Day 1

Professor Elizabeth is arranging the equipment on the table.

MC: (in her mind) Wow! There is a "magical solid glass ball." I am going to explore that glass ball later.

MC: (in her mind) I'm so excited! Because this glass ball reminded me about the Snow White story which I like to read when I was young. There is a magical mirror in that story and I have a magical glass ball now. Let me think what should I do with the magical glass ball later.

Professor Elizabeth: ….. Okay, it's time for us to move to the mirrors and lenses experiment. Each of you can take something on the table and play with them. Observe carefully what you see in the experiment.

MC quickly grabs the magical glass ball and returns her seat. She puts the glass ball on the table and places a white card behind the glass ball. There is a MIT Medical logo on that white card.

MC: Cool! The image appears on the glass ball is magnify and inverted.

MC: (in her mind) Why isn't so? We can only see the image becomes larger under a convex lens. Isn't because of the glass ball has the convex surface too? Let me draw what I have seen on the glass ball first! (MC is looking closely to the glass ball while she is drawing.)

MC takes some other lenses (e.g. convex lens, concave lens and flat mirror) on the table.

MC: (place a concave lens in front of the glass ball) It's awesome!

LJ: What do you see?

MC: (remove the concave lens) First, you look at this glass ball. What do you see?

LJ: The image is larger and inverted.

MC: (place a concave lens in front of the glass ball) What do you see now?

LJ: Cool! The image at the center part of the glass ball is smaller and inverted. But the image outside the center part of the glass ball is larger and inverted.

Day 2

Most of the classmates are so excited when we are doing this experiment in the class. Because of different people has discovered different things in the class, and most of us cannot even tell the theory behind of the things we discovered.

MC: (in her heart) Before this, I don't realize that there are so many mystery hidden behind these tiny reflective things in my life. Sooner I feel that I am glad that I have attend this class, I am now paying more attention to the things in my life regardless of its complexity in the nature.

MC continues her lenses explorations with the glass ball. She places the glass ball on the green surface table.

MC: I discovered that the top half part of the glass ball is green whereas the bottom half part remains transparent.

MC: (in her heart) It is like a magic show!

MC: From my past experience with this "magic ball", I know that the image formed in the"magic ball" will be upside down. Therefore, I think that the "magic ball" is reflected the green color of the table. This is why only the top part of the "magic ball" is green.

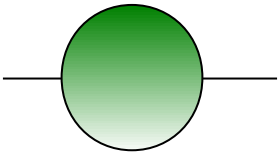


Illustration 1: *Front View of Glass Ball*

After that discovery, MC began to play with her torch light and lenses. Her torch light is made up of nine small LEDs and arranged in a circle.

MC: (She directed the light source onto the lenses.) Wow!

TA: What do you discover?

MC: For the first time in my life, I discovered that there are two images formed on the lenses under one light source. I see one small flower pattern and a big flower pattern appeared on the lenses.

LJ and TA: Yes, you are right! We can see two images on the lens too.

MC: Why isn't so?

Everyone looking at each other, none of us can explain the reason behind.

YY: Do you see the same thing if you directed the light source onto a plane mirror?

MC: Good idea. Let's try!

Without any hesitation, she try to apply the same the light source onto a plane mirror.

MC: I only see one image on this plane mirror.

YY and LJ and TA: Yes, only one image.

MC: I do not know the theory behind, but this is an interesting discovery for me. It is very difficult to use word to describe the feeling when you have discovered something new in your life.

