

FACULTY NOTES

The LTAs and Spinoffs are designed so that each professor can implement them in a way that is consistent with his/her teaching style and course objectives. This may range from using the materials as out-of-class projects with minimal in-class guidance to doing most of the work in class. The LTAs and Spinoffs are amenable to small group cooperative work and typically benefit from the use of some learning technology. Since the objective of the LTAs and Spinoffs is to support the specific academic goals you have set for your students, the Faculty Notes are not intended to be prescriptive. The purpose of the Faculty Notes is to provide information that assists you to take full advantage of the LTAs and Spinoffs. This includes suggestions for instruction as well as answers for the exercises.



FACULTY NOTES

LTA 10

Exploring NASA's Automated Window Inspection Device (AWID)

Introduction

This project explores NASA's Automated Window Inspection Device (AWID). The device is placed on the Orbiter's windows and scans for defects. The surface of the window is scanned photographically, and the interior of the window is scanned using polarized light. Defects are located, examined and cataloged by the AWID. NASA scientists then determine if the window can be used on another flight or must be replaced.

Background Information

Prerequisite Skills: 2-D coordinate systems, lines.

Mathematics Explored: Vectors

Class Level: This LTA may be used anywhere you wish to apply or introduce vectors. This may be in precalculus, technical math, linear algebra, college algebra, 2nd or 3rd semester calculus, or physics.

Other Concepts: Polarized light.

Order of the LTA

AWID - Background: This is meant to introduce the basic idea of the AWID and why it is needed. It should be given to the students or presented to the students before starting the LTA.

The following describes an optional in-class demonstration that the instructor might perform to help students understand polarized light and the way it is used by the AWID to find defects.

Crossed Polarizer Demonstration: This should be done to demonstrate the way AWID uses polarized light to find defects on the Orbiter windows. The AWID distinguishes between surface dust or contamination and real defects in the Orbiter window by using polarized light. We have found that it is difficult to show this effect with glass, but it can be seen with the following setup.

- **Materials Needed:**
Overhead projector, two large (6" diameter) polarizers, thick "zip-lock" clear plastic bag or other clear, thick plastic storage bag.

- Procedure:
 1. Make a significant cut in one area of the plastic bag. Draw a dark line on the surface of another area of the plastic bag.
 2. Show the students the bag and make the distinction between the surface mark and the major cut.
 3. Place the plastic bag between the polarizers. Place all three on the overhead and shine light through them. Move the top polarizer until the transmitted light is minimized. (You may want someone to hold the plastic bag and bottom of the polarizer.) If all goes well, the surface mark you made will be blacked-out along with most of the light. The major cut, representing a major flaw in the shuttle window, will change the polarization and should still allow some light to be passed through it.
- Comments:

This is not a perfect representation of the AWID method, but it should give the basic idea. A major fold in the plastic bag should also work. We suggest you play with this ahead of time.

Experiment - Polarized Light and Defects in Transparent Materials: Since math students, and math faculty, may not have much familiarity with polarized light and how it can be used to see defects in windows, an experiment is included with this LTA. Your physics lab should have all the necessary equipment, and your local physicist should be able to help set things up. You and your local physicist can best determine how to produce transparent materials that have defects. Though it will take some extra time, we feel the experiment is essential for motivating the mathematics and understanding the Automated Window Inspection Device. It's also fun.

AWID Overview: (optional) This is a more detailed explanation of the AWID. The Overview is provided for the instructor, but it is written for students in case you would like to give the full context for the LTA. We have done our best to cover all the major properties of the AWID without writing a novel. Note: This is a good place for your students to do some research and writing. Topics could include: NASA, other properties of light, the history of glass making, meteors, space “junk” orbiting the earth, craters on the moon, etc.

Vector Worksheet: This worksheet is provided as a homework/classwork assignment. Even if the students have previously studied vectors, we have found that exercises such as these are necessary before proceeding. Note: If you have NOT taught vectors yet, now is the time to do so.

Vector Worksheet Solutions: Worksheet solutions are included.

Polarization of Light - The Vector Connection: This is an attempt to link polarized light and vectors.

Polarization of Light - The Vector Connection -Solutions: A solution set for the “Connections” is included.

