To anybody fond of physics demonstrations:

Please find enclosed five demonstration articles by a retired Finnish physics teacher. All the articles have been published at The Physics Teacher (TPT), the journal of AAPT, the American Association of Physics Teachers:

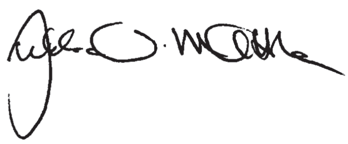
1. "A post-prandial altimeter", TPT September 1981, p. 410-411
2. "Physics at the Fire Station", TPT October 1988, p. 440
3. "Spectral Experiments with White Light", TPT September 1994, p. 338-339
4. "Laptop Art", TPT February 1996, p. 78-79
5. "Reindeer Diode", TPT January 2013

Three of the articles (3, 4 and 5) have given rise to the cover picture of TPT.

In addition there is an article "The Foucault pendulum as a teaching aid", published by the British IOP Publishing Ltd at Physics Education 26 (1991)

A live demonstration: http://www.youtube.com/watch?v=BpYs4YfEEuY

With best regards,



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How to turn your aircraft lunch tray into an altitude meter

A post-prandial altimeter

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I read with enthusiasm the article, "Science activities for school trips," by Walter C. Quint [Phys. Teach. **18**, 584 (1980)]. It reminded me of a recent trip to Hungary made by the Association of Finnish Teachers of Mathematics, Physics, and Chemistry, in June 1979. Altogether 319 members and family members of our society took part in this week-long endeavor, during which we attended lectures and recreation provided by our Hungarian host, the Roland Eötvös Physical Society.

On the flight back from Budapest to Helsinki, lunch was served by the air hostesses. Among the other items on the crowded lunch tray there was a tightly sealed plastic fresh-water cup. Its both ends bulged markedly. The reason for the bulging became clear when the pilot announced over the intercom that our altitude was 11 900 m and that the cabin pressure corresponded to an altitude of 2400 m. Thus, the air space of the cup functioned like the pressure casing of an aneroid barometer.

As I was the leader of our touring group of 319 educative people, I felt it my duty to turn that bulged fresh-water pressure casing into a physics demonstration. I decided to construct an altitude meter, using only the material existing on my lunch tray. The result can be seen in the photograph.

The pressure casing (1) is the tightly sealed fresh-water cup.

The base-plate (2) is the warm-food tray, emptied, wiped clean, and turned upside down.

The indicator (3) is made of the aluminium wrapper of the warm-food tray. By rolling the rectangular wrapper diagonally a long, light, and rigid indicator was produced. The other end of the indicator was "glued" on top of the pressure casing with jam (also found on the tray).

The indicator fulcrum system (4) was constructed by fixing the toothpick vertically between the indicator and the base-plate alongside of the pressure casing.

The scale (5) was drawn on the backside of a brochure. Unfortunately, there was no suitable large-size scale material on the lunch tray.

I visited the cockpit to show the altitude meter to the pilot. (On the way to the cockpit one of the air hostesses almost crushed my dream by assuming that I was bringing the tray garbage to her!)

The pilot confirmed that the cabin pressure really is approximately inversely proportionate to the altitude of the plane so that my instrument could indeed be used as an altitude meter. Of course, the device was first and foremost a pressure indicator, even quite an accurate one, but at that moment, approaching home again, the decreasing altitude was a much more interesting quantity than the pressure itself.

We agreed that the pilot would announce even kilometers – 11, 10, 9, 8, etc. – over the intercom during our descent on approaching the Helsinki airport. This was done and the scale could thus be calibrated. The whole planeful of colleagues witnessed the constant rising of the indicator tip during the descent. At ground zero I crushed the device and drank the water.

The end of the indicator moved 60 mm in all. The enclosed photograph was taken at the ceiling altitude, so the lower altitude numbers were still missing.