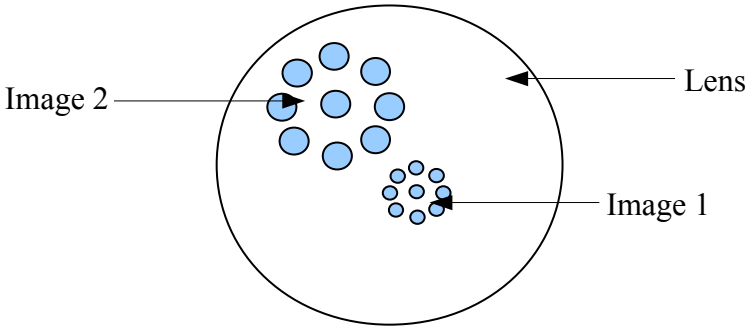


Illustration 2: *Images Formed on the Lens Under a Torch Light*

Day 3

MC continues her lenses and mirror experiment. Today, her target objects are the First Aid Box in the classroom. She uses a plano-convex lens and a biconvex lens for her explorations.

First, she holds the plano-convex lens in front of the first aid box, at least 2m away from the first aid box. She discovers that the image formed on the plano-convex lens is inverted and smaller than the actual object.

Then, she redo the same experiment again with a biconvex lens. She notices that the image formed on the biconvex lens is inverted and smaller than the actual object. But the image formed on the biconvex lens is slightly bigger than the image formed on the plano-convex lens.

MC: Why isn't so? Never mind, I will find out the reasons later. Let me continue my explorations first!

MC redo the same experiment again but this time she is standing in front of the first aid box (less than 30cm from the first aid box). She is focusing the lens on the red number 8161 on the blue first aid box.

Professor Elizabeth: (holding a ruler from the blue first aid box) Tell me what do you see?

MC: When I place the plano-convex lens close to the object (approximately 3 inches or less), the image formed on the convex lens is magnify. However, the image becomes less sharp when I move the lens further away from the object (more than 3 inches but less than 9 inches). An inverted image is formed on the convex lens when the lens is place at further distance from the object (approximately 9 inches or more). But this image becomes smaller and smaller as the plano-convex lens moves away from the object.

After the class, MC starts her lenses and light explorations when she back to her dorm. She takes out the lenses borrowed from Professor Elizabeth and arranges them on the table. All the lenses are laid on the table (refer to the attachment).

Procedures:

1) Place all the lenses on a flat non-reflective surface table.
2) Direct the torch light onto the top surface of the biconvex lens from point A, 30cm above the table.
3) Observe the images formed in/on the lenses. Record your observations with some sketches.
4) Direct the torch light onto the top surface of the biconvex lens from point C, 30cm above the table.
5) Observe the images formed in/on the lenses. Record your observations with some sketches.
6) Repeat steps (2) to (5) for the following lenses:
   (a) negative meniscus lens
   (b) biconcave lens
   (c) combination of a negative meniscus lens place at the bottom (the curved surface face down) and a biconvex lens on top of the negative meniscus lens

(d) combination of a negative meniscus lens place at the bottom (the curved surface face down) and a biconcave lens on top of the negative meniscus lens
(e) combination of a biconcave lens place at the bottom and a negative meniscus lens (the curved surface face up) on top of the biconcave lens
(f) combination of a biconcave lens place at the bottom and a biconvex lens
(g) combination of a biconcave lens place at the bottom, a biconvex lens place at the middle and a negative meniscus lens place on top of the biconvex lens (the curved surface face up)
(h) combination of a negative meniscus lens (the curved surface face up) place at the bottom, a biconvex lens place at the middle and a biconcave lens place on top of the biconvex lens
(i) combination of a biconcave lens place at the bottom, a biconvex lens place at the middle and a negative meniscus lens (the curved surface face up) place at on top of the biconvex lens; a piece of flat mirror is place at the bottom of this model

7) Observe the images formed in/on the lenses. Record your observations with some sketches.

MC: (directed the torch light onto the center part of a biconvex lens) There are two bright and sharp images formed on the lens. One of the images is slightly bigger than the other one.

MC: (directed the torch light onto the center part of a negative meniscus lens) There are two bright and sharp images formed on the lens. One of the images is bigger than the other one.

MC: (directed the torch light onto the center part of a biconcave lens) There are two bright and sharp images formed on the lens. One of the images is much bigger than the other one.

