lens curves out on one-side but is flat on the other.

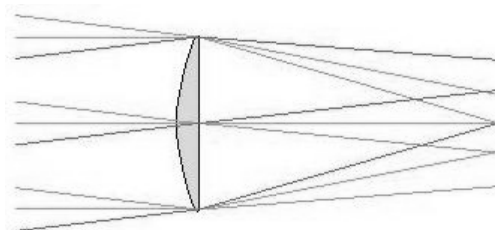


Figure 2 – A half positive or plano-convex lens – curved on the object side and flat on the eye side.

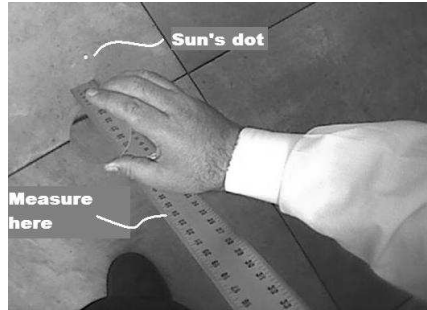
If your kit does have this kind of lens just remember to always point the curved side at the object and keep the flat side on the side toward your eye.

- **Find the focal length of the big lens – the objective lens**

Materials: Yardstick, ruler and big lens.

With the Sun overhead, hold the big lenses over some concrete or paper on table. (If it is overcast, ask your presenter to use a collimated light source.)

Move the lens so the image of the Sun focuses to a point or the smallest possible circle. (Be careful you do not set the paper on fire!)



**Figure 3 - Finding the focal length (75 cm lens) with a yardstick and the Sun – make the light circle as small as possible**

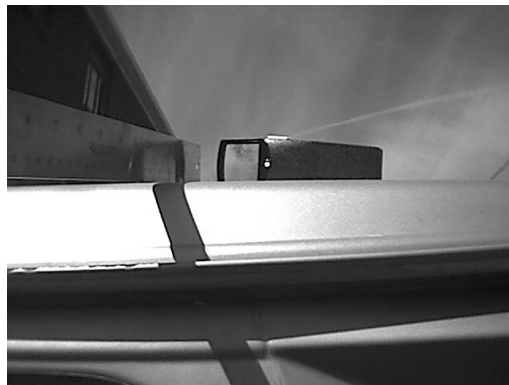
If the Sun is overcast by clouds, use a light bright light source -



**Figure 4 - Finding the focal length (20cm lens) with a ruler and light source – make the light circle as small as possible**

Use the ruler or yardstick to measure the distance from the middle of the lens to the flat surface. Just estimate – you do not have to be accurate.

A third method to find the focal length of a lens is to sight along a yardstick. Slowly move the lens away from your eye. As the lens approaches one focal length, the image will magnify to infinity and invert.



**Figure 5 - Finding the focal length (17cm lens) with a ruler and positioning the lens at the point where a distant image first inverts**

This third method is sensitive your vision. If you wear eyepieces, the power of your eyeglass lens will change the measurement. In the preceding figure, a tree across the street is seen in the lens upside down.

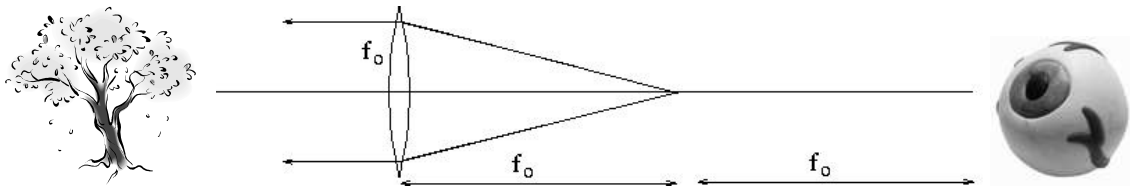
Again, just estimate the focal length distance. It is not important to be precise.

Big lens focal length is \_\_\_\_\_ inches or \_\_\_\_\_ centimeters.

The big lens is a positive lens – also called a “convex” lens. It is “positive” because it sticks “out” from the middle.

- **How to use the big lens or the small lens as a hand magnifier.**

A single positive lens, like your big lens, when used by itself is a hand-magnifier.



**Figure 6 - Hand magnification with a single positive lens**

We will explore two basic cases for single-lens hand-magnification:

- Case 1 magnification: The object is *far away* – more than 2 times the focal length of the lens.
- Case 2 magnification: The object is *very close* - between 0 and 2 times the focal length of the lens – but within 0 to 2 focal lengths of your eye.

- **Case 2 magnification: The object is *very close* - between 0 and 1 times the focal length of the lens.**

Take your positive lens and an object that interests you – something that you want to look at magnified. Common examples are a leaf, a blade of grass, a bug, the grain in the top of table, a concrete sidewalk, the back of your hand, or the pores on your friend’s nose.



**Figure 7 - A common object magnified**

Here, we'll use a newspaper puzzle as an example. With the lens held next to the newspaper there is no magnification.



**Figure 8 - Lens held 0 focal lengths in distance from the nearby object**

Moving the lens between 0 focal lengths in distance from the object to 1 focal length in distance from the object – magnification occurs.



**Figure 9 - Lens held about 1 focal length in distance from the nearby object**

What happens when you hold the lens various distances away from your object of interest?

Big lens distance from the object in focal lengths	Distance in inches or centimeters	How big does the object appear?	Is your object in focus?	Does it look upside down?
0 times the focal length	0			
1 times the focal length				
2 times the focal length				
3 times the focal length				

What happens when you move the lens between 1 focal length and 2 focal lengths from your nearby object? Between 2 focal lengths and 3 focal lengths from your object?

- **The image you will see in the lens using Case 2 magnification is *virtual*. What is a *virtual* image?**

While holding up your lens to the nearby object, move your head backwards and forwards from the little or eyepiece lens. Notice that the magnified image does not, like most things in the world, get bigger and smaller as you move your head closer to further away from the lens.

Images in the world are *real* or *virtual*.

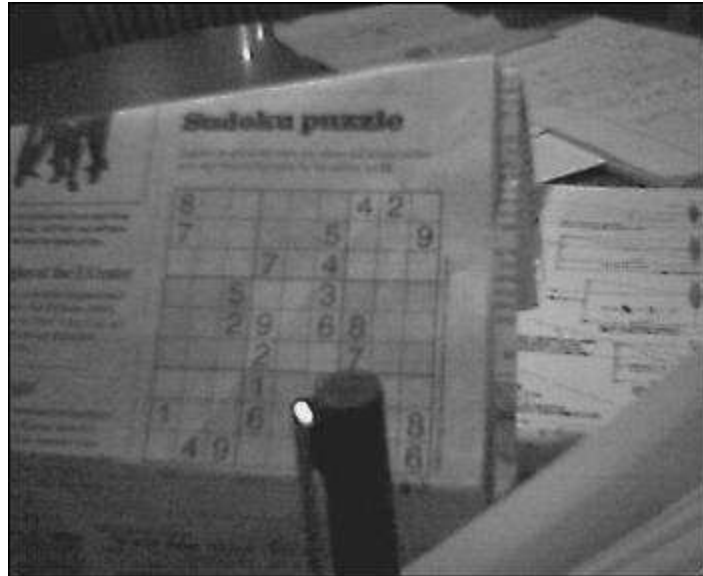
*Real images* are what we experience for most nearby objects. Ask a friend to stand 10' feet (about 3 meters) away. Look at your friend's head. Move closer and then further away from your friend. The *angular size* or *apparent size* of their head will become bigger or smaller.

*Virtual images* are different. If you move closer or further away from the object, they stay the same size. *Virtual images* are all around you. Look at a distant mountain top or a tall building – more than one or two miles (about 2 or 4 kilometers) away. Now take a couple of steps backwards away from the distant object and then a couple of steps closer to the distant object. The *angular size* or *apparent size* of the distant mountain top or building, unlike your friend's head, will not appear to get bigger or smaller.

When you look at the hand-magnifier lens held at a nearby object, the magnified image that you see is *virtual*. If you move your head back and forth, the *apparent size* or *angular size* of the image stays the same.

- **What is magnification? How can I describe it?**

*Magnification* is the change in the *apparent size* or *angular size* of an object. It is easily measured with respect to a foreground object, like your finger tip on an outstretched hand.



**Figure 10 -The unmagnified newspaper puzzle and its apparent and actual size measured against a pen in the foreground**

Here we will use Case 2 magnification – an object within one focal length of the lens – to show apparent magnification.



**Figure 11 - Magnified newspaper puzzle and its magnified apparent size measured against a pen in the foreground – the “6” and “8” are magnified about 2 times**

In the two above pictures the numbers “6” and the “8” have a magnified angular size that is about twice their actual physical size. You can also measure their relative size in the two photographs using a ruler.

- **Case 1 magnification: The object is more than 1 focal length away – but the lens is within 0 to 2 focal lengths of your eye.**

A single lens acts differently – very differently – when an object is far away. Far away objects of interest might be a distant mountain top, a tree, a building, or a friend standing 20 or 30 feet (or about 6 to 10 meters) away.

To explore Case 1 magnification, where the object is far away from the lens, we will use a chair and a picture across the room.

Begin by holding the lens at your eye slowly move it out to one focal length. As you move between 0 and 1 focal lengths, the image will be erect but out-of-focus. The image will slowly magnify and reach infinite magnification near one focal length.



**Figure 12 - The lens is close to the eye looking at a picture across the room – the erect virtual image but it will be slightly out-of-focus**

As you move the lens away from your eye. The image magnifies.



**Figure 13 - As the lens moves towards one-focal length, the image of the picture on the wall remains erect and virtual but magnifies**

Just past one focal length, the image of the object at the other side of the room will invert – or become upside – and be magnified:





**Figure 14 - Lens held about 1 focal length *from your eye* and looking at two distant chairs next to each other – one magnified and upside down – the other not magnified**

Here we see two chairs – one unmagnified – and a second magnified through a single hand lens. Notice that the magnified chair seat appears upside down! The same thing occurs with the picture on the other side of the room – or a planet on the other side of the solar system:



**Figure 15 - Just past one focal length, the image of the picture on the wall becomes upside down – it *inverts* - and becomes real**

The magnified image of the chair is a *real image* – when you move your eye towards and away from the lens, the image of the chair gets bigger and smaller – just like nearby objects in the real world. This differs from Case 2 magnification that you explored above – magnification of a nearby object. In Case 2 magnification, the image is *virtual* – it stays the same size when you move your head backwards and forwards.

In Case 1 magnification of a distant object, as you move the lens between one and two focal lengths, it remains in-focus, upside down (inverted) and will reduce in apparent size until you reach 2 focal lengths. At two focal lengths, the image has the same apparent size as the object.

What happens when you hold the lens various distances away from your eye while looking at a distant object of interest – like a tree across the street?

<b>Big lens distance from your eye to the lens in focal lengths</b>	<b>Distance in inches or centimeters</b>	<b>How big does the object appear?</b>	<b>Is your object in focus?</b>	<b>Does it look upside down?</b>
0 times the focal length	0			
1 times the focal length				
2 times the focal length				
3 times the focal length				

What happens when you move the lens between 1 focal length and 2 focal lengths from your nearby object? Between 2 focal lengths and 3 focal lengths from your object?