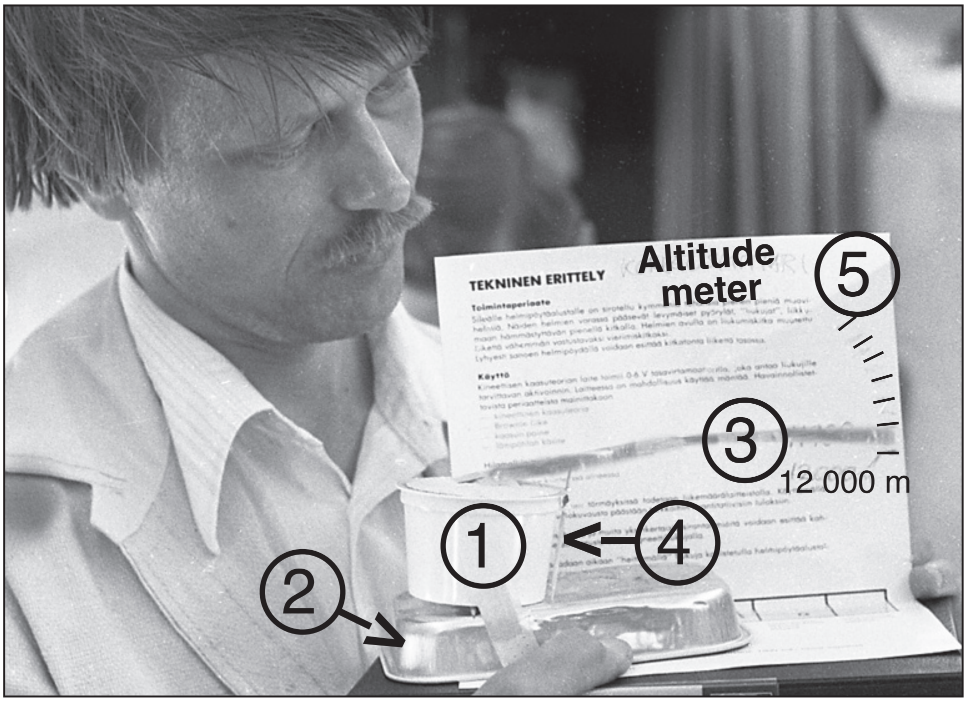

Fig. 1. An altimeter using materials on airline lunch tray.

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Having performed this demonstration several times I have learned a hard lesson. There are two types of empty 200 liter oil barrels: light and heavy. The latter do not crush. If you want to perform this demo, take two identical barrels. Test one of these first. If it works, crush the other one with audience. – JOM

Physics at the Fire Station

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There is a lot of physics involved in the everyday work of the fire brigade. Modern rescue work necessitates sophisticated devices, such as metal detectors and instruments for measuring radioactivity.

Much of the rescue equipment deals with pressure differences. You can lift a car by pumping air into a huge air bag placed under the vehicle, or empty a leaking oil container by attaching a large vacuum suction cup to it.

To complete a set of pressure demonstrations for a physics class visiting our local fire station, we performed the popular classroom demonstration of crushing an oil container using air pressure but on a larger scale, using a 200-liter oil barrel. The fire brigade had everything needed for the task, even the free time!□

Fig. 1. One liter of water is poured into an empty 200-liter oil barrel.

Fig. 2. Fireman Pertti Siren watches steam rise from the barrel while he heats the bottom with a torch. After 4–5 min of boiling, the cap was screwed on tightly.

Fig. 3. A cold spray of water cools the barrel and condenses the steam inside. Air pressure crushes the barrel rapidly.

Fig. 4. To measure the final volume, the crushed barrel was filled with water. Result: 35 liter.

This single experiment might be my greatest contribution to physics teaching. It was a glorious sunny day when I had a physics class, eagerly experimenting with ample sunlight. We were all like in a "flow" state. Suddenly I found that it was possible to extract any colour perpendicularly to the spectrum (Fig. 1). Replacing the prism with a grating (Fig. 2) resulted into a concrete way for proving that violet light really has shorter wavelength than red light. – JOM

Spectral Experiments with White Light

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Of all physics experiments, demonstrations with optical spectra have an exceptional number of functions and broad base of appeal. Through them we can explain the structure of atomic systems, as well as reveal the composition of the most remote celestial objects. Spectral experiments are also quite inexpensive and, by definition, colorful. I have found that my female students are particularly intrigued with spectral physics.

In 1991 Sadler introduced to *TPT* readers the holographic diffraction grating for classroom use.[1] This grating greatly adds to the attractiveness of spectral experiments. Before becoming aware of the holographic diffraction grating, I used a direct-vision prism and an ordinary 1750-nm optical grating for a number of spectral experiments.

Inspiration came on a warm and sunny spring day a few years ago as I captured a bundle of sunbeams by setting a mirror in our classroom window. Reflected from the mirror, the rays passed horizontally along the demonstration table at a height of about 10 cm, and after going through the direct-vision prism, the light was spread into a wide horizontal spectrum on the white wall opposite the window. For simplicity, let us in this discussion assume a horizontal spectrum to be cast on a vertical screen.

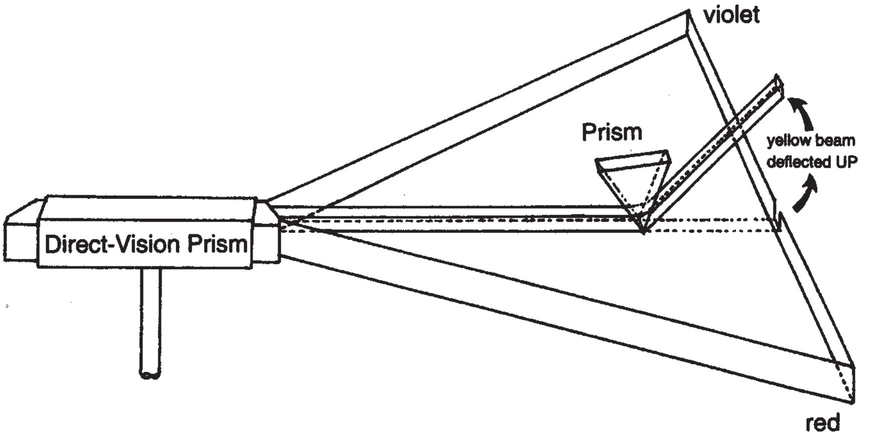

Fig. 1. A light beam dispersed into a colored spectrum does not break into more colors when a segment is defracted again.

Newton's Experiment in Another Way

According to the well-known experiment of Isaac Newton, a monochromatic beam extracted from a spectrum of white light doesn't break into further colors. Such an experiment is usually executed by extracting a narrow beam from the spectrum of white light, for example green, by means of a narrow transverse slit set in front of the spectrum. The green light remains green even after passing through another prism.

Even though I had performed the experiment many times, I always found it somewhat awkward. The practical difficulties were connected with the height adjustment of the second prism, as well as to the fact that the monochromatic ray always seemed to enter from an unexpected direction, usually resulting in difficulty in positioning the transparent screen on the crowded table. (Due to the high cost of a direct-vision prism, our second prism has been a conventional one.)

Apparently these earlier experiences served as a subconscious urge for me to try a new approach. It was easy to see that even as the monochromatic light could be turned to the right or left after having passed the slit, it could also be refracted up or down directly from the spectrum itself. Therefore, I discarded the narrow slit and held the edge of the second prism near the wall at the green part of the spectrum. A green color was seen on the wall above the horizontal spectrum. I passed the edge to the yellow, resulting in the yellow color appearing on the wall (see Fig. 1). Then I let the edge of the prism pass over the whole spectrum, from end to end. All the colors, one after the other, were refracted on the wall. My students could verify that monochromatic light does not break into further colors. Newton's original experiment was greatly simplified.

Your hand is enough to stabilize the second prism. The shorter the edge of that second prism, the more monochromatic will be the refracted light.

Visualizing the Connection between Wavelength and Color

We still had the magnificent spectrum in front of us, from violet to red. As the Sun moved a bit during the performance, we had to slightly readjust the mirror sitting by the window. Violet

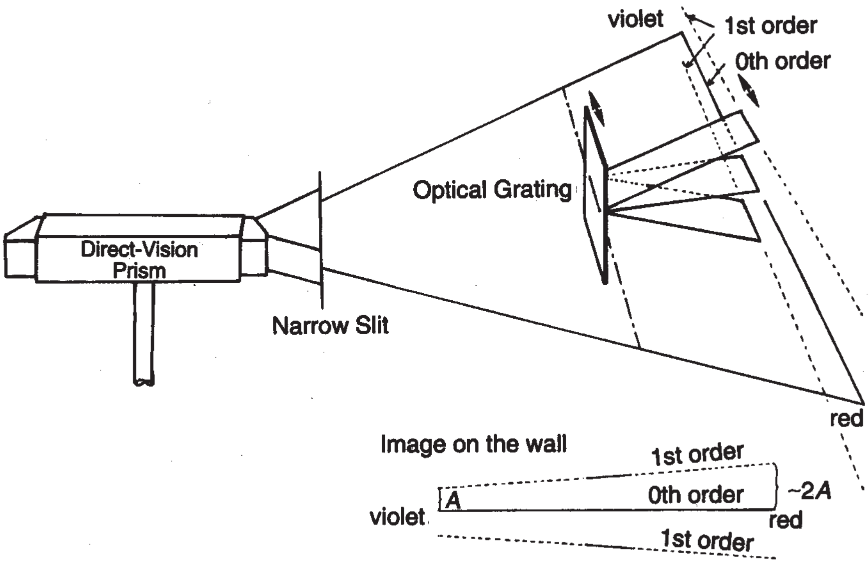

Fig. 2. Displacement of the interference pattern is proportional to wavelength.

wavelengths are shorter than red ones. I had always explained to previous classes that "the human eye perceives different wavelengths as different colors." How could I make the comparison in absolute terms of length? In other words, how could I quit the psychophysiological explanation and concentrate on the physical one?

As shown in Fig. 2, I compressed the spectrum on the wall into a narrow horizontal line by positioning a narrow slit horizontally after the direct-vision prism. Having done this, I took an optical grating and placed it in front of the spectrum with a constant distance of about 30 cm from the wall (and, consequently, from the narrow horizontal spectrum on the same wall).

The grating was a good one with a grating constant of 1750 nm, giving a clear first-order diffraction line both above and beneath the spectrum on the wall. What astonished the pupils was that the first-order diffraction line at the red end was about twice as far from the spectrum as it was at the violet end (although the grating was constantly held at equal distance from the wall)! However, the explanation was clear: the sine of the angle of diffraction is directly proportional to the wavelength. A little calculation reveals that the vertical displacement on the wall is almost directly proportional to the wavelength. In this way it is possible to visualize the wavelength in absolute terms of length (instead of colors).

Those who are not content with qualitative conceptual physics can attach the grating to an optical bench parallel to the spectrum on the wall and "drive" with the grating from one end of the spectrum to the other. If a piece of white paper is fixed to the wall, both the spectrum and the first-order lines can be marked on it, along with labels for the colors.

About the Equipment

In our experiment the Sun was used as the light source. A conventional lamp from the optical laboratory could be used instead, but for the development of the thinking of the students, it is quite a desirable thing to use materials from nature itself rather than from the dusty shelves of the laboratory storage room.