Solutions

Vector Worksheet Practice Problems

Given the magnitude and θ , sketch the following vectors and find the vector components, v_x and v_y :

1) $|\mathbf{v}| = 2.398$, $\theta = 32.7^\circ$

$$v_x = |\mathbf{v}| \cos(\theta)$$

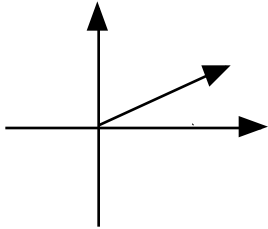
$$v_y = |\mathbf{v}| \sin(\theta)$$

$$v_x = 2.398 \cos(32.7^\circ)$$

$$v_y = 2.398 \sin(32.7^\circ)$$

$$v_x = 2.0179$$

$$v_y = 1.2955$$



2) $|\mathbf{v}| = 12.89$, $\theta = \frac{8}{7}$ radians

$$v_x = |\mathbf{v}| \cos(\theta)$$

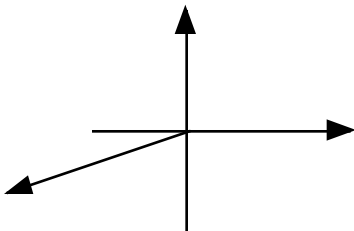
$$v_y = |\mathbf{v}| \sin(\theta)$$

$$v_x = 12.89 \cos\left(\frac{8}{7} \text{ rad}\right)$$

$$v_y = 12.89 \sin\left(\frac{8}{7} \text{ rad}\right)$$

$$v_x = -11.6135$$

$$v_y = -5.5928$$



3) $|\mathbf{v}| = 8.9823,$ $\theta = -108.72^\circ$

$$v_x = |\mathbf{v}| \cos(\theta)$$

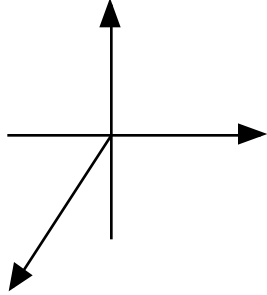
$$v_y = |\mathbf{v}| \sin(\theta)$$

$$v_x = 8.9823 \cos(-108.72^\circ)$$

$$v_y = 8.9823 \sin(-108.72^\circ)$$

$$v_x = -2.8828$$

$$v_y = -8.5071$$



Find the magnitude, $|\mathbf{v}| = \sqrt{v_x^2 + v_y^2}$, of each of the following vectors.

4) $\mathbf{v} = 3.34\mathbf{i} + 7.891\mathbf{j}$

$$|\mathbf{v}| = 8.5678$$

5) $\mathbf{v} = -2.268\mathbf{i} + 0.23\mathbf{j}$

$$|\mathbf{v}| = 2.2796$$

6) $\mathbf{v} = (4.764 \times 10^{-3})\mathbf{i} + (-3.124 \times 10^7)\mathbf{j}$

