Hands on Experiments with Light

Elena Vladescu
evladescu@gmail.com
National Vocational College “Nicolae Titulescu”, Slatina, Romania

Reteaua educationala
Hands-on Science - Romania
Instruire prin experiment

Education and Culture
Socrates
Comenius

Hands on Science

Center for Science Education and Training

1. Introduction

- “Hands on Science Romania” network and Center for Science Education and Training CSET, coordinated by Mr. dr. Dan Sporea, INFLPR Bucharest, received recently some OSA (Optical Society of America) kits - Optics Discovery Kit, in the frame of Photonics project, in partnership with New England Board of Higher Education (NEBHE), USA.
- Project Principal Investigator is Fenna Hanes (NEBHE). Co-principal Investigators are Professor Judy Donnelly (Three Rivers Community College), Dean Nicholas Massa (CCSU), and Marijke Kehrhahn (University of Connecticut). Also, Vernier Software & Technology, USA donated sensors for physics lab.

PHOTON2

New England Board of Higher Education · 1955 ·

Vernier
Vernier Software & Technology
www.vernier.com

Colegiul Național Vocațional „Nicolae Titulescu”

What is Photonics?

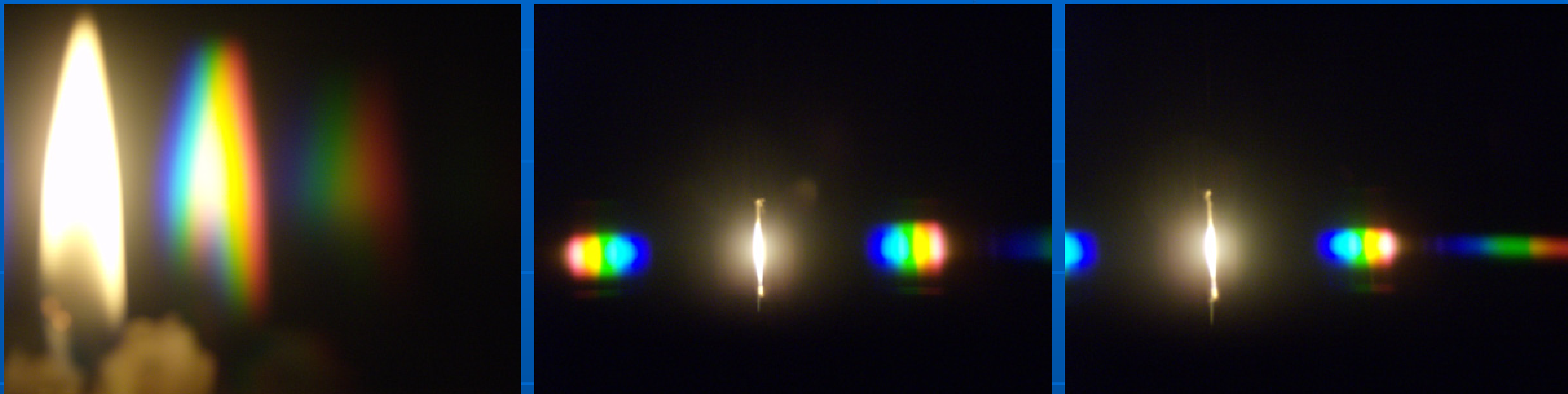
- Photonics is the practical application of light and optics. It is an enabling technology that integrates lasers, optics and electronics to develop applications in industries such as telecommunications, information technology, entertainment and displays, lighting, consumer products, precision manufacturing, biology and medicine, environmental sensing, homeland security and defense, astronomy and aerospace, and research. In this twelve-week online course educators learn about the science and technology of photonics through reading, problem solving, hands-on activities and discussion with peers. The overarching theme of the course is "How can I teach optics/photonics to my own students with the resources I have at hand?" The course have 6 optics/photonics units plus a "get acquainted" week and a summary week. Instructors: Professor Judy Donnelly (Three Rivers Community College, Norwich, CT, USA) and Donna Goyette (H.H. Ellis Technical High School in Danielson, CT, USA).

- National Vocational College “Nicolae Titulescu”, Slatina, Olt, Romania is an associated member of the “Hands on Science” network from 2004. A diversity of activities were developed: the promotion of physics experiments, as well as the set-up of a web site with our results, a secondary school contest “The web site of my class”, an art exhibition organized by the best students of art classes, our participation on “Hands on Science” network’s exhibition to the European Commission, activities of the biology club and of the chemistry club.
- As a reward of our participation in HSCI, we received two training kits for mechanics, an OSA kit and Vernier sensors of motion, force and temperature. Unfortunately, our Physics laboratory’s endowment is very old and inadequate. Therefore, these training kits were welcomed.
- I will present you some hand-on experiments with this equipment, in the Photonics project.

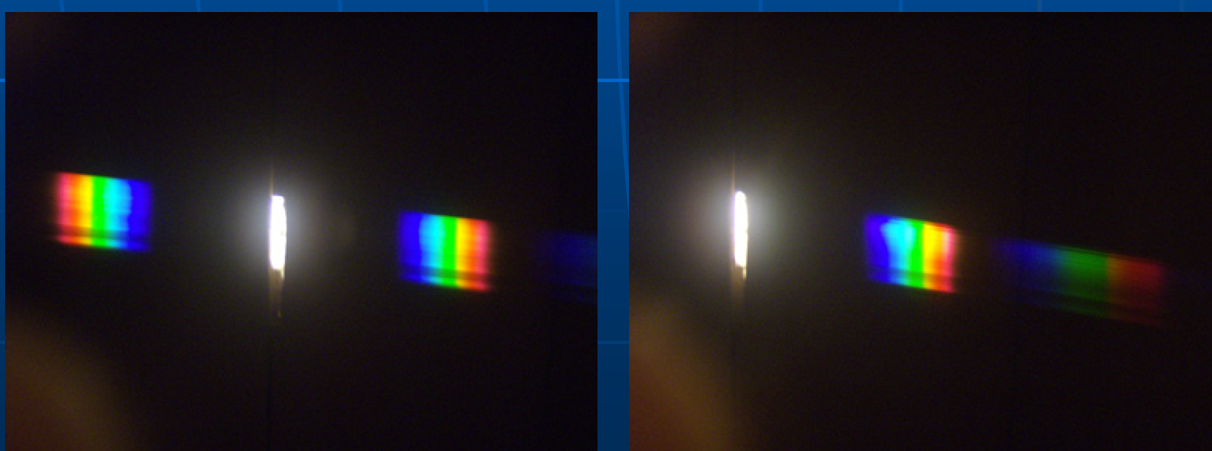
1. Exploring Light Spectra

- Objective: the study of spectra for different sources of light (candle, incandescent bulb with various colored filters, Laser pointer, LED on electronic equipment, fluorescent bulbs, LCD monitor, and Sun light)

- Materials: OSA Kit 500 lines/mm grating, a "toilet paper tube spectrometer‟, a cardboard box with slit .