The Sun's rays can best be caught from the window by a ball-pivot mirror. Once you use a good-quality direct-vision prism and a good grating, you will certainly not want to return to a less dramatic alternative.

Reference

1. Philip M. Sadler, "Projecting spectra for classroom investigations," *Phys. Teach.* **29**, 423 (1991).

This month's cover...

Isaac Newton was famous for his work in optics, as well as in dynamics and gravitation. One of his famous optics demonstrations showed that white light was composed of a spectrum of colored light which, when recombined, yielded white light again. In a similar analysis, he showed that a colored band in the spectrum did not further decompose when sent through a second prism.

Our cover painting shows Newton, in a heroic but rather allegorical pose, casting a spectrum from sunlight. We are grateful to Bausch & Lomb Optical Co. (Rochester, NY) for providing us with a print of the painting and permission to reproduce it. On page 338 there is a note by J. Mattila describing how you can reproduce these demonstrations in your classroom.

This finding of "Laptop Art" started from the discovery that laptop computer screen is a large source of polarized light. The inspired eagerness of the physics teacher (very late in the evening at school) awaked special interest at the Security alarm center, as can be found at the end of the article! – JOM

Laptop Art

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In the course of technological development it sometimes happens that old things mingle with something very modern to create a completely new version of an old demonstration. This recently happened to me when I was composing a paragraph about polarization.

It is generally known that cellophane and acrylics create colorful patterns when placed between two polarizing filters.[1] This is due to the optical anisotropy of the materials. Changing the alignment of the polarizing filters or exerting mechanical stress on the optically anisotropic bodies results in changing colors. The strains of mechanical engineering objects such as gear teeth and hooks for lifting payloads can be analyzed by constructing acrylic models of the artifacts and exposing the models to stress between two polarizing filters.

While writing about polarization for my new high-school physics text, I had to make clear the principle behind a liquid-crystal display (LCD). I made a drawing showing how the black and light segments are formed (see Fig. 1)[2] and then tested the principle by placing all kinds of optically active materials in front of the LCD display of my pocket calculator and watching them through a polarizing sheet. Frustrated by the tiny 10 × 32 mm "screen," I looked around for a larger one. Suddenly the idea of using a laptop computer hit me: the screen of a laptop computer should also act as a source of polarized light—and a big one!

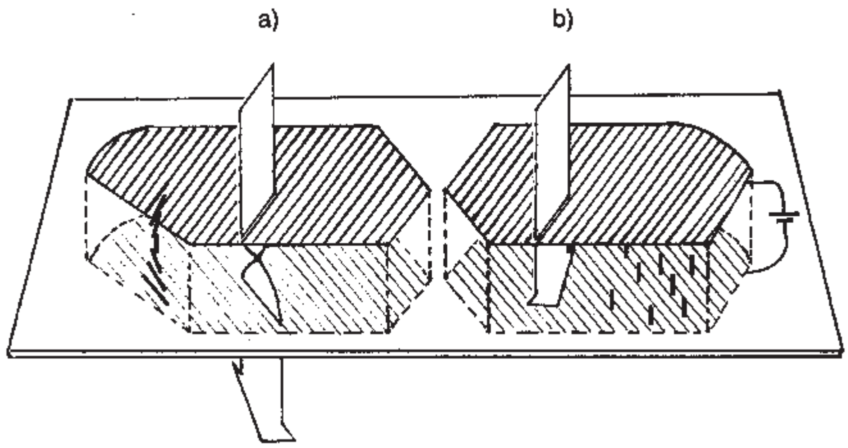

Fig. 1. Illustration of two segments of an LCD display. Space between the two parallel but perpendicularly aligned polarizers is filled with needlelike liquid crystals. a) The topmost and bottommost crystals (nearest to the two polarizers) align along the polarizers, and the crystals between these two layers twist to form a helix. Light, entering the system from top, twists along with the crystals, traverses the bottom polarizer, reflects up from a mirror underneath (not shown), traverses the bottom polarizer again and twists at the liquid crystal space, leaving through the top polarizer. The segment appears light. b) Applying voltage between the polarizers aligns the crystals vertically. Light, entering the system from top, traverses the system (without twisting) and is absorbed at the bottom polarizer. The segment appears black.

So I put action to my late-night idea and dashed back to school, located a laptop, gathered some acrylic plastic, cellophane, and other optically active artifacts and began experimenting.

A sample of what I saw is reproduced on the cover. There is a stunning beauty in the colors. Hues vary from deep violet to light yellow, green, and red—any color! Wrinkled cellophane looks especially interesting because the wrinkles divide the colors into sharply defined areas. As you turn the wrinkled cellophane around, all the facets change their colors continuously.

When using a laptop display for color art, I found it advisable to dim the light of the display until the text on the screen disappears and the whole screen becomes evenly lit. Using ordinary polarized sunglasses as the "polarizing sheet" (see Fig. 2) leaves hands free to pose or wrinkle the artifacts any way you want, letting you fully enjoy this interactive performance.

