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Prelab 2	Introduction to Experimental Physics II	October 24, 2022

Collaborators

I worked with **Andrew Binder** to complete this assignment. The plots were mostly created by him (since he knows Ti*k*Z better than I do), but I'm slowly learning so the plot for the electric field in part c) and the last plot in part d) were created by me.

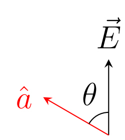
Problem 1

Consider a linearly polarized beam of light propagating out of the plane of the page wiwth a vertical polarization Figure 1. shows how the electric field vector of the lieght wave changed over one full period at a particular point in space.

Consider the electric field vector $\vec{E}$ of magnitude $|\vec{E}| = E_0$ from Figure 1 at time $t = 0$. Let axis $\hat{a}$ be oriented at an angle θ counterclockwise of the $+\hat{y}$-axis. When the light passes through a ***linear polarizing filter*** with a transmission axis along the $\hat{a}$-direction, only the projection of the electric field onto the $\hat{a}$-axis gets transmitted.

a) What is the magnitude of the electric field after passing thorugh the polarizer? What is the intensity?

Solution: Refer to the following diagram:



As we can see, the intensity would be $|E| = E_0 \cos\theta$.

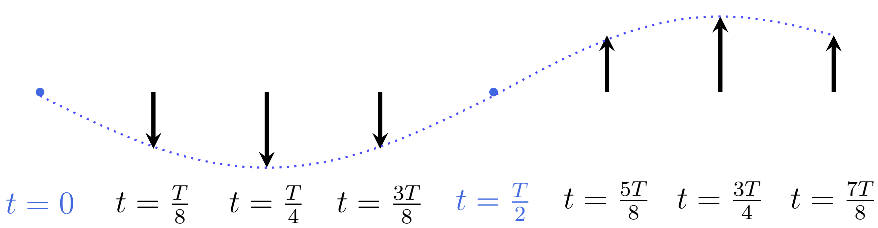
Problem 2

Consider vertically polarized light incident on a ***quarter-wave plate.*** After passing thorugh the quarter-wave plate, the phase of the component of the electric field parallel to the first axis has advanced one quarter of a cycle more compared to the component of the elecctric field parallel to the slow axis.

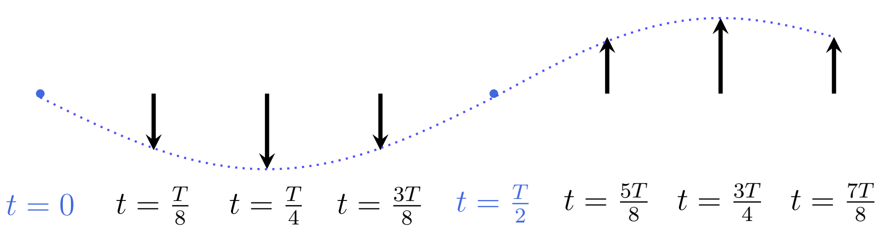
Consider a copy of the sketches from Figure 1.

a) Suppose the light passes through a quarter-wave plate with a fast axis along the vertical. Draw sketches as in Figure 1 showing the $\hat{x}$- and $\hat{y}$ components of the electric field vector *after* passing through the quarter-wave plate. Next to your sketches draw the shape traced out by the tip of the electric field vector, including an arrow indicating direction. [*Note: The x component will be particularly boring in this case!*]

Solution: Since the fast axis is along the vertical, we just take every single phase and shift it forward by a phase of $T/4$:



We can connect the tips of these vectors to produce a sine wave propagating in the $\hat{y}$ direction:

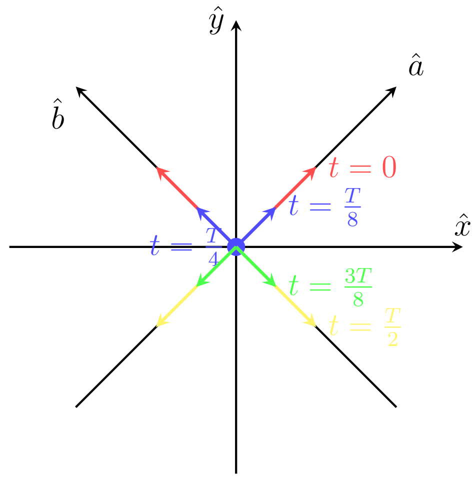


You should have found that your light was still vertically lineraly polarized (even though it's starting at a different point in the cycle). Similarly, if the fast axis were oriented along the $\hat{x}$-axis, we would also find that the light remains a vertical linear polarization. But what happens if we use a different axis?

Consider axes $\hat{a}$ and $\hat{b}$, oriented at angles of $\pm 45°$ relative to the $+y$-axis as shown to the right.

b) Draw a copy of Figure 1 and add in the projections of the electric field vector onto the two axes. This is our "starting point" for light before it passes through the quarter-wave plate.

Solution: Our vector projecton would look like this:



The idea is that as the wave is linearly polarized along the $\hat{y}$ direction, its magnitude reduces and becomes negative, but it is even split among the $\hat{a}$ and $\hat{b}$ axes.