MC: It's interesting to find out the different sizes of the images formed on different lenses. What can I see if I put lens on top of the other lens?

MC: (a negative meniscus lens is place at the bottom where the curve surface is facing down; a biconvex lens is put on top of the negative meniscus lens; light source is apply directly above the center part of the lenses) Cool! There are four bright and sharp images formed on the lens. Moreover, the two bright and sharp images are slightly bigger than the other two images at the middle.

MC: Wait a minute! I see another two blurry images in between the lenses. What are these images? Where do these images origin from?

MC: (move the light source to the left hand side of the lenses) Amazing! The arrangement of these four bright and sharp images are not in a straight line now. The first top image appears to move to the right hand side while the middle two images remain at the the center part of the lenses. The one at bottom appears to move in the same direction with the light source.

MC: I think there are too many mysteries hidden behind these lenses and light. It's time for me to explore them!

MC: OMG! I still have to finish a problem set. But I do not want to stop this interesting experiment now! What should I do?

MC: Let's continues this experiment. I will do the problem set later. Hopefully, I can finish everything on time.

MC repeats her explorations with different combination of lenses. The following is the summary of her observations:

Type of Lenses	Total No. of Images Appeared on the Lenses
single biconvex lens	2 sharp bright images - one of the images is slightly bigger than the other one
single negative meniscus lens	2 sharp bright images - one of the images is bigger than the other one
single biconcave lens	2 sharp bright images - one of the images is much more bigger than the other one
combination of a negative meniscus lens place at the bottom (the curved surface face down) and a biconvex lens on top of the negative meniscus lens	4 sharp bright images and 2 less sharp images (in between the lenses) - two of the sharp bright images are slightly bigger than the other two at the middle.
combination of a negative meniscus lens place at the bottom (the curved surface face down) and a biconcave lens on top of the negative meniscus lens	4 sharp bright images and 2 less sharp images (in between the lenses) - four sharp bright images have different sizes.
combination of a biconcave lens place at the bottom and a negative meniscus lens (the curved surface face up) on top of the biconcave lens	4 sharp bright images - first top two images are smaller than the bottom one
combination of a biconcave lens place at the bottom and a biconvex lens	4 sharp bright images and 2 less sharp images - first top two images are smaller than the bottom one
combination of a biconcave lens place at the bottom, a biconvex lens place at the middle and a negative meniscus lens place on top of the biconvex lens (the curved surface face up)	6 sharp bright images - the bottom two images are larger than the other four images above; the two images at the middle are the smallest in size among the six images.
combination of a negative meniscus lens (the curved surface face up) place at the bottom, a biconvex lens place at the middle and a biconcave lens place on top of the biconvex lens	5 sharp bright images - the first top image is the largest; the three images at the middle are the smallest in size among the five images; the image at the bottom is slightly larger than the three images formed at the middle.
combination of a biconcave lens place at the bottom, a biconvex lens place at the middle and a negative meniscus lens (the curved surface face up) place at on top of the biconvex lens; a piece of flat mirror is place at the bottom of this model	6 sharp bright images, 4 less bright images and 6 less sharp and bright images - For the bright sharp images: the bottom two images are larger than the other four images above; the two images at the middle are the smallest in size among the six images. - For the less bright images: four images have the same size

Day 4

After reading Professor Elizabeth's comments, MC decided to continue her lenses and light explorations. Today, she comes out different set up for the lenses: all the lenses are "standing" vertically. Just to quick refresh with what she has done on Day 3, she has explored the lenses and the lights by stacking the lenses in a vertical direction.

Today, she will repeat this experiment again but the arrangement of the lenses is different. The lenses are now placed vertical on the table at equal spacing (e.g. 5cm, 10cm and 15cm) and the torch light is placed at approximately 7cm from the 15cm horizontal line on the white paper. Please refer to the scan document for the setting up details and procedures.

Interested to find out what she has noticed in this experiment? Look on her journal and you will be surprised. She has taken some photographs when she conducts this experiment but the resolution of the photographs might not be good due to the reflection of the light on the lenses.