You could create a colorful art show by placing several laptops side by side and letting people watch a set of optically active artifacts through large polarizing sheets. Revolving the objects with tiny motors results in continuous changing of the hues and colors, adding to the artistic charm of the performance.

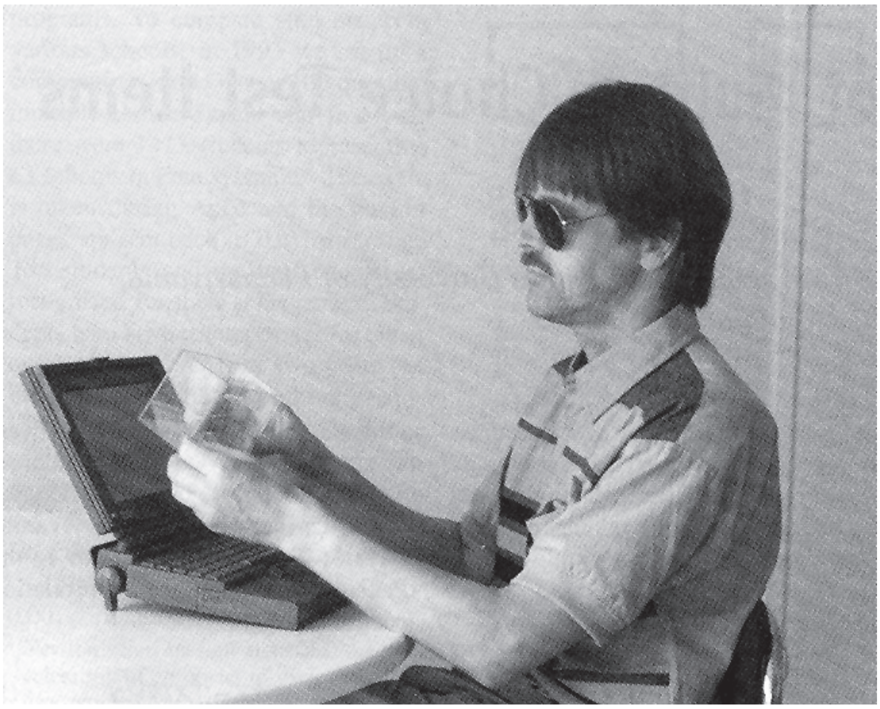

Fig. 2. Author sees beautiful color patterns (as shown on this month's cover) when looking through polarized sunglasses at optically active materials illuminated by the polarized light of a laptop computer screen.

It was almost midnight when I left the school, happy as always with a new experiment. In the dark school yard two uniformed guards suddenly stepped out of their car and demanded to see my ID. Although I had properly first deactivated and then activated the electronic warning system of the school building, the guard on duty at the alarm center had become suspicious about a late visitor and sent a patrol for inspection.

Who would visit an empty school building at the middle of the night? True indeed are the words of Orear: "Physics is what physicists do late in the night"!

References

1. Eugene Hecht and Alfred Zajac, *Optics* (Addison-Wesley, Reading, MA, 1974), pp. 260–261.
2. See also R. Ondris-Crawford et al., *Phys. Teach.* **30**, 332 (September 1992) and **33**, 104 (February 1995).

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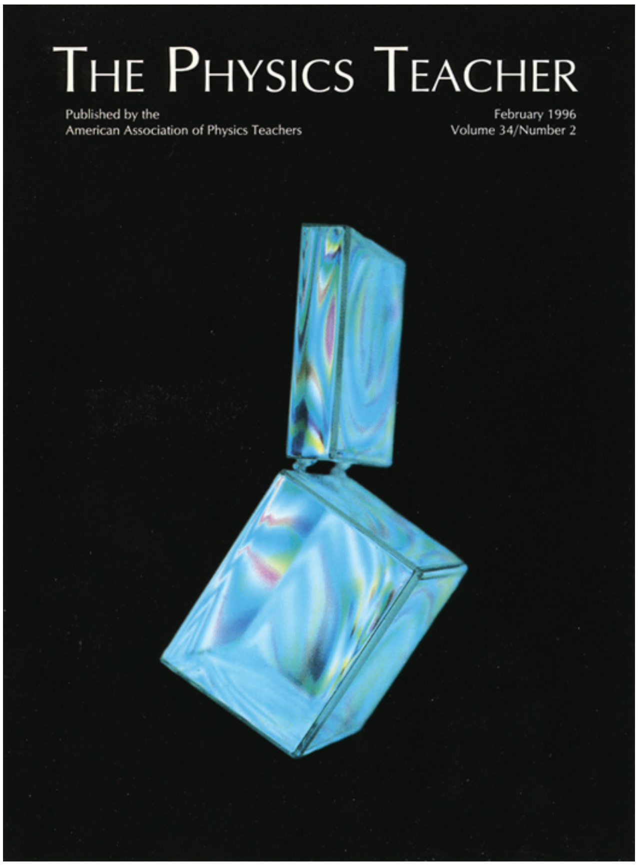
This Month's Cover...