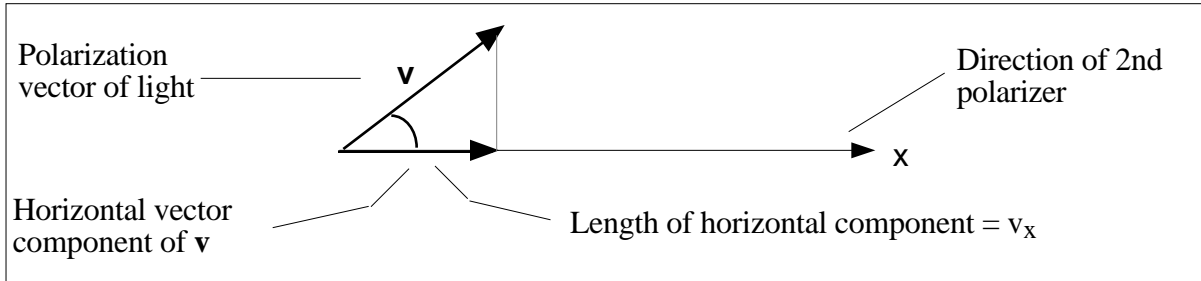
$$|\mathbf{v}| = 31,240,000$$

AWID - Polarization of Light - The Vector Connection

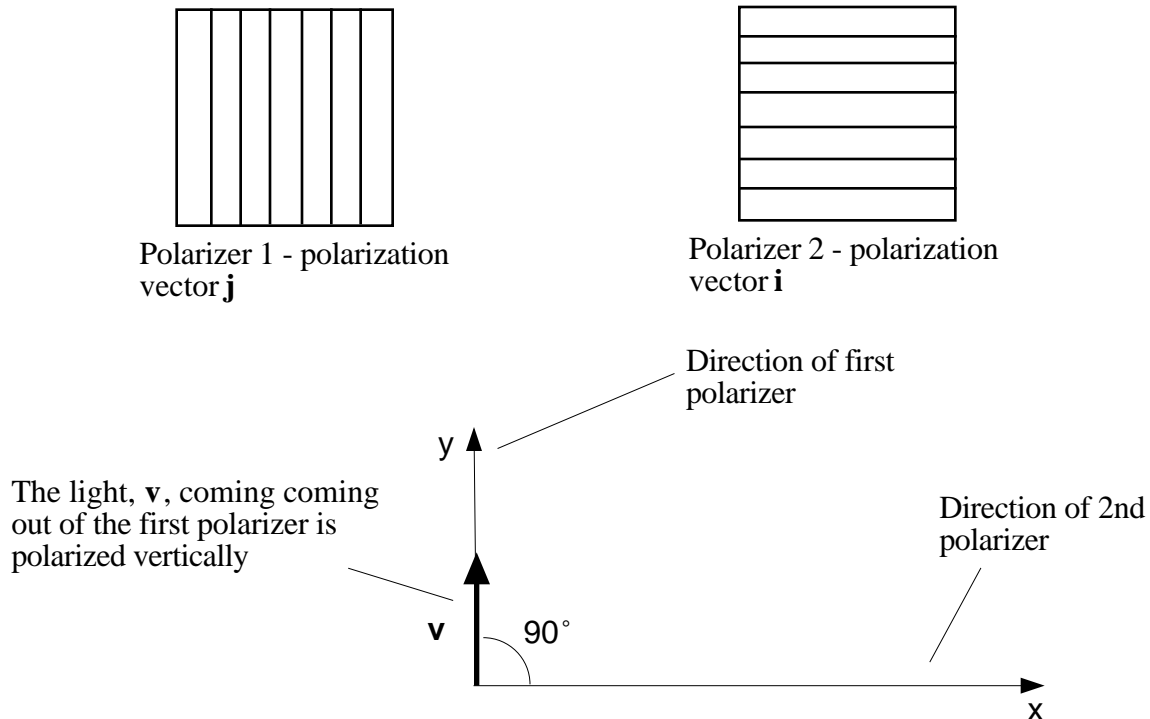
- 7) If θ is the angle between the polarizer and the polarization vector of the light, write an equation for the fraction of the polarization along the polarizer.

In the Figure below, only the horizontal component of the light's polarization would get through the polarizer. The length of the horizontal component of \mathbf{v} is v_x . As a result we have:

$$\text{Fraction of polarization along the direction of the 2nd filter} = \frac{v_x}{|\mathbf{v}|} = \cos(\theta)$$



- 8) In the **Experiment - Polarized Light and Defects in Transparent Materials** you adjusted the polarizers to eliminate all light passing through the second filter. Show, using vector components, how you were able to do this.



The horizontal scalar component, v_x , of \mathbf{v} is equal to 0. That is, $v_x = |\mathbf{v}| \cos(90^\circ) = 0$.

- 9) What should be the difference in the angles of polarization between two polarizers if you only wanted half the polarization to be along the direction of the second polarizer? $2/3$ of the polarization?

Note: If θ is the angle between the polarizer and the polarization vector of the light, then the amount of polarization along the polarizer will be proportional to $\cos(\theta)$.

- a) For $1/2$ the polarization to be along the polarizer direction, we want $\cos(\theta) = 0.5$ or $\cos^{-1}(0.5) = 60^\circ$.

$$v_x = \frac{1}{2} |\mathbf{v}| \quad \text{and} \quad v_x = |\mathbf{v}| \cos(\theta)$$

$$\frac{1}{2} |\mathbf{v}| = |\mathbf{v}| \cos(\theta)$$

$$\frac{1}{2} = \cos(\theta)$$

$$= \cos^{-1}(1/2)$$

$$= 60^\circ$$

- b) For $2/3$ the polarization to be along the polarizer direction, we want $\cos(\theta) = 2/3$ or $\cos^{-1}(2/3) = 48.19^\circ$.

$$v_x = \frac{2}{3} |\mathbf{v}| \quad \text{and} \quad v_x = |\mathbf{v}| \cos(\theta)$$

$$\frac{2}{3} |\mathbf{v}| = |\mathbf{v}| \cos(\theta)$$

$$\frac{2}{3} = \cos(\theta)$$

$$= \cos^{-1}(2/3)$$

$$= 48.19^\circ$$