MC has choose to elaborate one of the most interesting part of her explorations today. The arrangement of the lenses are shown as below:
A biconcave lens is place at 5cm from the black screen, a biconvex lens is place at 10cm from the black screen, and a negative meniscus is place at 15cm from the black screen.

MC: It's amazing! I can see a total number of five images on the lenses.

MC: How can I distinguish which images are belong to which lens?

MC: (stares at the color transparent papers) I have the idea!

MC: Let put the pale pink color transparent paper behind the biconcave lens.

MC: Interesting! No image formed behind the biconcave lens. Let moves the pale pink color transparent paper in front of the biconcave lens.

MC: Okay, I see one pale pink image (image 5). So this image should belong to the biconcave lens.

MC: Let put another purple color transparent paper in front of the biconvex lens.

MC: Now I can see one pale pink image and two purple images (image 3 and 4). Apparently, these two purple images belong to the biconvex lens.

MC: (in her mind) The remaining two images should belong to the negative meniscus!

MC: Let put another blue color transparent paper in front of the negative meniscus lens.

MC: (smile) My guessing is correct. There are two blue images (image 1 and 2) in front of the purple and pale pink images.

MC: Fantastic!

MC: Let me record down what I see now. Okay, there are a total five images ……. three small images and two big images. Image 2 is the largest and image 3 and 4 are the smallest.

MC: If I move the torch light to the left, image 1, 2 and 4 will move to the same direction as the torch light moves. However, image 3 and 5 will move to the opposite direction as the torch light moves.

Day 5

DS: Does any one has discover how the biconvex lens works? I have read through the information on the Wikipedia, but I still not very understand.

MC: Actually, I do not have any answer fro your question. However, I have done some experiment and recorded down all the things I seen. (She pass her journal to DS) May be it will give you some hints.

DS: Can you help us to set up your experiment?

MC: Sure!

MC has set up her lenses and light experiment in the class. Her classmates are very interested in this experiment.

DS and JF: Okay, let us begin with the biconvex lens alone.

JF: Do you see there are three images on the lens?

DS: Yes. One is brighter and the other two images are in pale brown color.

JF and DS discuss how the light travels through the lens.

JF: What can we see if we remove the wooden block? (She removes the wooden block)

JF: We can only see one image now.

DS: That means the two pale brown images are the reflected images of the wooden block of the brighter image.

JF: Interesting! But why isn't so?

Professor Elizabeth: I've borrowed a light ray box from the Physics Department which might give you some hints for those questions in your mind.

MC: (in her mind) Hints! Questions!

MC stops her motion explorations and quickly walks to the direction of the light ray box.

DS turns on the power. We see three light rays emerging from the light ray box. One of the light rays is red in color.

JF put a biconvex lens in front of the light ray box. She starts to move the biconvex lens to different distance from the light ray box.

JF: We need more white papers.

MC: I have many white papers! (She takes some white papers from her book)

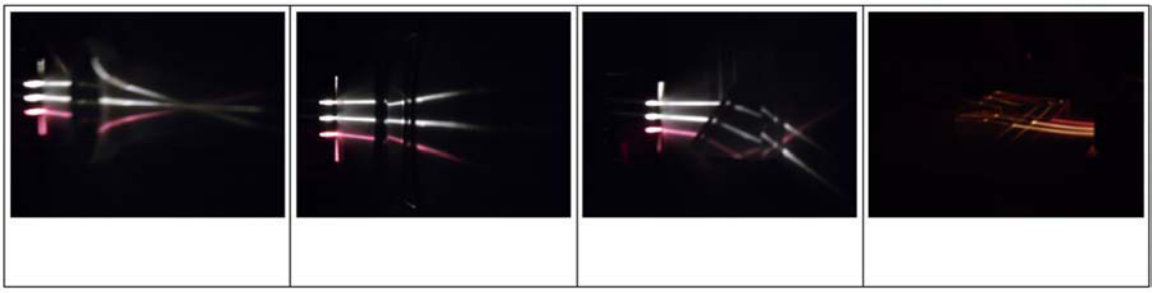
DS: The red light rays is on the other side after it passing through the biconvex lens. This explains why the image formed on the biconvex lens is inverted.