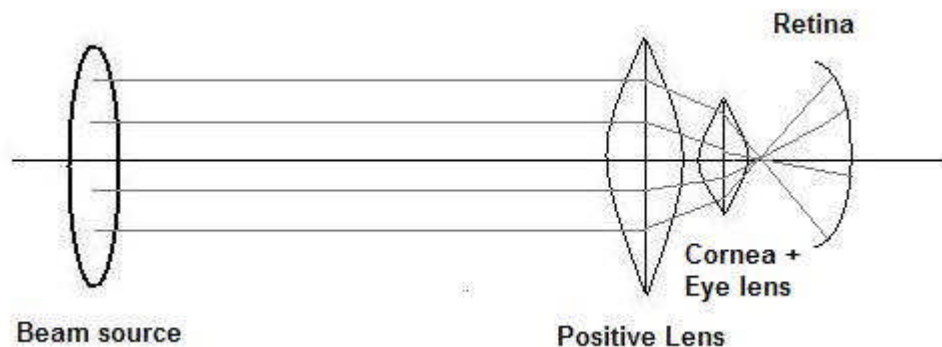
When held more than 2 focal lengths from your eye, a single lens focused on a distant object will start to look smaller than the actual object. This is called *tele-compression* – the opposite of magnification.



**Figure 16 - Seen at about 4 focal lengths, the upside image of the telephone pole in the lens is smaller than the telephone pole itself.**

- **Why does the image act they way that it does when in Case 1 magnification of a distant object, the lens is moved from the eye to zero, to 2 and then to 3 focal lengths?**

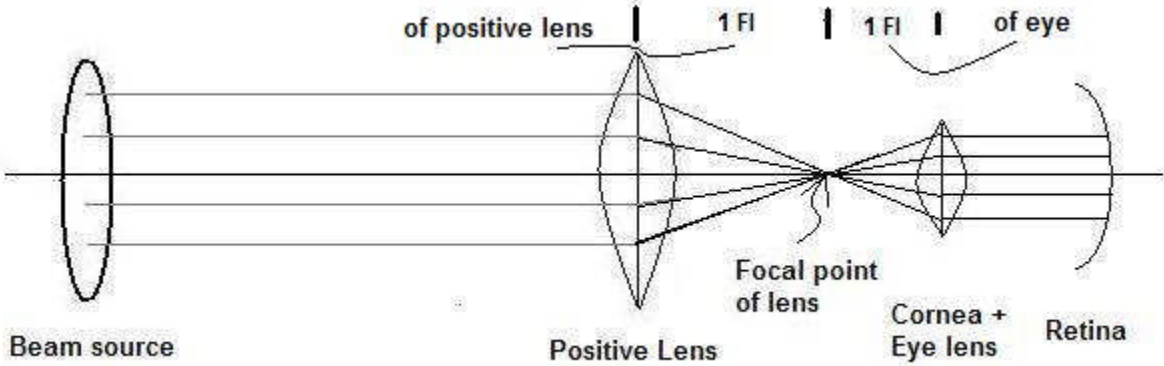
When the positive lens is held right near the eye, the upright or erect image is out-of-focus. This is because the lens in your eye – the cornea – is not at the focal plane of the big lens. The focal plane of the big lens is at one focal length. No image is formed by the lens until light has traveled one focal length past the positive lens.



**Figure 17 - Light rays moving from a distant beam source through a single lens and into your eye - unfocused**

Light from a distant source comes into the lens in parallel lines. It is called a beam source.

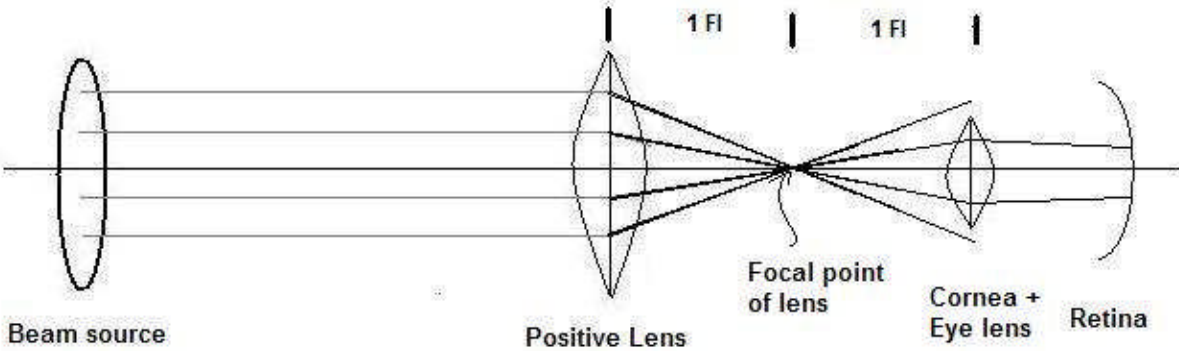
When you move the lens to one focal length from your eye, the image inverts and is upside down. Initially the image is out of focus. As you move the single lens a little further, its focal length will overlap the focal length of your eye and the inverted image snaps in focus.