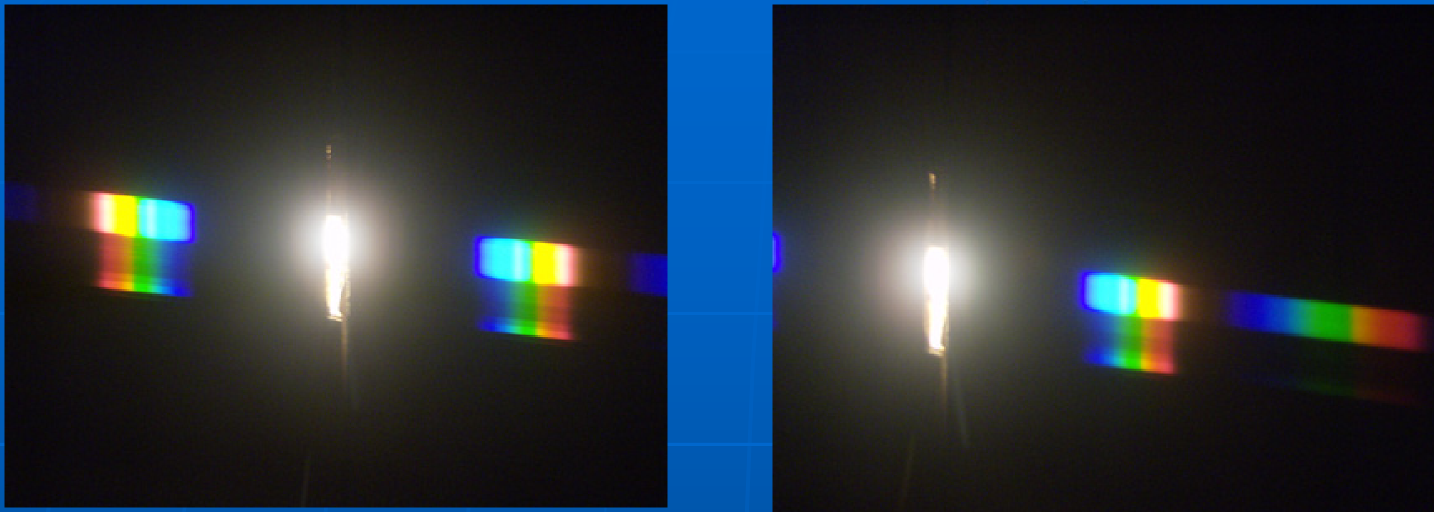


a candle flame spectrum

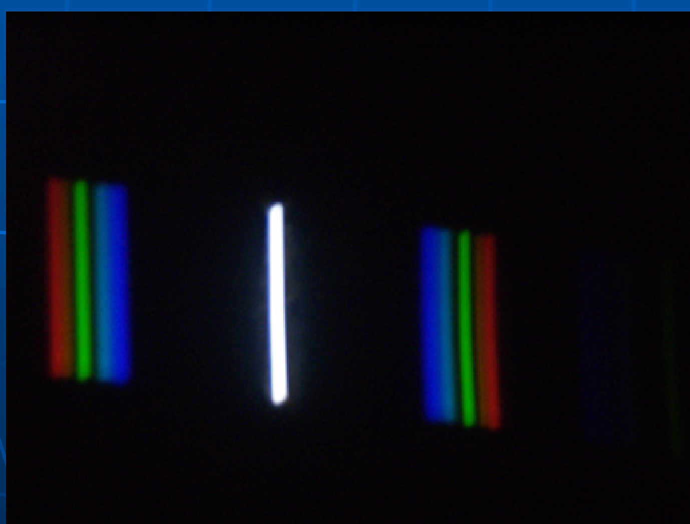


incandescent clear bulb

Sun light spectrum



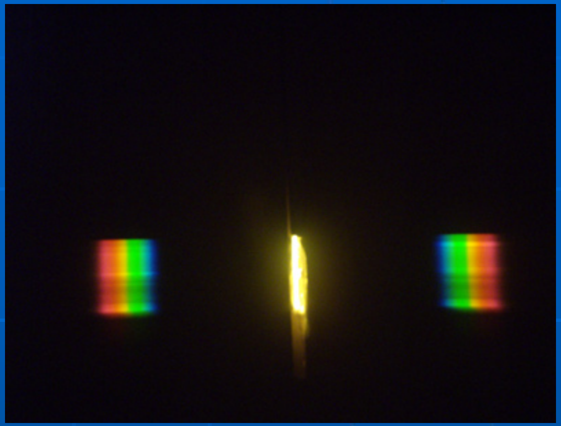
Fluorescent bulb



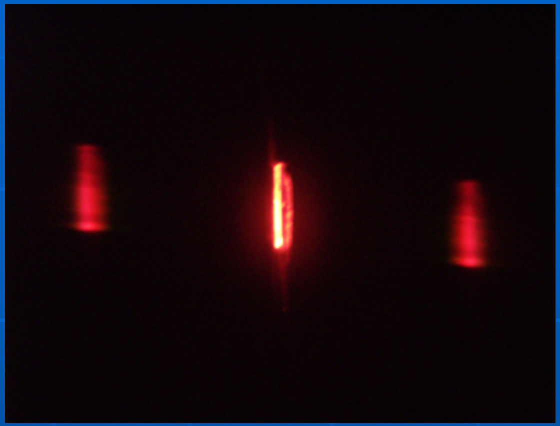
LCD Monitor

LED

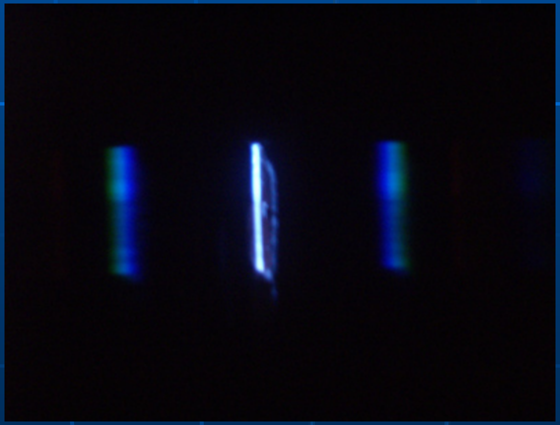
- For the incandescent clear bulb, I used also color filters. Here are my observations:
- 1) Yellow filter – removes violet and most of blue; allows through red, orange, yellow, green and a little blue
- 2) Red filter – removes all colors except red
- 3) Blue filter – removes orange, yellow and red; allows through violet, blue, and green
- 4) Green filter – removes violet, orange and yellow; allows through a little blue, a lot of green, and a little red



