

Friday 10th March - Materials Decathlon - Challenge n°9 - 40'

INVISIBILITY CLOAK

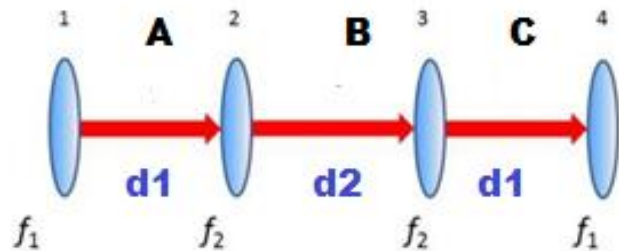
On the desk you have 4 lenses: two of them with a focus length of 150 mm and the other two of 50 mm.

Q1. Identify the two types of lens and for each of them verify that the focus really is as mentioned above. Describe how you tested it.

From now onward we will call **L1** the lenses with focal length $f_1 = 150 \text{ mm}$ and with **L2** the lenses with focal length $f_2 = 50 \text{ mm}$.

1. Calculate $d_1 = f_1 + f_2$ and $d_2 = 2 * f_2 * (f_1 + f_2) / (f_1 - f_2)$

Then use a ruler to measure the distances and put the 4 lenses as in the picture.



2. Put a screen at a certain distance from lens 4 and observe it through the four lenses. The observer should be at the opposite side of the lens system (lens 1) and at a distance between 2 and 3 metres approximately.

3. Test the lens system for perfect alignment with a laser beam. Everything will be ok if the laser beam spot on the screen is bright, focused and small! The laser beam should not spread wide as it goes across the lenses, but appear as a tiny dot on the screen.

4. **The invisibility cloak is ready!** Now explore the cloaked regions by slowly moving a pencil in between two lenses, perpendicularly to the optical axis. Repeat it in different areas of the three regions (A, B, C). Annotate on the picture the cloaked regions that you have found.

Take **pictures and/or videos** [at least one for each region A, B, C] proving the existence of the cloaked regions and clearly showing the “disappearing” pencil in some areas.

5. Take a sheet of graph paper and using a ruler draw the lens system with extreme accuracy (**Graph 1**). Note on the optical axis the point where is positioned the **focus** of each lens. Finally trace the path of the light rays parallel to the optical axis (“coming from infinity”) starting from the first lens and going through all the 4 lenses.

Q2. Can you identify on your drawing the cloaked regions? Can you explain their presence in that specific position? Do they correspond to the areas you already found in step 4.? If not, go back to the real lens system and test them (take more pictures/videos!)

Q3. When you move the pencil perpendicularly to the optical axis and it enters the uncloaked region is its behaviour exactly the same in all the three regions A, B, C or do you notice any difference?

OUTPUT WANTED: answer to Q1-Q3 + Graph1 + Videos/Pictures

Teachers' Notes

Technical notes:

- Perfect activity when you introduce lenses and the graphical way to obtain an object image. At the same time it can be used as an introduction to metamaterials, materials that are able to bend light around objects making them invisible to the observers' eye

Organizational notes:

- Each student will keep a copy of the students' sheet but the group will collectively fill in the answer sheet and give it over to the teacher in charge at the end of the lab.