Your laptop computer is a source of polarized light. This month's cover shows the beautiful color effects when this polarized light illuminates optically active material (here, a hinged acrylic box) and then is seen through polarized glasses. For more suggestions about how to do this, see the note starting on page 78, written by J.O. Mattila, who also provided the cover photo.



Reindeer Diode

Jukka O. Mattila, Torpankuja 6, FIN-13880 Hattula, Finland; jukka.o.mattila@pp.inet.fi

In Finnish Lapland, like in other Northern European regions by the Arctic Sea, aboriginal Sami people still base much of their daily income on reindeer. Earlier the Sami people followed their reindeer herds more or less all the year round, in nomadic fashion. Moving to fixed dwellings has created a problem in herding and guarding the property of the moving wild packs of hundreds or thousands of reindeer, which Sami families usually possess. Already for decades the mobility provided by Ski-Doos—along with herding dogs—has helped with the job. However, the era of limitless wilderness in reindeer herding is over. Nowadays hundreds of kilometers of reindeer fence separate Sami herding districts from each other.

The problem of guarding the livestock property does not arise with the adult reindeer because each of them is physically earmarked to belong to their owner. However, on spring snow new reindeer are born, and during the following months their ownership is only identified by the nearness of their nurturing earmarked mother.

One of the purposes of a reindeer fence is to keep these young non-earmarked reindeer on their owner's side of the fence. In the wilderness makeshift gates can be used for permitting trespassing people. However, gates cannot be used where the highway cuts the fence line. Ingenuity has helped some reindeer herders in solving even the highway problem. At the roadside fence crossing point they have placed an ordinary concrete mixer. To start the concrete mixer revolving, there is an electronic motion detector (see Fig. 1) directed toward potential approaching reindeer on *their* side of the fence. In case of approaching reindeer, the motion detector is activated and the concrete mixer starts running. Inside of it loose boulder stones loudly cut the silence of the wilderness and the reindeer run frightened back where they belong. Adding to the frightening noise there is a black plastic sheet revolving around as it is fixed to the running barrel of the mixer.

The key is in the asymmetry of the device. Yes, there is a motion detector aimed toward the side of the reindeer herders who brought and assembled the mixer to prevent their reindeer from escaping. However, there is no motion detector—and consequently no frightening action—toward the neighboring herder's side. Thus, orphan non-earmarked reindeer of neighboring herders are welcome to add to the pack on the side of the herder who owns the concrete mixer reindeer diode (see Fig. 2). After reaching the sector of the motion detector on the wrong side, the newcomer reindeer can even be frightened into gathering speed toward their new pastures!

Fig. 1. A roadside reindeer diode consists of a motion detector (in the foreground) and an ordinary concrete mixer (behind).

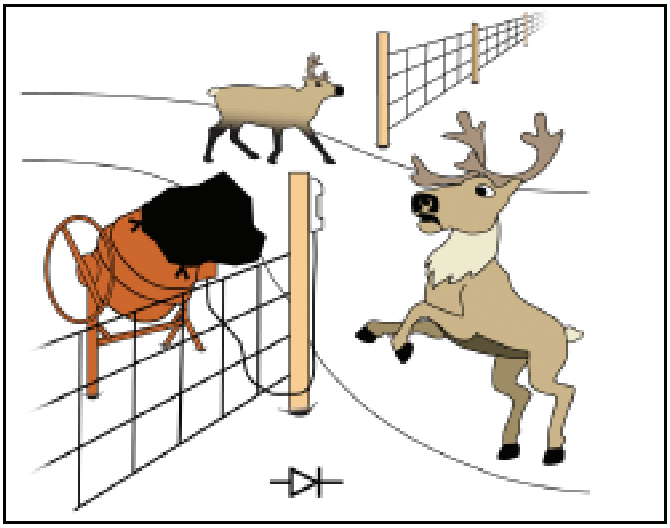
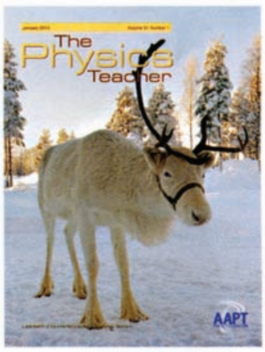


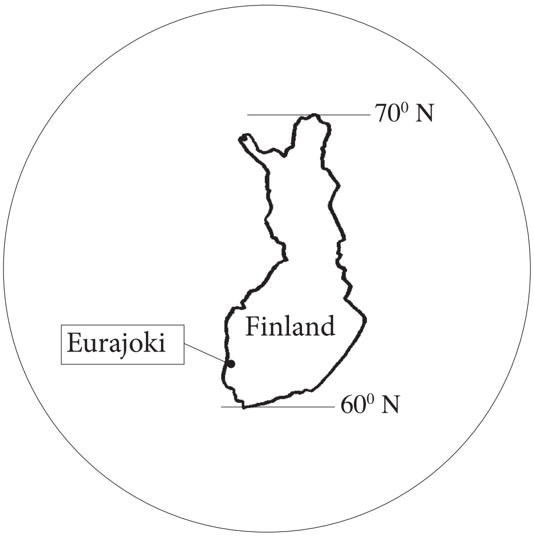
Fig. 2. When the reindeer enter the sector of the motion detector, the mixer starts running and frightens the reindeer back. As there is no motion detector to the opposite direction, the reindeer from the neighboring herding district can enter unhindered into their new owner's territory.