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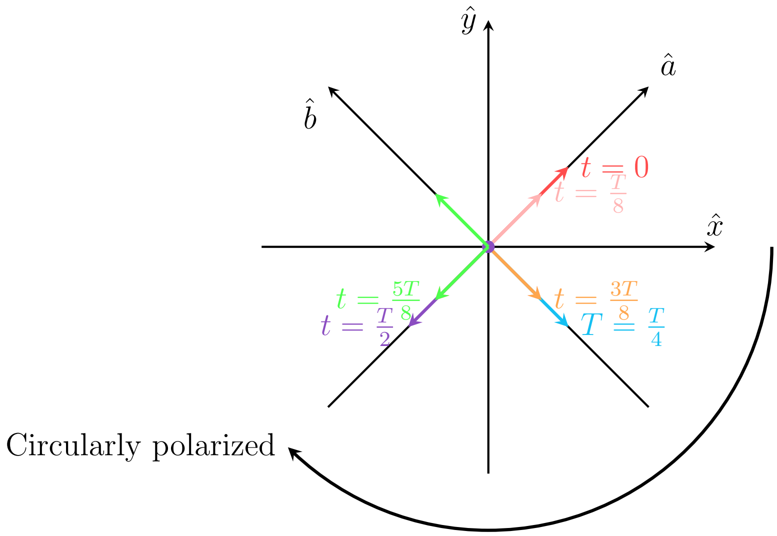
c) Suppose the fast axis of the quarter wave plate was oriented along the $\hat{b}$ direction. using your sketches from part (b), draw sketches showing the $\hat{a}$- and $\hat{b}$-components of the electric field vector ***after*** passing thorugh the quarter wave plate. In a different color, add the total electric field vector to your sketches. Is this left- or right-circularly polarized light?

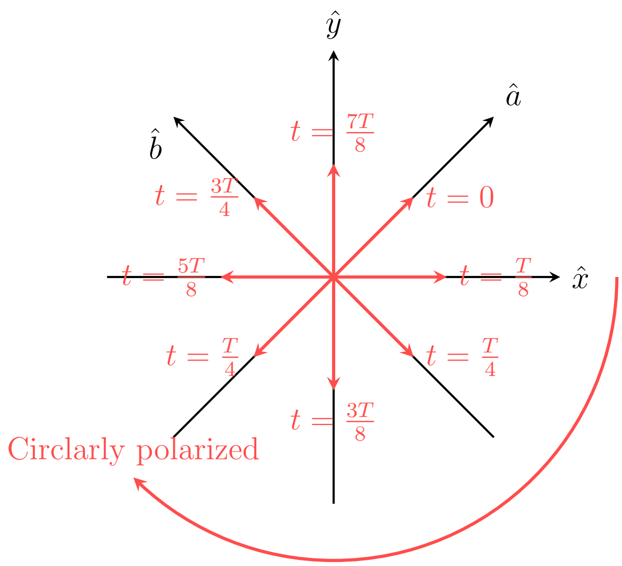
Hint: It may help to draw the shape traced out by the tip of the electric field vector, including an arrow indicating direction.

Note: Aligning the optical axis with the $\hat{a}$-axis will produce the opposite circular polarization

Solution: Refer to the following diagram:



Apologies for the bad diagram, the point is to show that at every point in time the vectors rotate along the $\hat{a}$ and $\hat{b}$ axes. If we sum up all these vectors, we get:

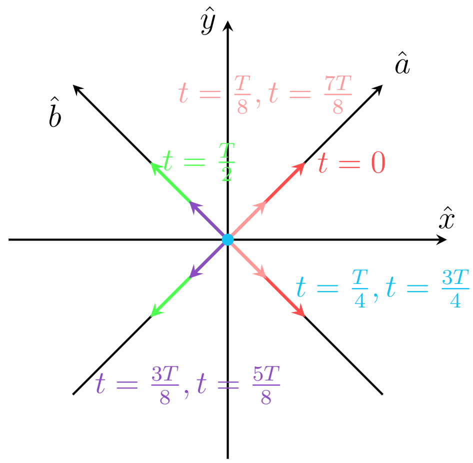


As we can see, the electric field vector appears to be moving clockwise, so this is **right circularly polarised light.**

Finally, suppose the light passes through a ***half-wave plate*** with the fast axis along the $\hat{b}$ direction.

d) Using your sketches from part (b), draw sketches showing the $\hat{a}$- and $\hat{b}$- components of the electric field vector ***after*** passing through the half-wave plate. In a different color, add the total electric field vector to your sketches. You should wind up with linearly polarized light. What is the polarization axis?

Solution: When the light passes through the half-wave plate, we see that the light is indeed linearly polarized, however we get that the light is polarized linearly along both the $\hat{a}$ and $\hat{b}$ axes.



Apologies for the diagram. The light is linearly polarized along the positive $\hat{a}$ axis and the negative $\hat{b}$ axis, then half a period later it flips to being a positive $\hat{b}$ axis and a negative $\hat{a}$ axis.

The net electric field sums to be linearly polarized light along the $\hat{x}$ axis: