Name: **SNC2(D/P)1**

Building and Mapping out the region of a cloaking device

Before carrying out the experiment, students are required to watch a 3-minute video on the cloaking device. The video is available from YouTube™ (https://www.youtube.com/watch?v=vtKBzwKfP8E or search 'The Rochester Cloak' on YouTube™) or from http://www.rochester.edu/newscenter/watch-rochester-cloak-uses-ordinary-lenses-to-hide-objects-across-continuous-range-of-angles-70592/

Answer the following questions after watching the video:

1. What is cloaking?

2. How many lenses do you need to make a simplest cloaking device?

3. Discuss with your elbow partner and describe two areas of application where 'cloaking' can be useful.

4. Pause the video at 11 seconds and at 25 seconds. Question: Why are the fingers not closed at the center of the lens? Why is the ruler not at the center of the lens? (Hint: Pause the video at 2 minutes and listen carefully.)

So why does cloaking work? Simply speaking, a set of four convex lenses allow light to 'bend' around an object, which will otherwise block the view. The star on the left is real. When the star is viewed from the right, rectangular objects block the view. As a result, the image on the right is missing the top and the bottom portions of the star. When the cloaking device is placed in front of the real image (the 'star'), the light from the star is converged by the first convex lens. The converged light is sent from the second to the third lens using a narrow path. The fourth lens rebuilds the narrow light to the original size, which forms the original image. The net result is amazing! The cloaking device makes the rectangular blocking objects 'cloaked'.
Note: If you block the 'center' of the setup, the converged light will not be able to escape the view-blocking object and the cloaking will fail.

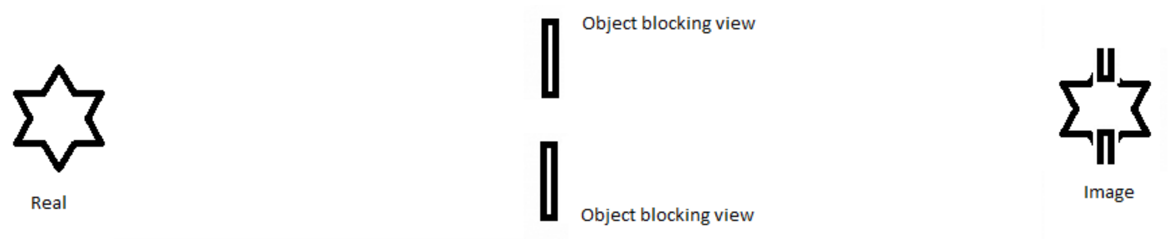

Figure 2A

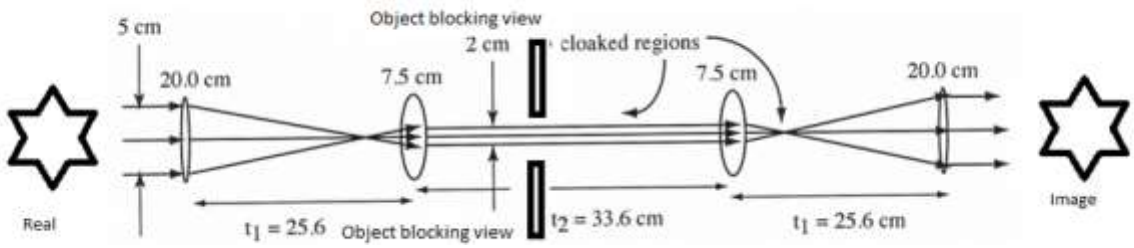

Figure 2B

Figure 2: The real object and its image with (Figure2A) and without (Figure 2B) a cloaking device. (Courtesy: Harvard Natural Sciences Lecture Demonstration) Please visit https://sciencedemonstrations.fas.harvard.edu/presentations/paraxial-ray-optics-cloaking).

