Friday 10th March - Materials Decathlon - Challenge n°6 - 40’

CIRCULAR POLARIZATION

On the desk you have a pile of numbered grey plastic squares, namely polarizing filters. But they are not all alike: some of them are linear polarizers, some are circular ones.

1. Sort into two different piles the two types of polarizer.
   You are free to test in any possible way provided that the tests are NOT destructive!
   - ***Suggestion1**: watch a PC[1] screen while rotating the filters, for each filter repeat the rotation after having flipped it (= exchanging upper and lower face).*
   - ***Suggestion 2**: put the filters on a mirror or other highly reflective surface. For each filter repeat after flipping upper and lower face.*

   Q1. Which numbers correspond to ***linear*** polarizers and which ones to **circular**? Fill in the table in the answer sheet and explain which tests you did and what you observed.

2. Take two circular polarizers, put them back to back and rotate them together in front of the PC screen. What do you notice?

3. Keep one of those two polarizers and repeat step 2 with <u>all</u> the other circular polarizers: do you notice any differences?

   Q2. Are the circular polarizers all alike? If not how many types can you distinguish? How?

4. **Q3.** Are circular polarizers really polarizers? That is to say: is the light coming out of a circular polarizer oscillating on a specific plane (polarization plane)?

   <u>To answer</u> this question run the following test:
   - Put a circular polarizers on top of a linear one and both of them in front of a polarized light source (such as a PC screen). Rotate the linear one till you find a position producing a complete light extinction (dark!), that means that the light reaching your eye was linearly polarized (due to the linear filter) .
   - Now invert the position of the two polarizers: circular directly in front of the PC screen and linear on top of it. Rotate the linear polarizer once again. Can you find a position producing extinction now? And if you flip the circular polarizer? What can you deduce about the light transmitted by the circular polarizer?

5. Put sellotape on a microscope glass longitudinally (= along the main length) and put the linear polarizer perpendicularly on top. Rotate them together in front of the PC screen and next to them rotate also a circular polarizer till you see the same colour in both systems. From this point on rotate them together with similar angles: which colour do they produce? Is it different?

   Q4. The circular polarizer is therefore equivalent to ... (What?). But with some differences: which ones? [*Suggestion: see step 4.*]

☞ **OUTPUT WANTED : Answer to Q1-Q4 + at least 2 pictures of apparatus and/or detail**

[1] If you don’t have a pc use a smartphone screen ***BUT be careful***! Differently from laptops some are linearly polarized, some are not!

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Answer sheet

GROUP N°___________

Ch.6 --- CIRCULAR POLARIZATION

Q1

Linear polarizers N°	Circularpolarizers N°

Q2

Q3

Q4

PICTURES [*Sent by Whatsapp to your group – See general instruction to share pictures or files*]

- **Picture 1 description:**

- **Picture 2 description:**

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Teachers' Notes

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	Sort filters correctly (2) and explain how (2)	4
Q2	Sort right and left filters (2) and explain how (2)	4
Q3	No extinction (2) a circ polarizer doesn't linearly polarize(2)	4
Q4	Equivalent to linear + circular (2) but differences[2] (2)	4
Picture 1	Meaningful (Yes/No: 1 point); beautiful (Yes/No: 1 point)*	2
Picture 2	Meaningful (Yes/No: 1 point); beautiful (Yes/No: 1 point)*	2

***Pictures**: are the pictures meaningful? [*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

Q1

The most evident difference is that in the linear polarizers the two faces behave exactly in the same way, while in circular polarizers there's a privileged side:If you rotate them in front of a pc screen only one of the two sides produces extinction upon rotation. The other side instead doesn't produce any extinction but alternates with 90° rotations of blue (corresponding to total extinction if I'm looking through the other side) and yellow.(corresponding to maximum luminosity if you look from the other side).

The difference between the two sides of a circular polarizers is quite evident also if you put them on a mirror: one looks black and the other clear whatever the rotation. This doesn't happen with a linear polrizer. This is due to the fact that a clockwise polarized light becomes an anticlockwise one upon reflection on a mirror (a clockwise screw on a mirror is reflected as an anticlockwise screw) This brings to extinction .

Q2

Are circular filters all alike? Take two of them and put them dark to dark (= back to back where back means the side through which I could see extinction at appropriate angle).Let's rotate them as if they were one thing and as you rotate look through them at the PC screen. You will see that sometimes you are not able to see any light. The same happens if you put the clear sides back to back and rotate

Finally if you put a clear side back to back to a dark side it never becomes competerly clear but shomehow changes with rotation. All this happens because you have two different types.If both the two filters were of the same type RR or LL, then repaeting the above steps as you rotate you can read through because it becomes transparent So: it's not easy to say whether you have a L or a R, but it's relatively easy to see if you have two of the same type.

[2]There's no "dark" side and clear one

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<u>Q3</u> Circular polarizers DO NOT produce polarized light'. In order to prove this take in the exact order a PC screen (polarized light) a linear polarizer and a circular polarizer. Now rotate the linear polarizer. You will reach the total extinction

Now shift the position of the two filters and rotate the circular one: you want see any extinction. This proves that the circular polarizers let the light go and oscillate in every direction and the linear polarizer is neber able to block it all