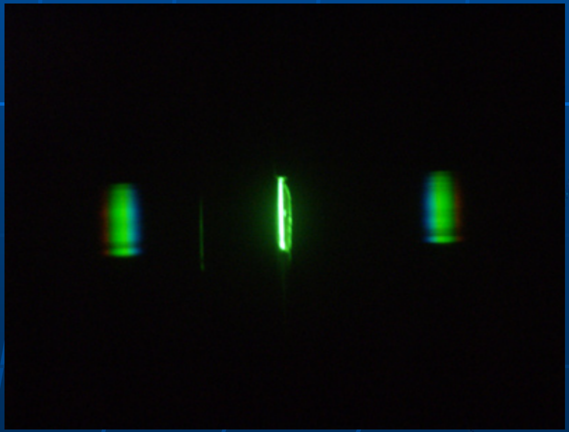
Yellow filter



Red filter



Blue filter



Green filter

- Conclusions:
- After this lab, I can’t tell what colors are in a light source by looking at it with my unaided eye. LCD monitor surprised me. I am sure now that all white lights have the same colors spectrum, depending on the substance of the source. This experiment was used for the study of continuous emission spectra, but can be improved for the band and lines emission spectra and absorption spectra.

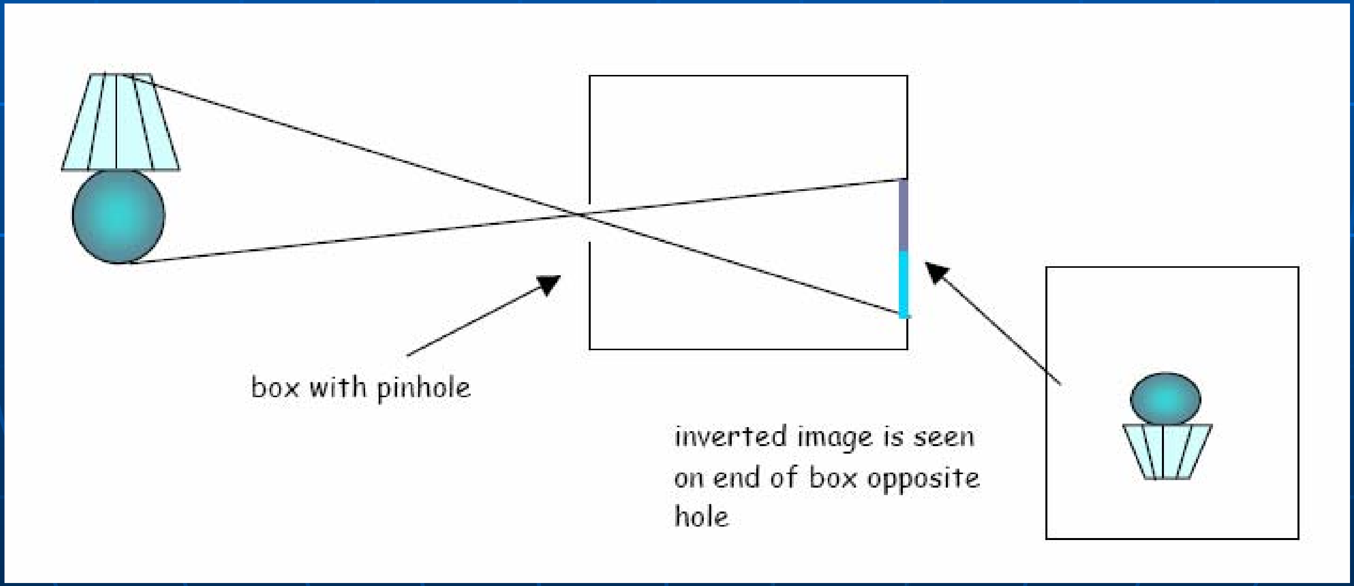
2. The Color Spectrum (http://school.discovery.com/lessonplans/programs/colorspectrum/)

- Objective: to create a model of the infrared, visible, and ultraviolet portions of the electromagnetic spectrum
- Materials: Meter stick or metric ruler (marked in millimeters), scissors, scotch tape, several pieces of paper in the following colors: red, orange, yellow, green, blue, violet, white, and black (paper will be cut into 1-inch-wide strips), black marker, prism, flashlight (optional), a copy of The Color Spectrum: How Does It Work? Data Sheet for each student
- Procedure: The scale that will be used to build their model of the spectrum is 1 nanometer equals 1 millimeter. So if a wavelength is *X* nanometers, the model for that wavelength should measure *X* millimeters. Students will need to show the work they've done on their calculations in the space provided on the data sheet. The class is divided into small groups of two or four. Work together as a class on the metric conversion calculation for red light. Red paper will be used for the wavelength of red light, orange paper for orange light, and so on. White paper will represent infrared, and black paper will represent ultraviolet. After groups have completed their model spectrum, they will shine white light through a prism in order to see the visible spectrum they have just modeled.

A model of the IR, VIS, and UV portions of the electromagnetic spectrum created by two 10th grade students

3. Pinhole Camera

- Objective: the study of the image formed by a pinhole camera
- Materials: Large carton or box with the bottom removed, Aluminum foil, needle, tape
- Procedure: Cut a hole approximately 5 cm square in the center of one end of the box. Tape an aluminum foil with a pinhole over the hole in the box, centering the pinhole. Aim the pinhole toward a light source and look up through the open bottom of the box to observe the image on the end opposite the pinhole. Like a lens, the pinhole can form an image on a screen. The rays from the bottom of the lamp do not overlap the rays from the top because of the small size of the pinhole.



The pinhole camera viewer (Copyright Project PHOTON. © New England Board of Higher Education, 2005. Used with permission.)