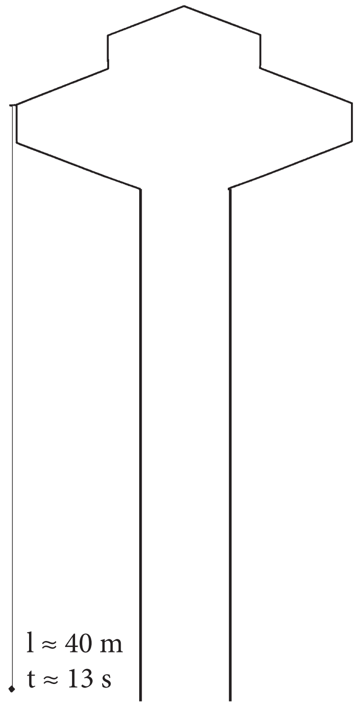
This Month's Cover...

Jukka O. Mattila's amusing article, "Reindeer Diode," appears on p. 12 of this issue.



The 40 m long Foucault pendulum
of Eurajoki water tower, western Finland





The Foucault pendulum as a teaching aid

J O Mattila
Parainen Senior Secondary School, Finland

For over a decade I used the Foucault pendulum for qualitative observations only. A 3 metre pendulum was suspended from the ceiling of the classroom. I would position a tuning fork on either side of the pathway of the swinging bob. My students would stand around expectantly as the plane of the swinging pendulum rotated slowly clockwise. The bob would hit one of the tuning forks and the show was over.

The bob was a standard Leybold pendulum of mass about 600 g. Special care had to be taken to start the pendulum without any lateral motion. Air circulation was minimized by closing the windows and doors well before the experiment. We adopted Léon Foucault's initial method of starting. A loose loop of thin string was wound around the bob (see the illustration in the Box). The bob was drawn aside to its maximum amplitude. We would wait, barely breathing, until the bob was still. A match was lit and the string burnt. The loop would fall, starting the bob swinging.

A quantitative approach

In 1982 I spoiled the demonstration. I had placed the tuning forks too far from the starting point. As the amplitude diminished due to air friction, it became evident that the bob would not be able to hit the fork.

I decided to redesign the experiment and use a laser. I used the horizontal beam to cast a shadow of the pendulum wire on the opposite wall (see Box). It enlarged the lateral movement of the bob

Table 1. Turning of the oscillation plane of a Foucault pendulum in 24 hours, showing variation with latitude.

North Pole	360°
Eurajoki	315°
Edinburgh	298°
London	282°
Sydney	−201°
South Pole	−360°

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Physics Education 26 (1991), IOP Publishing Ltd. Reprint by permission of the author.

Experiment. How to measure latitude with a 3 metre Foucault pendulum and a laser

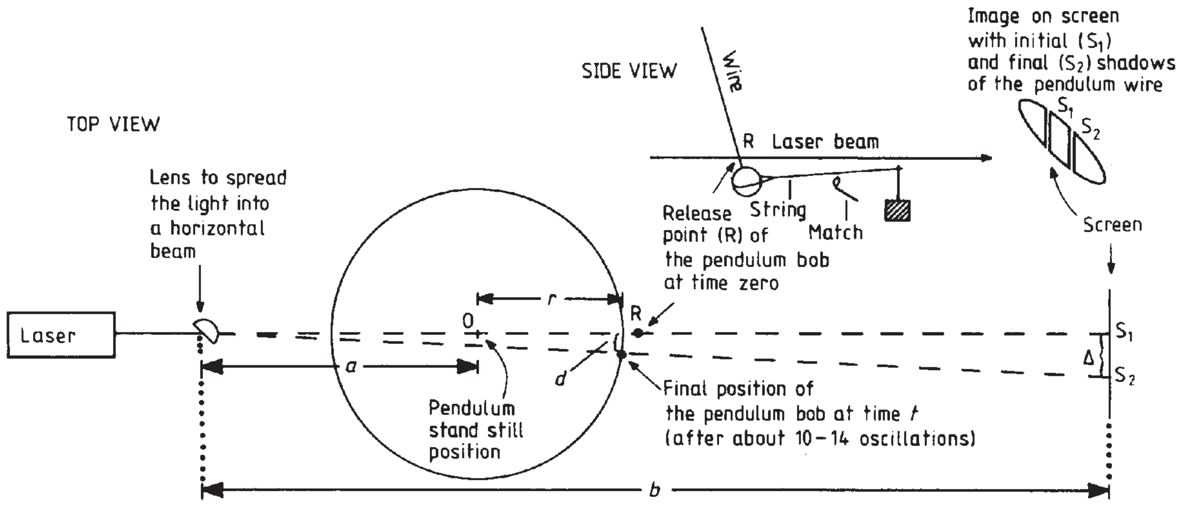
Procedure. Set up the measuring system according to the diagram. The amplitude of the oscillation is roughly one metre. Adjust the height of the laser (and the lens) so that the horizontal beam intersects the pendulum wire just above the bob at the intended maximum deviation.