Materials

Achromatic lenses and metal rail are available from

https://www.surplusshed.com/pages/item/l14575.html

1. Six cemented doublet achromats (2 single achromats and 2 double achromats), 34 mm diameter
2. a metal rail
3. white sheet
4. 1-metre ruler
5. a wooden support onto which the metal rod was attached to
6. 4-6 transparent tape fillers
7. metal paper clips (3.1 cm in length)
8. pencil and eraser and a ruler (30 cm)
9. graph paper
10. calculator

Step-by-step procedure (*Please follow the steps and answer questions as you proceed*)

1. You are given two sets of lenses. There are two single convex lenses (two F1's) with focal length (*f*1) of 150 mm and two other double achromatic lenses (two F2's) with focal length (*f*2) of 50 mm.
2. Calculate *t*1 and *t*2 distances according to the formulae below:

$$t1 = F1 + F2$$

$$t2 = \frac{2(F1 + F2)F2}{F1 - F2}$$

   Write the values for *t*1 and *t*2 in your notebook. Show your calculation.
3. Place the lenses based on your calculated values of *t*1 and *t*2 along the rail provided (see figure 1A and 1B).

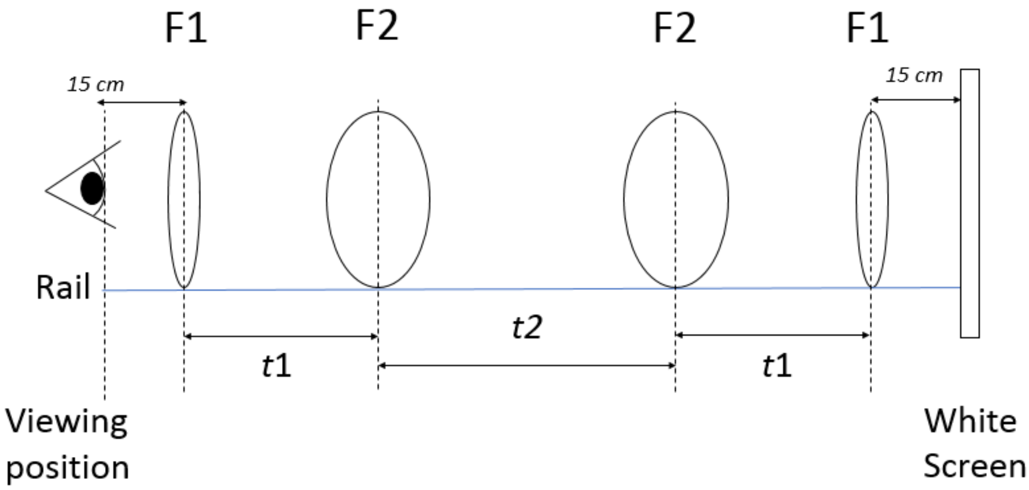

Figure 1A. shows the positions of the lenses to be placed with t1 and t2 distances.

Figure 1B shows the positions of the lenses to be placed with t1 and t2 distances and the transparent tape (to be placed later on) between F1 and F2.

4. Place a white paper with crossed lines approximately 15 cm behind the F1 lens on the right.
5. Take a look at the screen through the F1 lens on the left. Try to place your view point approximately at the center of the F1 lens on the left. A sharp image must be seen. Adjust the lens distances accordingly for the best sharp image.

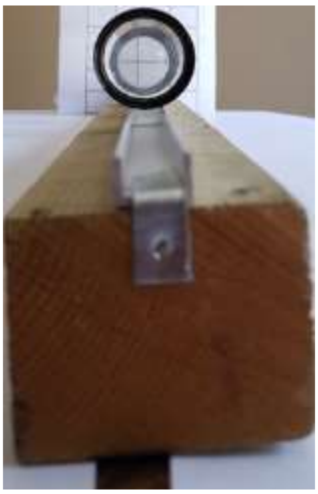

Figure 2 shows the sharp image through 4 lenses and care must be taken to always keep taking the reading through the centre of all lenses.

6. Replace the sheet by a blank white sheet. Straighten out five paper clips and wrap them around five circular tape rolls according to the Figure 3 below. It is advisable to secure the straight clips firmly on the side of the tape rolls. Measure the height of the straightened portion of the paper clips from the base of the paper rolls.

Figure 3 shows different heights h of the metal object to be positioned on the metal rail as shown in figure 1B.

7. Now place the first filler roll between the F1 and the F2 lenses on the left-hand side.

8. One student should systematically slide the paper roll along the rail and the second student should indicate when the straightened portion of the paper clip becomes invisible (`cloaked`). Record the distance (d) of the paper clip from the center of the F1 lens on the left.