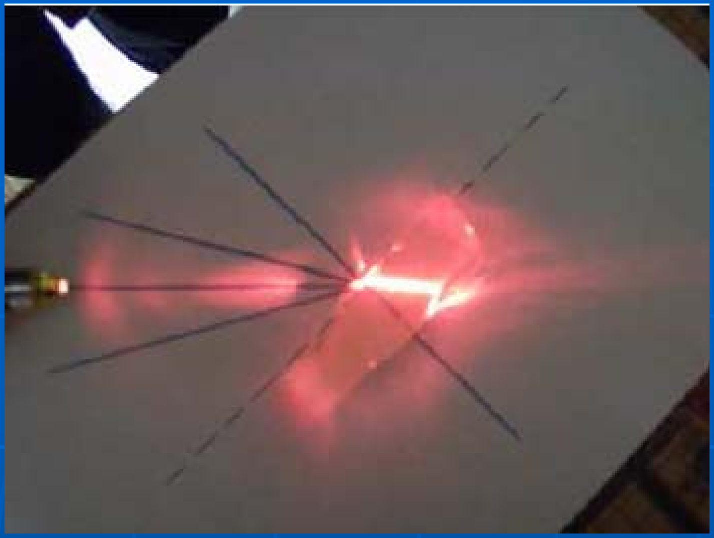
- Because the pinhole is
- small, exposure times are very long compared to those with a lens. The height of the image (hi) are calculated by similar triangles.:

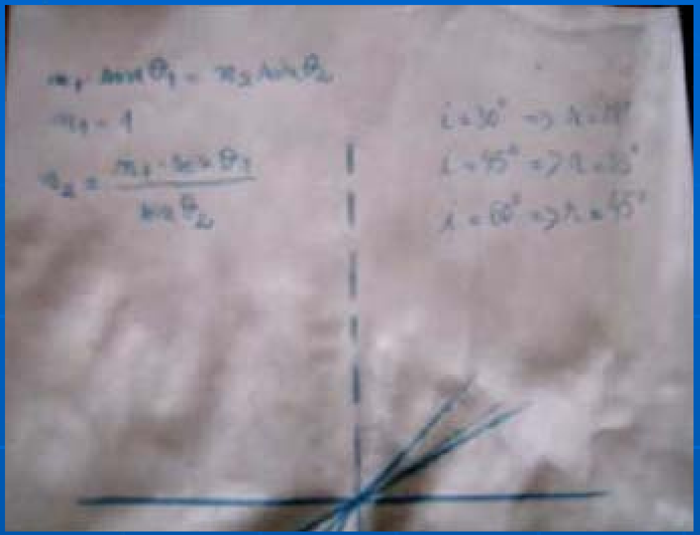
$$\frac{h_i}{h_o} = \frac{d_i}{d_o}$$

- For a distance from the pinhole to the screen di=30cm, a height of the object h0=10cm and a distance from the object to the pinhole d0=1m, we obtained hi=3cm.

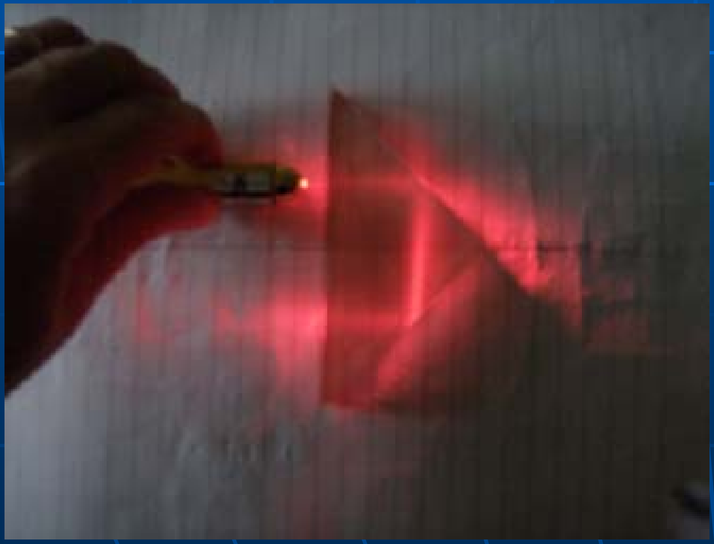
4. Refraction

- Objectives: demonstrate Snell's law of refraction, experimentally determine the index of refraction of gelatin, plastic and glass
- Materials: gelatin, laser pointer, protractor, a piece of white paper, a piece of plastic and another of glass
- Procedure: The heaviest but funniest thing to do is to make the block of gelatin. The object is to have a rectangle of gelatin about at least 2 cm thick and 4-5 cm square. The length is not too important, but the edges that light will travel through need to be very straight and flat. ; if you are not a patient man, use a piece of plastic or glass.
- We will need a piece of paper with optical axis, the normal and three angles of incidence of 30, 45 si 60 degrees drawn with a pencil. The laser must be directed so that the beam enters the gelatin at (above) the point where the normal line meets the surface, and we must note the point where the refracted beam exit on the other side. measured the angles of incidence and refraction, using the protractor from the normal line. I used Snell's Law $n_1 \sin\ \theta_1 = n_2 \sin\ \theta_2$
-
- to calculate gelatin’s index of refraction of gelatin, plastic and glass.
- Additional, you can make a gelatin "prism" (triangle) and see how some incident angles lead to total internal reflection at the opposite side, an optical "fiber‟ or lens shapes.