Q4

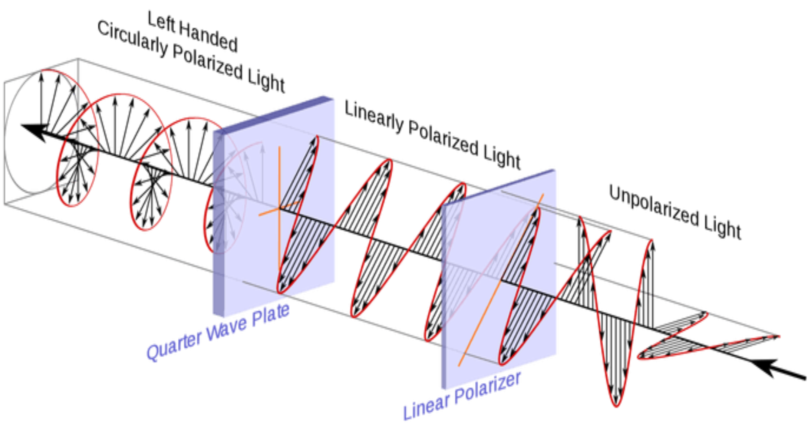
With the sellotape strip on the microscpe slide in the direction of the slide length, I obtain a quarterwaveplate. This is easily proved by putting a stack of 4 of these slides between the PC screen and the linear polarizers I don't see any differnce (while with 1, 2 or 3 I can see beautiful colours) Now move together the slide+ sellotape and the linear polarizer: you will see first the yello hue similar to the circular polarizers.

Now rotate them together (circular polarizer and linear polarizer with microscope slide): you will notice that they produce exactly the same colours! So now you know how to build a DIY circular polarizer

However there will be some differences: the black s(corresponding to yellow) and the clear (corresponding to blue) so typical of circular polarizers are not visible here! And if you take two of these systems and put them back to back it will not work as it does in circular polarizers.

As we have now understood, every circular polarizer has in itself a ¼ waveplate, which will work best for the specific wavelength decided by the manufacturer. For the other frequencies it will be ellittically polarized This is actually the reason why if you put the dark sides of two circular polarizers you will not have total extinction but rathe a dark blue Linear polarizers on the contrary work with no difference over the whole VIS spectra.

Finally if I put a quarter wave plate between mirror and circular polarized (in extinction position: balck) I see now a yellowish hue.



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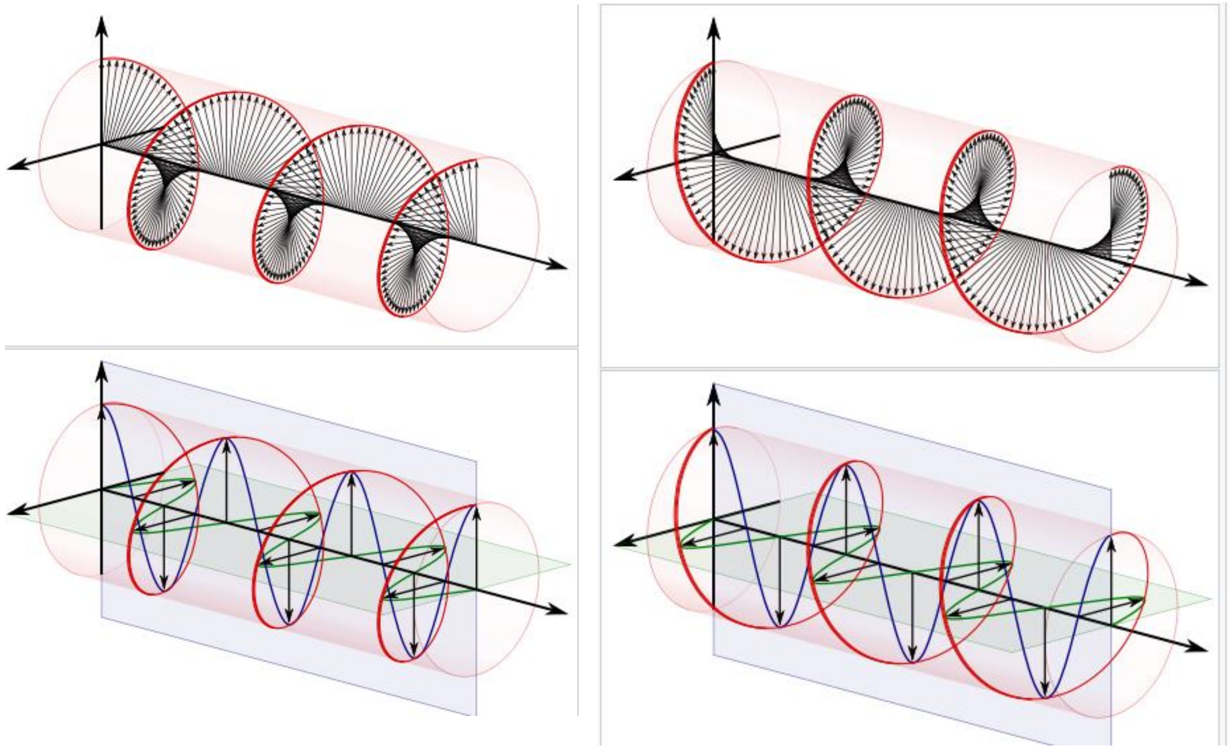

Source:Wikipedia public domain https://en.wikipedia.org/wiki/Circular_polarization

On the left: left handed circularly polarized filter. On the right: right handed circularly polarized filter

MoM Resources http://www.mattersofmatter.eu/mom-materials/

- Ch9_TEACH_EN_Optically active materials

References

1) https://www.youtube.com/watch?v=bi3Ene3pNAs
2) http://instructor.physics.lsa.umich.edu/int-labs/Chapter4.pdf
3) http://cameraplex.com/physics-how-do-circular-polarizers-work/http://cameraplex.com/physics-how-do-circular-polarizers-work/
4) https://www.youtube.com/watch?v=8YkfEft4p-w
5) https://www.youtube.com/watch?v=PJHCADY-Bio
6) http://hyperphysics.phy-astr.gsu.edu/hbase/phyopt/quarwv.html

Where to buy

- **Circular polarizers** Left and Right https://www.3dlens.com/ Cost: 1.5 to 3 $ each without shipping

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