1. Let the pendulum stand absolutely still at O. Mark carefully with a vertical line the shadow of the wire at screen at point S_1 (the screen may be a piece of white tape attached on the wall).
2. Move bob to release point R. Fine adjust the position of the bob so that the shadow of the wire falls precisely at point S_1. Let the bob stand absolutely still.
3. To release the bob, cut the string by burning with a match. After about 10–14 oscillations mark the shadow of the wire at S_2 (after more oscillations the elliptic motion tends to disturb the experiment). Measure Δ, *a, b, r* and *t*.

Calculate. Shift along the circle (d): $\frac{d}{a+r}=\frac{\Delta}{b} \Rightarrow d=\frac{\Delta(a+r)}{b}$.

Rotation angle per 24 hours (ψ): $\psi=\frac{(d/2\pi r)\times 360^\circ}{t/(24\times 3600\text{ s})}=\frac{d\times 24\times 3600\text{ s}\times 360^\circ}{2\pi rt}$.

Latitude (φ): $\sin\varphi=\frac{\psi}{360^\circ}$.



and string enough to permit quantitative measurements.

In the following years we used this method and attempted to measure the latitude of our physics classroom, starting the bob still more carefully. Accuracy was not too good! We were lucky to achieve a result that located us in the northern hemisphere. At best, our figures placed our school somewhere between Denmark (55°) and the Arctic Circle (66½°), although it was actually in southern Finland (61°). (See table 1.)

The main source of error was the slight asymmetry of the cast iron pendulum bob. It produced differences in air resistance on its asymmetric sides. This caused both a slight lateral variation of the shadow of wire on the wall and an increasing imbalance of the motion in general. A good bob should be as homogeneous as possible and preferably formed on a lathe. However, the major limitation was imposed by the height of the classroom ceiling which restricted the length of the pendulum to a maximum of 3 metres.

A 40 metre Foucault pendulum

In 1984–85, a 46 metre high water tower was erected near the school. It opened up the possibility to 'think big'. I proposed a 40 metre Foucault pendulum be built at the water tower.

Figure 1. The 110 kg bob swings sedately in a 20 × 7 m oval area, fenced off for safety.

The permission and funds for a 'functioning' Foucault were granted by local government.

The pendulum is located by the west coast highway 100 km north of the town of Turku. Since its inauguration in June 1986, the pendulum has served two purposes: as a tourist attraction for the small village of Eurajoki, where I used to live, and as a demonstration pendulum for the local secondary school. The Eurajoki Foucault pendulum was the first in Finland. Although others have since been erected, the Eurajoki pendulum remains the longest in Finland and the only one working in the open air.

Technical details

The pendulum hangs from the outer rim of the water reservoir. The bob is suspended by a stainless steel wire of diameter 5.0 mm and length approximately 40 m. Its period is 12.5 s.

The effect of wind resistance has been minimized by using a double conical bob of fairly large mass—110 kg. In calm air the lateral movement of the bob is 8 mm per swing for an amplitude of 10 m and consequently 4 mm for an amplitude of 5 m. Damping of the oscillation is quite large: about 20 cm per oscillation.

The water tower was build in a forest and originally the trees provided shelter against the wind. Unfortunately, many of the trees have now been felled. The wind easily sets the pendulum into a slightly elliptic motion but this does not affect the clockwise direction of the revolving plane of oscillation. The bob is heavy and the amplitude large; there would be some risk of the wire breaking through continuous bending at the point of suspension. So the pendulum is hung from gimbals with four ball bearings hermetically sealed within a weatherproof stainless casing.

Plans for a continuously driven laser pendulum

There were plans to build a 40 metre Foucault pendulum *inside* the 6 m wide stem of the water tower. This would have eliminated the effect of wind.

The design was for a short pendulum—only 2 m long and kept in motion by a pulse-driven electro-

Figure 2. The peg under the bob knocks down similar pegs on the observation platform, one at a time.

Figure 3. Artist's impression of the Eurajoki Foucault pendulum from a Christmas card (painting by Rauno Mäkimattila).

magnet. The bob would contain a He–Ne laser which would effectively extend the length of the pendulum by 38 m. Its continuous oscillation with the red spot tracing across the concrete floor was planned to demonstrate the revolution of the Earth underneath in a modern way. Unfortunately I moved from Eurajoki and could not complete the project. Nevertheless, a laser pendulum could be realized in many large spaces, as in modern hotels, shopping centres etc. Even height need not be a restriction: it would be possible to bend the beam with a torus-shaped prism so that the beam of light is cast onto the walls rather than onto the floor.

The 40 metre classical pendulum swings sedately. The oscillation of a laser pendulum could be much swifter. If the length of the mechanical pendulum to its 'laser bob' were 1 m, the period of the oscillating laser spot, however far from the pendulum, would be 2 s. If the beam were cast onto the walls, the beam would move from wall to wall after each second.