**Figure 18 - Light rays moving from a distant beam source through a single lens and into your eye – focused and upside-down image**

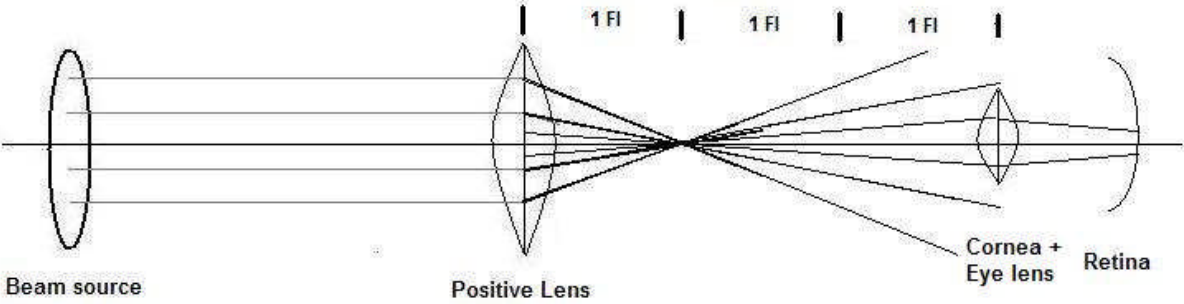
The image is magnified but real. It is at its greatest magnification. The image is inverted because the light rays have crossed at the focal point of the big lens.

As you move the lens between one and two focal lengths, the magnified image shrinks in apparent size. This occurs because the light rays are reaching your eye's lens at a shallower angle and are converging as they reach your retina. When you reach 2 focal lengths from the big lens, it will have the same apparent size as the actual object.



**Figure 19 - Light rays moving from a distant beam source through a single lens and into your eye – at 2 focal lengths – image is same size as object**

Moving between two and three focal lengths from the big lens, the image remains in-focus and inverted, but is smaller than the apparent size of the actual object. This is called tele-compression.

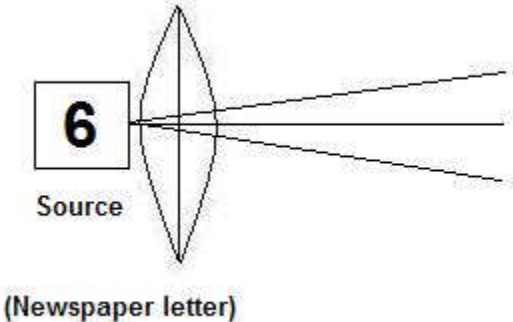


**Figure 20 - Light rays moving from a distant beam source through a single lens and into your eye – at 3 focal lengths – image is smaller than object**

Because the light rays converge as your eye from one to two focal lengths behind the lens, the image changes in size as your move. It is a real image.