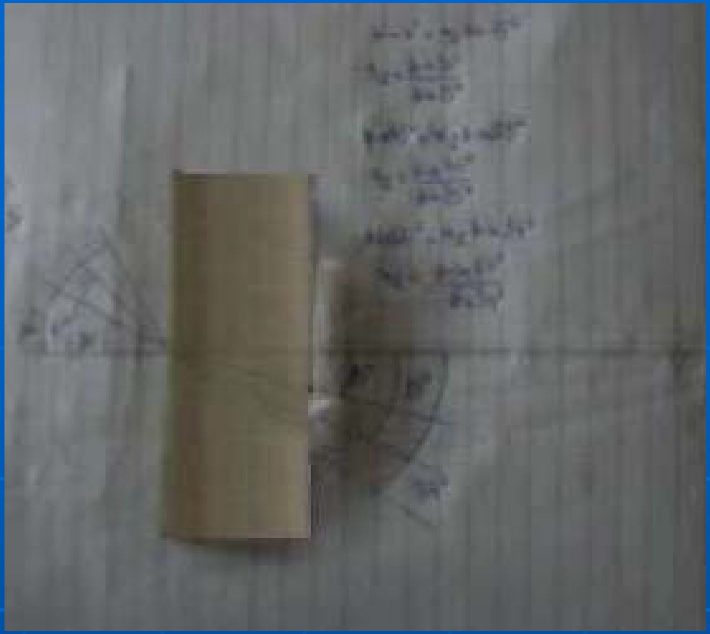




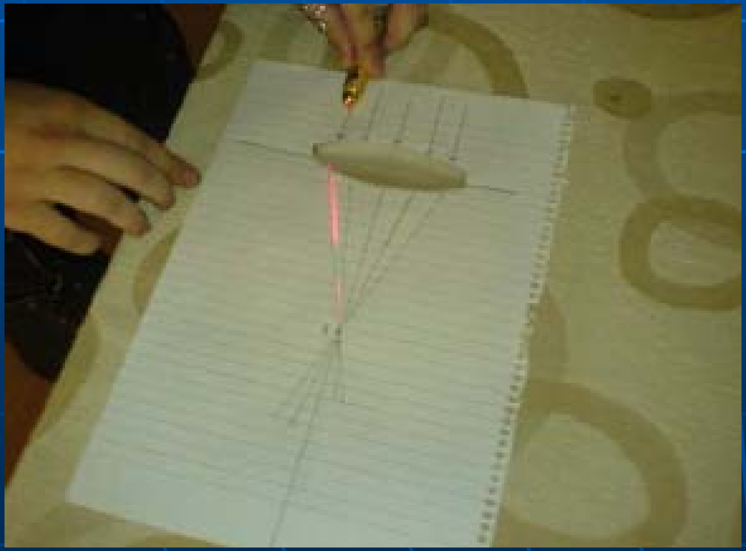
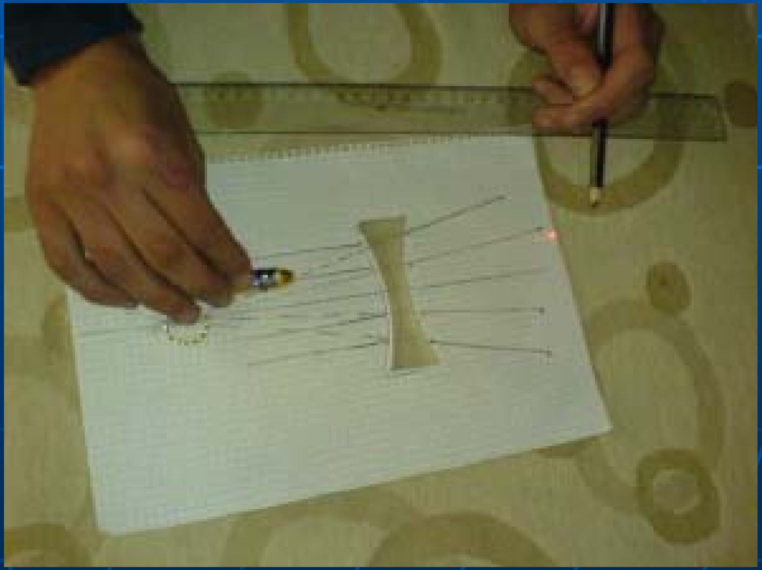
experimentally determine the index of refraction of gelatin



total internal reflection in a plastic “prism” and in a gelatin optical “fiber”




n for a piece of plastic

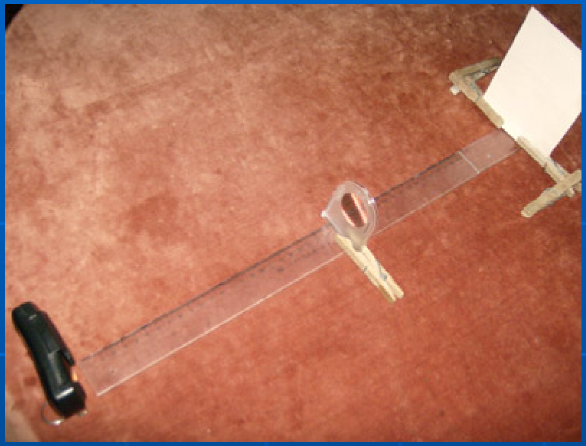
experimentally determine of the location of the focus for plastic lenses

5. The Thin Lens Equation

- Objective: To measure and observe image location, size and type for a converging lens
- Materials: small flashlight, the larger converging lenses from the OSA kit (labeled A), a small piece of aluminum foil, clothespins, card for screen, three rulers
- Procedure: The object was a small narrow triangle of aluminum foil taped to the center of the front of the flashlight, small enough so that light can shine around it on all sides. With object 30cm from the lens, I moved the screen back and forth until a
- clear image was formed. The image was 12.5cm to the right of the lens, inverted and smaller than the object. Using the thin lens equation

$$\frac{1}{-30cm}+\frac{1}{f}=\frac{1}{21.5cm}$$

$$f=12.52cm$$



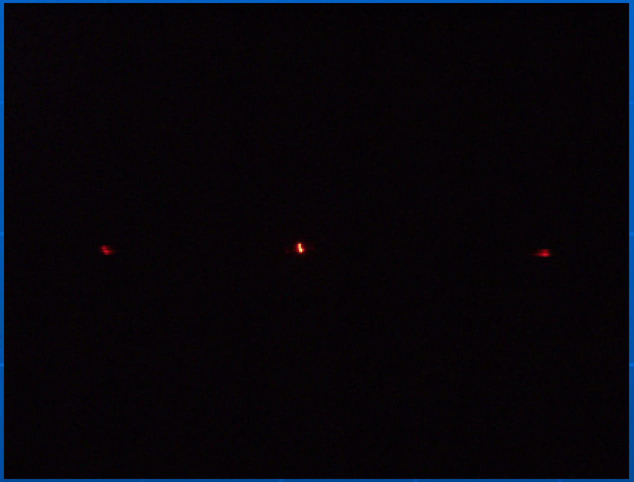
Experimental device

The object

- I calculated also the magnification M=-21.5/30=-0.71.
- I tried a few different object distances and calculate an average focal length from
- all my measurements: f=12,5 cm.
- If the object distance is 50cm to the left of the lens, using the thin lens equation I found that di=16.67cm.
- After I performed the experiment with the object set at 50cm to the left of the lens,
- I measured an image distance of 16.5 cm, close enough to my prediction.

6. The Diffraction Grating

- Objective: To determine the wavelength of diffracted light, by means of a transmission grating.
- Materials: Laser, Diffraction grating from OSA kit, a wall for the viewing screen
- Procedure: for a distance from the screen of x=1m I was able to see only the 1st order maximum, and for x=20cm I was able to observe 2 orders of diffraction (the second order only to the right side of the zero-order maximum. Formula used for i=0:
- $m \lambda = d \sin \theta$ si $tg\, \theta = y/x$.
- In the first case, I obtained λ=662nm, and in the second λ=654,5nm. My red laser pointer was an old toy laser and I couldn’t see the label. But, knowing that
- the wavelength of such a laser is typically 650 or 670 nm, and using the average wavelength of this range (660 nm), my percent error was -0.84%.



Diffraction pattern for x=1 m

Diffraction pattern for x=20cm

7. The Air Wedge

- Objectives: the study of interference fringes for an air wedge and the measurement of the thickness of hair
- Materials: laser pointer, rule, two microscope slides
- Procedure: I thoroughly cleaned two microscope slides and pushed them together, squishing out the air between. I looked at the light reflected from the slides: sun light, incandescent light bulb, and laser light (the picture was not good). To make a monochromatic source of light, I wrapped a mirror with wax paper and illuminate it with the laser beam.