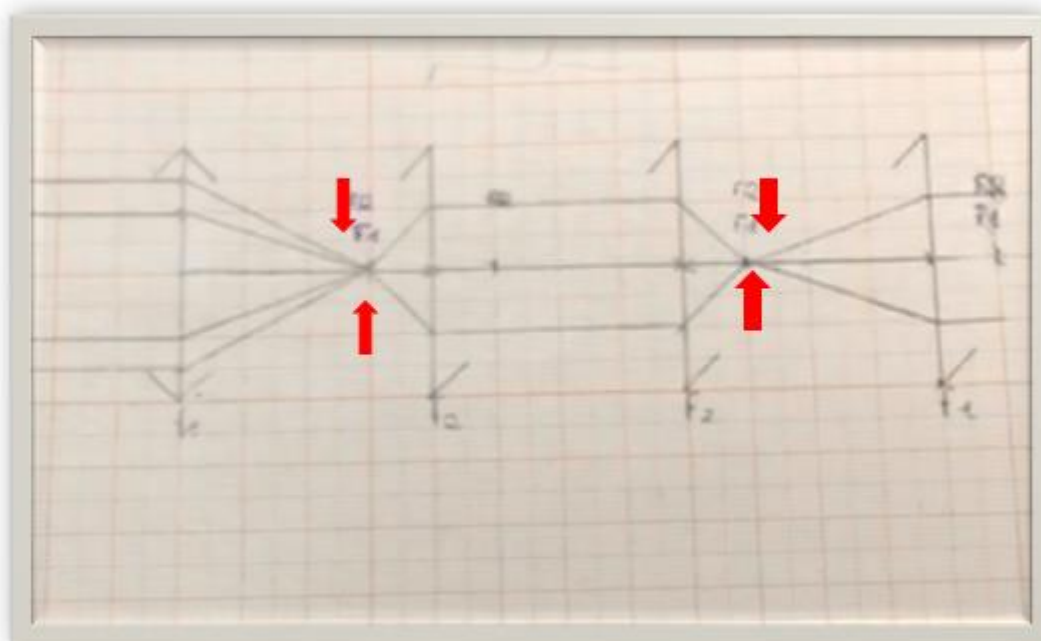
Correction grid

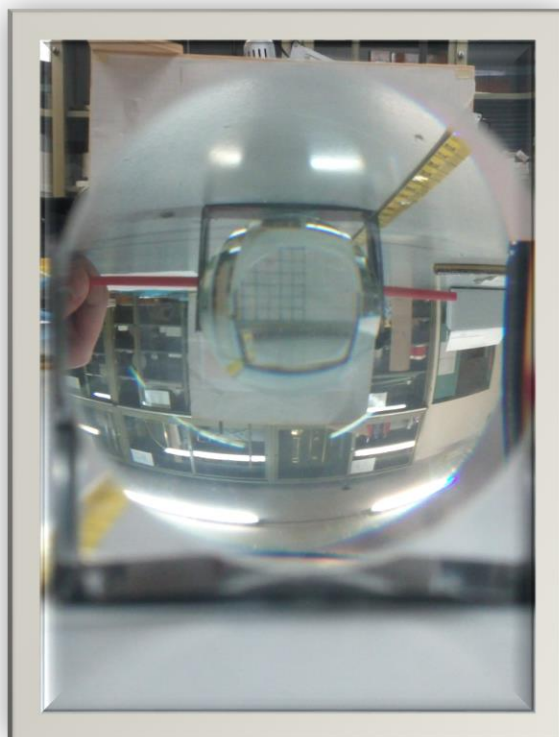
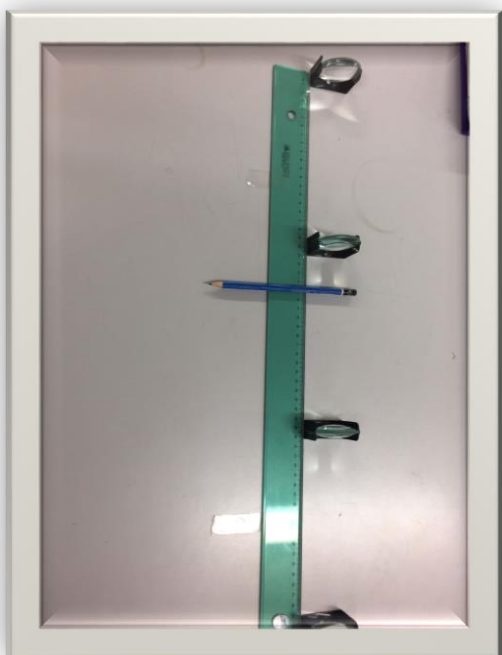
Question or Request	Note	Max. score
Q1	Check both answer (see key below) and method used	2
Graph 1	Check if it is correct and contain all the request made at point 5 of student sheet	3
Q2	2 points if answer is motivated by the Graph 2 points more if the right cloaked region have been founded	4
Q3	See key to answer	2
Picture/Video 1	Meaningful (Yes/No: 2 point); beautiful (Yes/No: 1 point)*	3
Picture/Video 1	Meaningful (Yes/No: 2 point); beautiful (Yes/No: 1 point)*	3
Picture/Video 1	Meaningful (Yes/No: 2 point); beautiful (Yes/No: 1 point)*	3

***Pictures/Videos:** are the pictures meaningful? **Do they clearly show the cloaked regions?** [To evaluate the "meaningful" see also the "Picture Description" on the Answer Sheet] Are they focusing on significant details or clearly showing the apparatus structure or the investigation results? Are they aesthetically beautiful?

Key to Answer

The "invisibility" areas are highlighted by the red arrow.





MoM Resources (<http://www.mattersofmatter.eu/mom-materials/>)

- MOM_INVISIBILITY_CLOAK_VIDEO
- MoM_PRESENT_Wednesday_Micro optics

Where to buy

- The kit of lenses is found at <http://laserclassroom.com/> but you actually can use any two couples of convex lenses with different focus. We used the plastic lenses of the photonics explorer kit. They work all right with the only issue that they are a bit too small in size: you need larger ones.



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