- **Why does the image act they way that it does when in Case 2 magnification (object within one focal length of the lens), the lens is moved from the object to one focal length?**

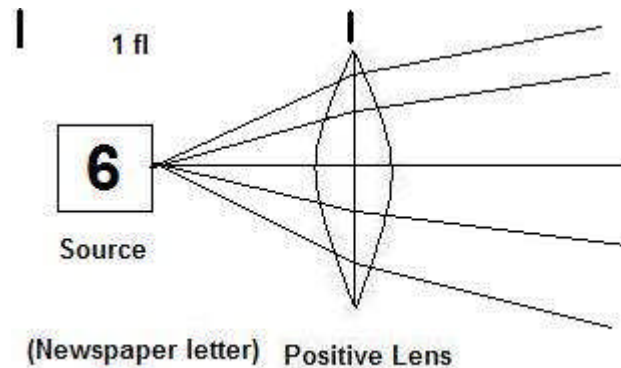
When the positive lens is held right near the object – for example our newspaper puzzle in Figure 8 above - eye, image appears the same size as the newsprint-object.



**Figure 21 - Light rays moving from a near point source through a single lens on top of the object and into your eye – focused and same size as image**

Because all the light rays move through the center of the lens, the lens does little to change their path. The object and the image seen through the lens appear the same.

As you move the lens further away from the newspaper puzzle, the image magnifies because more area of the lens has an opportunity to bend the light more.

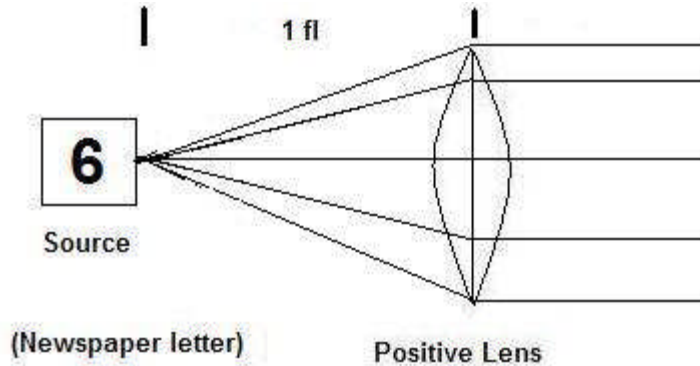


**Figure 22 - Light rays moving from a near point source through a single lens and into your eye – at one-half focal length between the object and image - focused and slightly magnified image**

The slightly magnified image of the object is virtual because all the light rays emerging from the lens (on the right side) still appears to be radiating or *diverging* from a common point. As you move your head further and closer to the lens in the radiating light rays, the apparent size of the image either grows or shrinks proportionately. So, you always see the same apparent image size – that is – a virtual image.

This differs from the *real image* in Case 1 magnification where the lens is more than one focal length from your eye (Figure 19). In Case 1 magnification, the light rays diverge (Figure 22) and the image is *virtual*.

A one focal length from the newspaper puzzle in Case 2 magnification, the lens produces an image with its greatest magnification. The image is virtual because the light rays are leaving the lens in a beam of parallel light rays.



**Figure 23 - Light rays moving from a near point source through a single lens and into your eye – at one focal length between the object and image – the greatest magnified image**

No matter where you place your head in this beam of parallel light rays, the image will have the same apparent size – that is – it is a virtual image.

- **If you drop your lens and the glass breaks, tell an adult and ask them to help sweep the glass up. Do not look at the sun through a lens. You'll go blind.**

- **Further reading**

Edmund Scientific. 2001. *Popular Optics*. Edmund Pub. No. 30094-45.  
<http://scientificsonline.com/>  
<http://scientificsonline.com/product.asp?pn=3009445>

Peterson, M. 2001. *Imaging with a Lens*. Java Ray Tracing Applet for Physics 301.  
<http://www.mtholyoke.edu/~mpeterso/classes/phys301/geomopti/lenses.html>

Peterson, M. 2001. *Lens combinations: Telescopes*. Java Ray Tracing Applet for Physics 301.  
<http://www.mtholyoke.edu/~mpeterso/classes/phys301/geomopti/twolenses.html>

- **Materials source**

Edmund Scientific Online. 2006. Bag of Lenses. Product No. 3082272. Count #20 per bag. (2 bags yields a mixture of about 10 Keplerian and Galileian telescopes) <http://scientificsonline.com/>  
<http://scientificsonline.com/product.asp?pn=3009445>