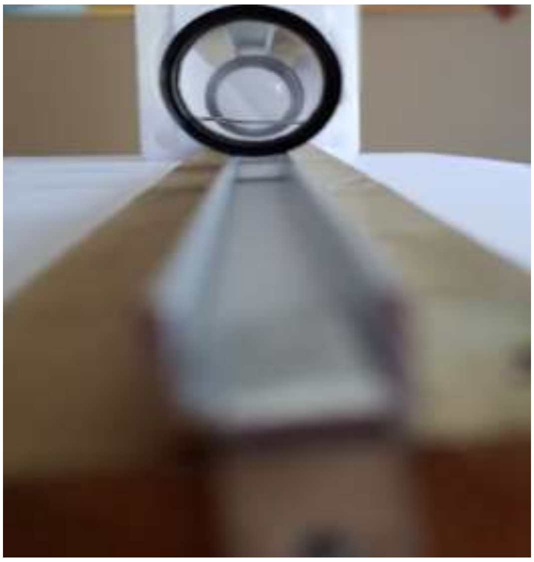

Figure 4A shows the metal clip at the centre of 4 lenses.

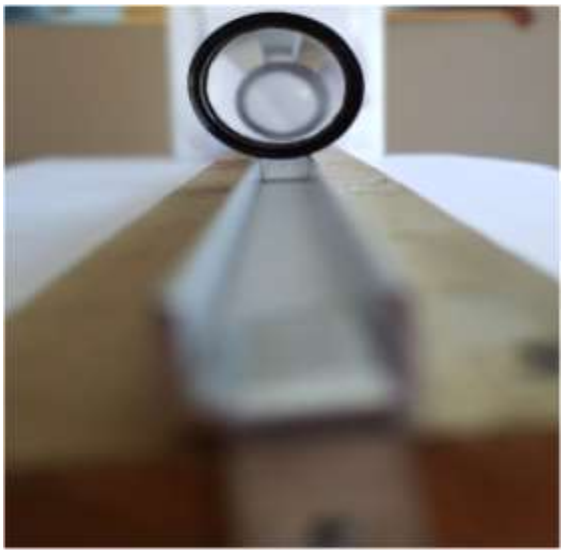

Figure 4B shows the first disappearance of the metal clip at the centre of 4 lenses.

9. Repeat the procedure in step 9 with four other paper rolls (fill in observation table 1 below).
10. On a graph paper, draw a horizontal line (X axis) and a vertical line (Y axis). The X axis represents the distance of the F1 and the F2 lenses on the left. The Y axis represents the height of the paper clip image as recorded by the student group.

Note that the height of the straightened portion of the paper clip is the independent variable and the distance of the paper clip from the F1 lens is the dependent variable. Typically, the independent and the dependent variables are plotted along the X-axis and the Y-axis, respectively. However, in this particular exercise you should plot the independent variable along the Y-axis and the dependent variable along the X-axis to make the graph look similar to your setup.

11. Measure the height of the F1 and the F2 lenses on the left.
12. Mark two points that designate the top and the bottom of the F1 lens on the left. Join them by a solid line.
13. Mark two points that designate the top and the bottom of the F2 lens on the left and join them by a second solid line.
14. Find the mid-point of both solid lines and join them by a horizontal dashed line.
15. Plot the focal length of the F1 lens on the left and mark the point on the horizontal solid line (Ray 1)
16. Draw a line between the top marked point of the F1 lens and the focal point. Extend the line until it intersects the F2 lens solid line (Ray 2).
17. Draw a second line between the bottom marked point of the F1 lens and the focal point. Extend the line until it intersects the F2 lens line.
18. Plot all five data points from your record as R1, R2, R3, R4, and R5.
19. Shade the area above and below Ray 1 and Ray 2. In this area, the clips are not visible.

<u>Observations (for mapping out the area of "cloaking")</u>

X= distance of lens from the bottom support (height of plastic support holding the achromatic lens)

Figure 5. Picture of the achromatic lens

Height of metal object from the rail(h)(cm)	Corrected height (h-x/cm)	Distance of metal clip from lens F1 (d/cm)		
		d1	d2	d =(d1 +d2)/2

Table 1 showing the heights, corrected heights and the distances of the metal objects at which cloaking occurs.