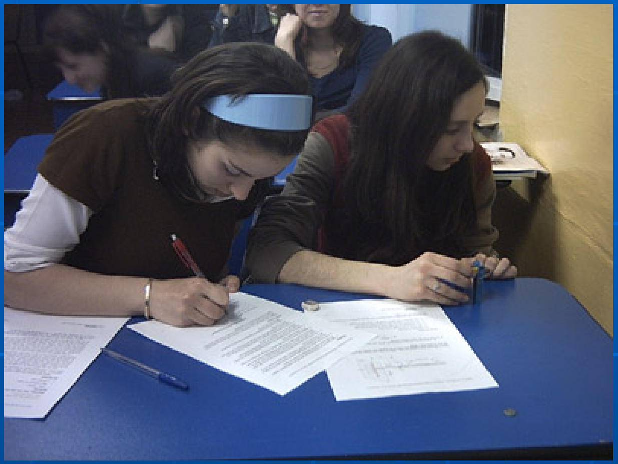
Interference fringes in sun light

Interference fringes in artificial white light

- I counted the number of fringes per 0.5 cm at several locations, because was very, very hard and I multiplied by the total length 7.5 cm. Also, my wrapped mirror didn't illuminate the whole length of the glass plates, but only a little area. In order to make a better counting, I marked the wax paper in 1 cm increments with a pencil.
- I found m=34 fringes/cm x 7.5 cm=255 fringes. I used a magnifying lens and my husband's hair (dark-haired). Unfortunately, I couldn't make a good photo.
- The thickness of hair measured by my air wedge was t=m8/2=(255 x 660 nm)/2=84,15 6m, which is reasonable, I think.

8. Diameter of a Hair

- Objective: Measuring the Diameter of a Hair by Diffraction
- Materials:Laser Pointer, Tape measure or ruler, 2 clothes pins
- Procedure: I set up this experiment with my students from 10th R2 grade. My students taped a piece of their hair across the output aperture of a red laser. The laser
- light diffracted around the hair and a pattern of light and dark spots were formed on a
- distant screen. We used for the diameter of the hair $d = \frac{m\lambda x}{y}$
- We measured the distance from the laser to the screen x= 2,38 m and for m=1, we found
- y=2 cm, so d = 78,54 6m.

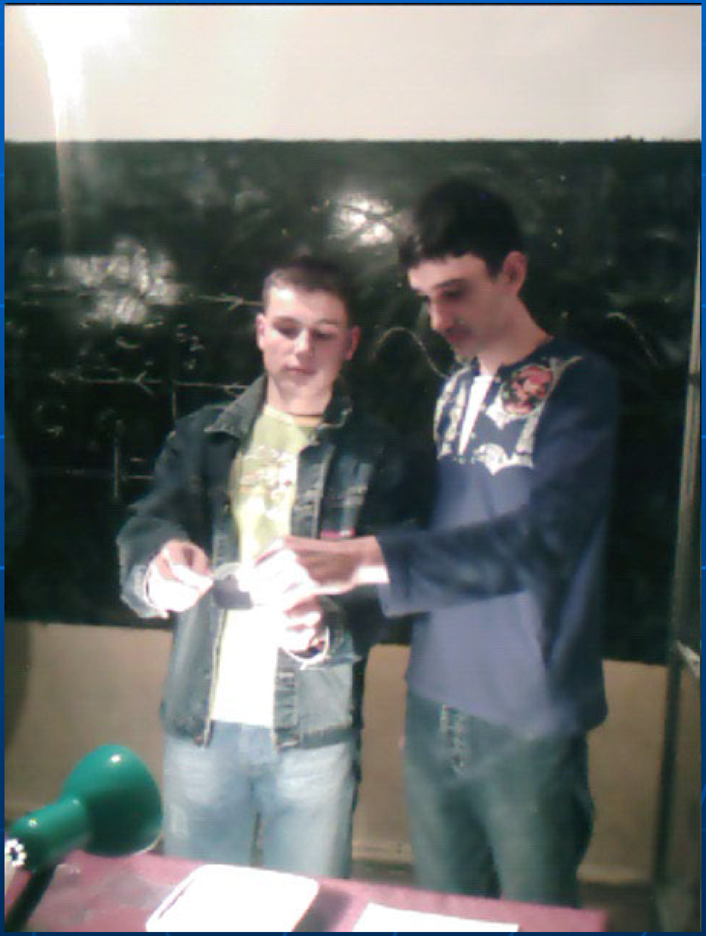


Experimental device

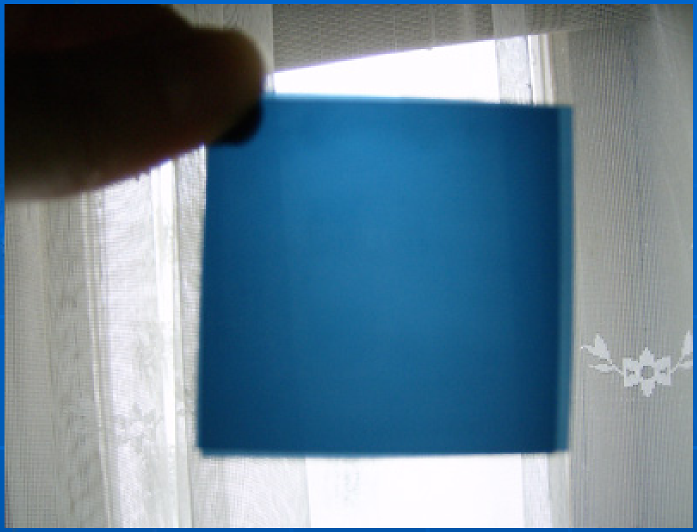
9. Polarization of light

- Objective: exploring polarization
- Materials: two pieces of polarizing plastic from the OSA Optics Discovery kit, bowl of water, transparent plastic objects: ruler, protractor, comb, etc.
- Procedure: "Natural" or randomly polarized light has light waves that vibrate in all directions, and the vibration directions vary randomly in time. When randomly polarized (natural) light is passed through an optical element known as a linear polarizer, one component of the electric field
- vector is absorbed, resulting in light that is strongly polarized in one direction.
- To determine the transmission axis of the polarizer, you need to view the glare or shine from surface such as glass, water or ice through one of the polarizing filters. While looking through the polarizer, rotate it and notice that the reflected light becomes dimmer and brighter. When you can see the reflection at its brightest, the transmission axis of the polarizer is horizontal.