JF removes the biconvex lens and replaces with a biconcave lens.

DS: Now we can see the light rays are diverging out.

DS removes the biconcave lens and replaces with a triangular lens.

JF: Interesting! (She moves the triangular lens to different angles)



Day 6

MC continues her light ray box and lenses experience in a dark room.

MC: (excited) This is my first time to conduct the experiment by myself at MIT classroom.

MC: What should I do now?

MC: (staring at the light ray box) I need to have three different color light rays.

MC stick a small piece of blue transparent paper at the one end and the red transparent paper at the other end.

MC: Done! I have three different light rays now. I can begin my experiment.

MC starts to plot the light rays with different lenses on different pieces of paper.

MC gets excited when she plays the light ray box with a triangular lens.

MC: Cool! The light rays reflect in different ways at different angles.

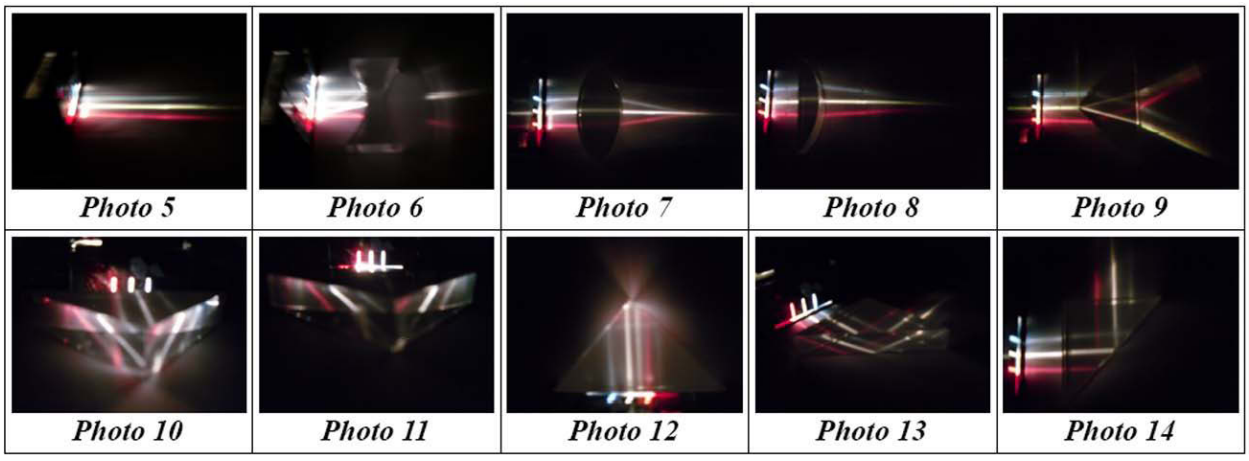
MC observes there are some light rays inside the triangular lens. She notices that the light rays in the triangular lens are reflect in different angles; none of the light rays are at 90 degrees.

MC: What can I see if I mark out the light rays in the triangular lens?

MC: (in her mind) t should be the patterns I seen in the triangular lens.

She marks the points accordingly to what she seen in the triangular lens. She discovers that all these points formed a 90 degrees straight line when she joins them together.

MC: I can't believe this! This is not what I seen in the triangular lens. What is happening inside and outside the lens?



(***Photo 5*** - Light ray box; ***Photo 6*** - Biconcave Lens; ***Photo 7*** - Biconvex Lens; ***Photo 8*** - Plano-convex Lens; ***Photo 9 ~ 14*** - Triangular Lens)

EC.050 Recreate Experiments from History: Inform the Future from the Past: Galileo
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