Conclusion

5. If an object had a height of 1.40 cm above the rail, what is the distance from F1 you would see it disappear? Show your reasoning on the graph you drew. (Hint: do not forget to do a corrected height measurement)

6. What are the possible errors in your experiment?

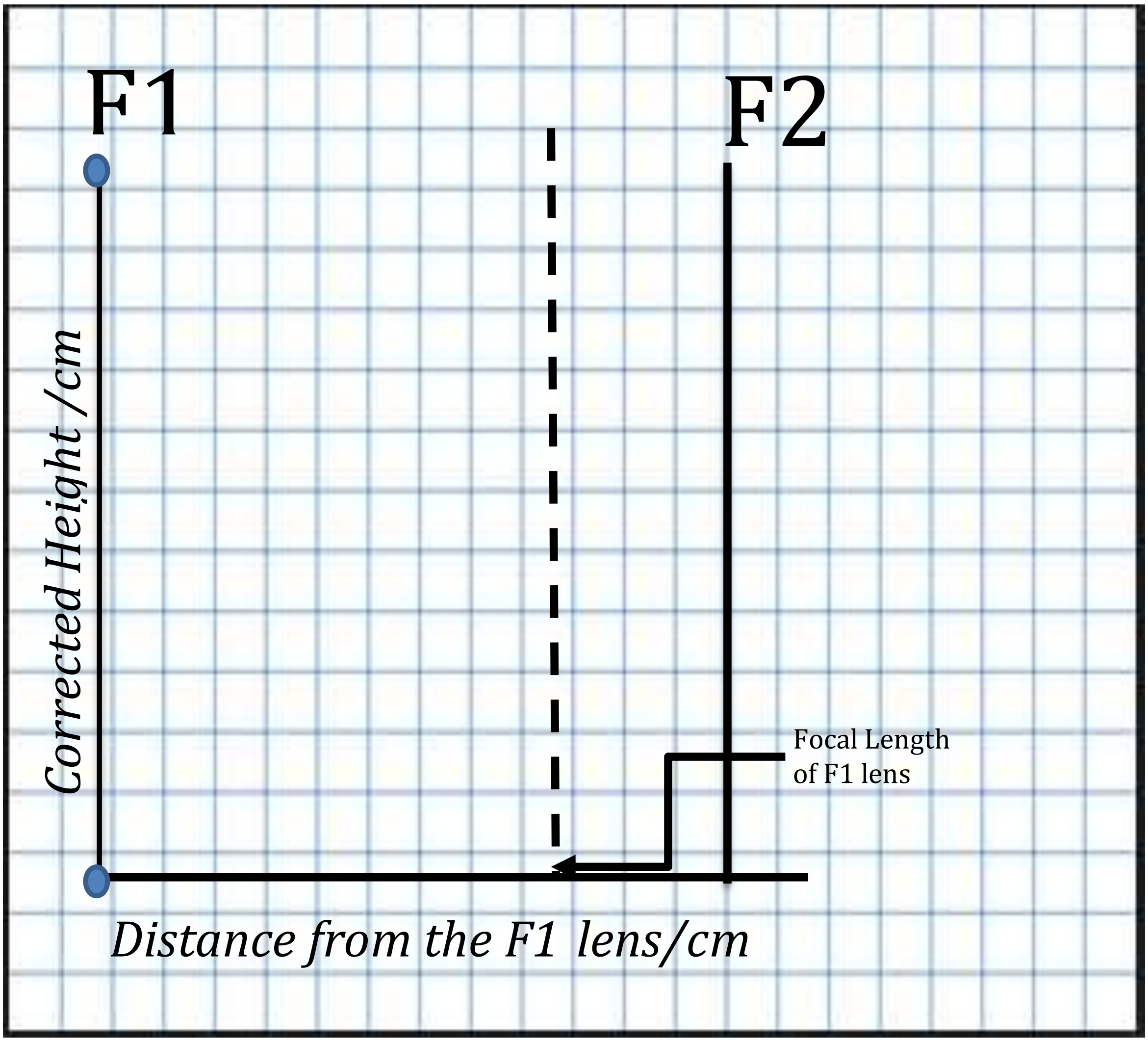

Figure 6. Graphical representation of corrected heights and distance from the F1 lens