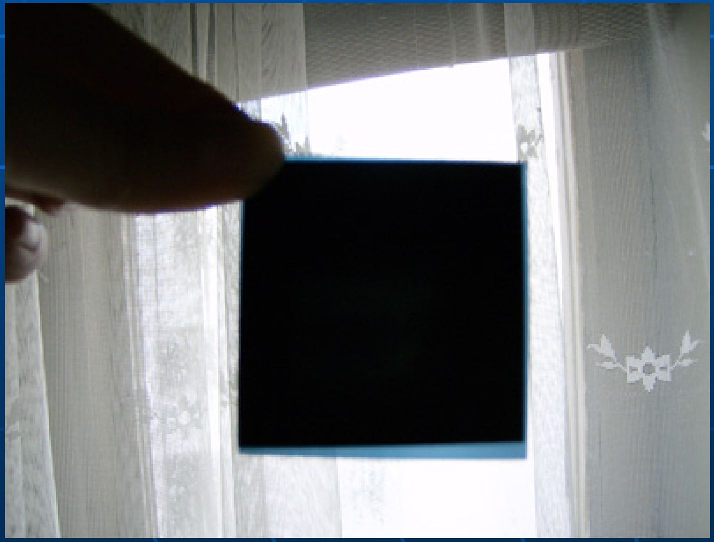
- We marked the polarizer with a piece of tape to know which direction is the transmission
- axis. We repeated with the other polarizer. The light is partially dimmed by the parallel polarizers and completely blocked when they are "crossed" or held with transmission axes perpendicular.
- When we place a transparent set square between the crossed polarizers, the plastic changes the plane of polarization an amount depending on the thickness of the square.
- The effect is wavelength dependent, producing beautiful clear colors.
- I set up this experiment with my students from 10^{th} R2 grade.



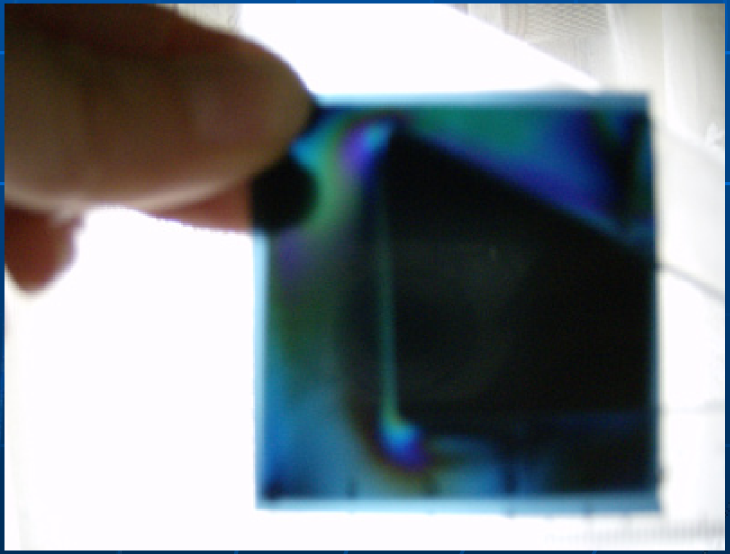
Natural light viewed through a linear polarizer



Two parallel polarizers



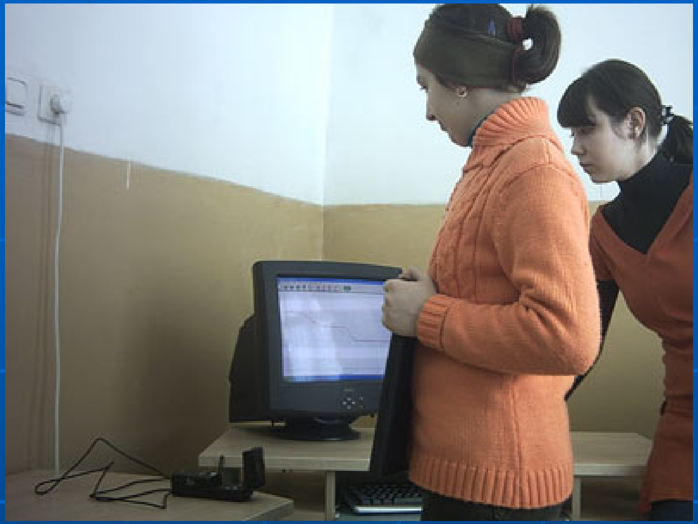
Two crossed polarizers



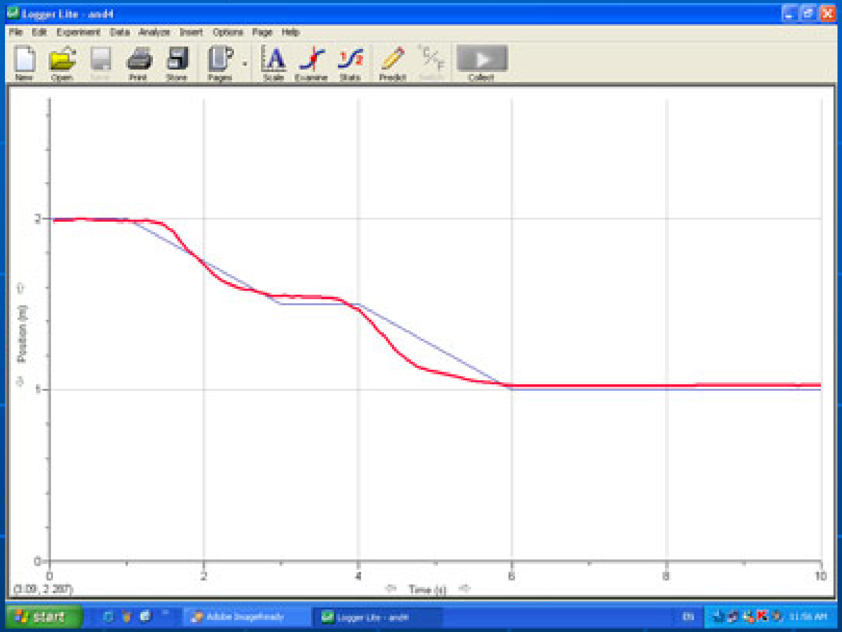
a set square between the crossed polarizers

10. Graph Matching

- Objectives: Analyze the motion of a student walking across the room, predict, sketch, and test position and velocity vs. time kinematics graphs.
- Materials: Vernier Motion Detector, computer, meter stick, masking tape
- Procedure: I set up this experiment with my students from 9th R2 grade.
- We placed the Motion Detector so that it points toward an open space at least 4 m long. We used short strips of masking tape on the floor to mark the 1 m, 2 m, 3 m positions from the Motion Detector. Using LoggerLite program, a student walk away from the detector with constant velocity and another click on “Collect” button.



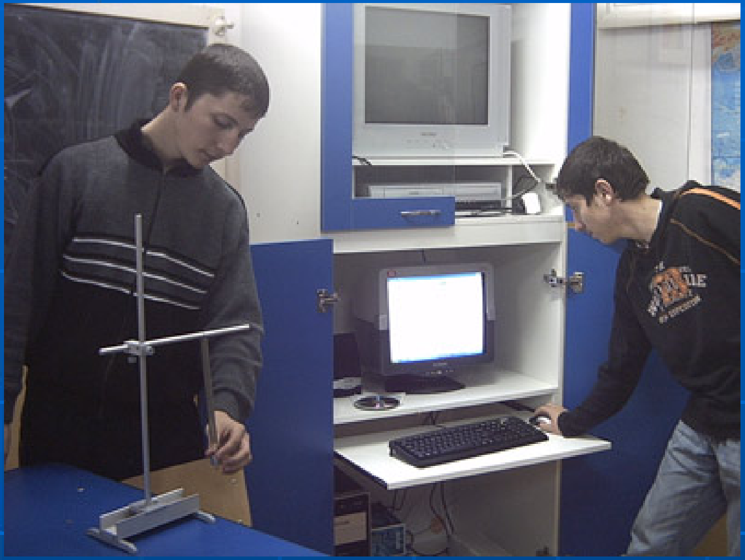
- The program sketch in the same time graphs d=f(t), v=f(t) si a=f(t). You can open the experiment file "01 Graph Matching." Some position and velocity vs. time graphs will appear.
- You can describe how you would walk to produce this target graph, and then test your prediction.

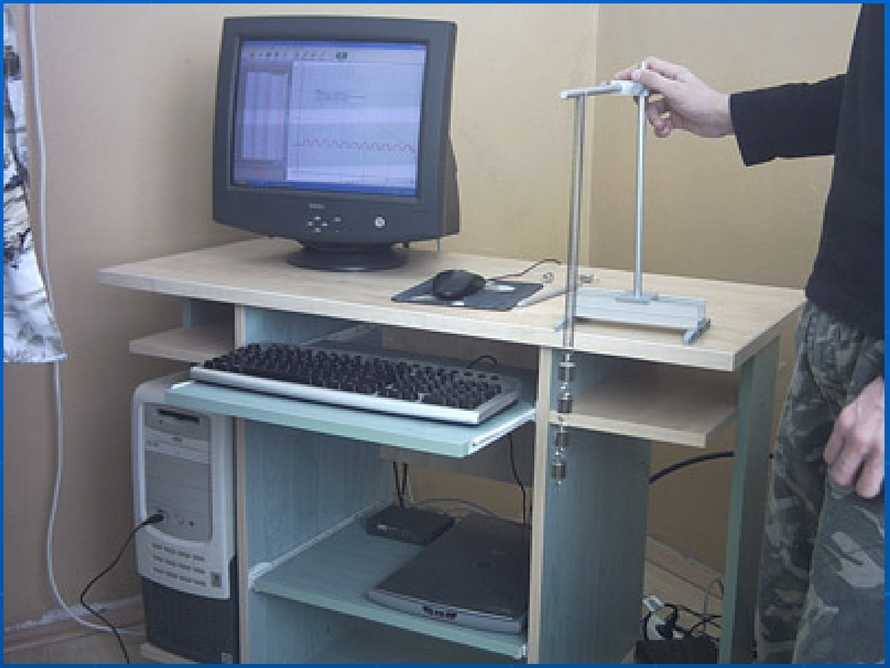


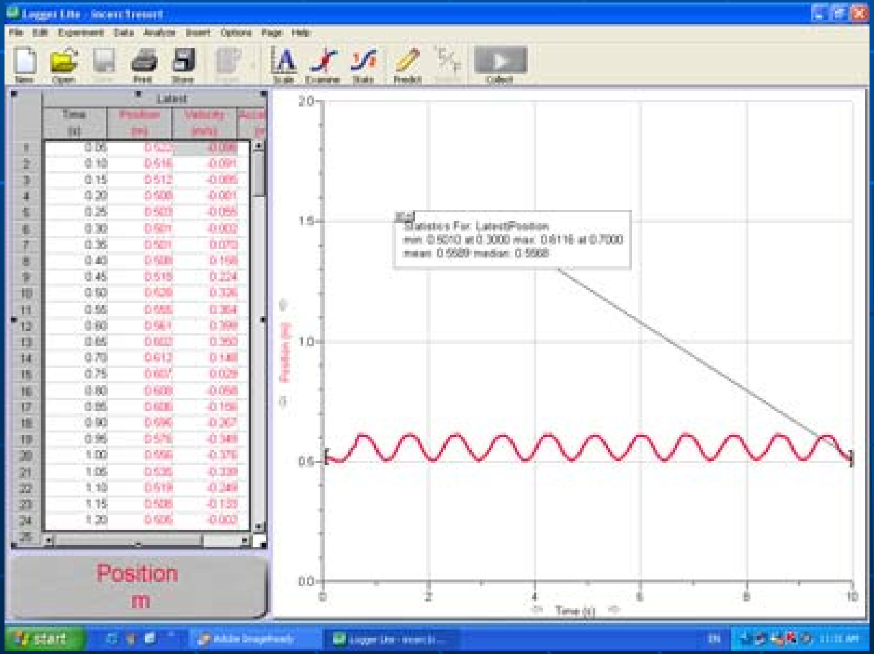
An exemple of d=f(t) graph obtained with Vernier Motion Detector

11. **Simple Harmonic Motion**

- <u>Objectives</u>: measure the position and velocity as a function of time for an oscillating mass and spring system, determine the amplitude, period, and the frequency of the observed simple harmonic motion using the Vernier Motion Detector
- <u>Materials</u>: spring, computer, Vernier Motion Detector, rods, ring stand, clamps
- <u>Procedure</u>: I set up this experiment with my students from 9th R2 and 11th R2 grades.
- First we established A=2cm and we collected data for a mass of m=150g, 200g si 250g hanged from a spring. After 10 s, data collection will stop. The position graph should show a clean sinusoidal curve. If it has flat regions or spikes, reposition the Motion Detector and try again. Using the position graph, we measured the *period*, *T*, of the motion and we calculated the frequency, *f* (*f* = 1/*T*).







An exemple of a simple harmonic motion graph obtained with Vernier Motion Detector

References

- www.nebhe.org
- www.inflpr.ro
- http://hypertextbook.com/physics/waves/refraction/
- http://www.hazelwood.k12.mo.us/~grichert/optics/intro.html
- http://www.edmundoptics.com/
- http://www.cvilaser.com/
- http://school.discovery.com/lessonplans/programs/colorspectrum/
- http://www.geocities.com/cnvntslatina
- http://www.geocities.com/physicsexperiments

Acknowledgements

- I would like to thank Ms. Fenna Hanes - Principal Investigator , Judith Donnelly, Donna Goyette and Mr. Nicholas Massa - Co-Principal Investigators New England Board of Higher Education (NEBHE), USA, the "Hands on Science Romania" and Center for Science Education and Training CSET national coordinator Dr. Dan Sporea for their support and encouragements.
- Also, I would like to thank Vernier Software & Technology, USA for their generous donations.