physics courses with "problems" saying: use single-concept so-and-so to calculate specific number what's-it in simple system . . . .

Dealing with the problem: Reemphasizing standards

The needs of society and posterity for more and more knowledgeable thinking people are increasingly in conflict with the growing pressures to water down learning requirements in physics. How can we overcome these pressures? The following suggestions are tentatively advanced to stimulate discussion.

First, the body of collegiate physics teachers should reach some agreement as to why we expect students to study physics. (The pages of this journal would be an excellent forum for reaching consensus on this matter.) Most colleges offer three different beginning physics sequences: Physical Science which is purely descriptive – a course full of information but usually short on knowledge; Liberal Arts Physics – the course, relying on simple algebra and geometry, which has, traditionally, emphasized problems and the development of scientific thinking; Physics for Scientists and Engineers, a calculus-based course emphasizing facts, theory and problem solving, leading to the practical applications of physics to science and engineering. It is the second category that concerns me in this essay. I believe that these courses have been traditionally based upon the building of student abilities up to the level of successfully dealing with relatively simple but *multiple-concept* problems. I hope that we can agree to have this category of courses continue to make such demands.

Explicit agreement as to what the transcript statement "College Physics" means should prove useful to students, faculty, professional schools, and potential employers. The agreement could be embodied in an AAPT-created book of examination problems from which participating faculty could select their exams. (Or, we could produce a series of different exam books for different level courses, the course level being determined by how many different concepts students would be expected to juggle in any one problem. College Physics should at least be a level two). AAPT could then publicize which schools use which exam books. Publicity from outside is one way to counter internal pressures to lower standards.

In a sense, I am asking for voluntary national standards for the introductory physics course. (Such standards already exist, *de facto*, for physics major courses in the Graduate Record Examinations.) This is not a very revolutionary suggestion since such voluntary standards now exist via national board exams in medicine and national components of the bar exam in law. The need for rational thinking on the part of our future citizenry is just as important as the need for skills among our future professionals. If necessary, we teachers of physics should adopt similar methods to insure that our teaching meets the standards that we say our society needs.

The physics of visual acuity

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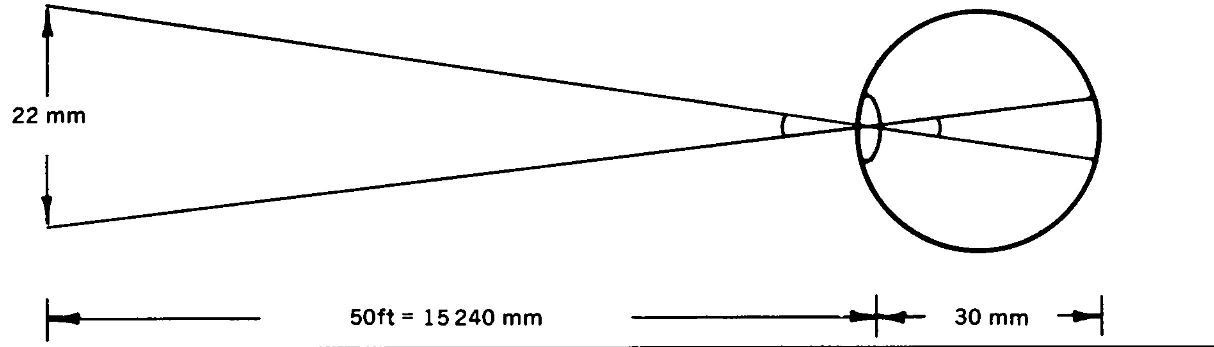
A very interesting optics experiment can be performed using an eye-test chart, a ruler, and a calculator. A satisfactory eye chart can be obtained from Sargent-Welch.[1] The objective of the experiment is to determine an estimate for the limit of visual acuity.

The student measures the length of the largest letter on the chart and notes at which distance the letter should be discernible. This minimizes experimental uncertainty which increases when measuring the smaller letters. For a letter which should be read at 50 ft by a normal eye, one finds that the linear dimension of the letter is 22 mm. Figure 1 shows how a simple proportion can be used in order to obtain the length of the real image of the letter on the retina. The length of the eye can be taken to be approxi-

Fig. 1. Schematic drawing of object, eye, and retinal real image.



mately 30 mm. We immediately find the following proportion:

$$\frac{22\ \text{mm}}{15\ 240\ \text{mm}} = \frac{x}{30\ \text{mm}}$$

$$x = 40\mu$$

where 1μ is one micron, which is one thousandth of a millimeter.

In order to distinguish a P from an F the observer must see clearly one half of the letter. The image of this portion of the letter has a linear dimension of 20μ. Since the mean spacing between the centers of the light receptors is about 3μ, one half of the letter is approximately 6 receptors in length. The student can now draw an array of circles as a model to represent the array of receptors in the retina. The student should recognize two points. First, for 20/20 *normal* vision, an individual is required to discern letters when the image of one half of the letter spans 6 receptors. Second, for the *best possible* vision the minimum number of receptors, in principle, needed to distinguish a P from an F is 3 x 3 receptors (Fig. 2). This problem is analogous to representing letters or numbers on the minimum number of light-emitting diodes in a calculator.

Most people cannot resolve a P or F when half of the letter falls on the minimum 3 x 3 receptors and the test for 20/20 vision does not require them to do so. However, some individuals have better vision than the normal 20/20 and the aim of the experiment is to place a limit on the best vision possible.

A reasonable estimate of the limit of visual acuity corresponds to the illustrated case where the upper half of the P or F falls on 3 x 3 receptors, i.e., the retinal image is one half of the size it would be for 20/20 vision. Therefore, the limit is realized by standing 100 ft from the chart rather than 50 ft in an attempt to identify a 22 mm letter. The visual acuity for an eye that can read the 20/a line of a Snellen chart at b feet is 20/20 (a/b). Our rough calculation

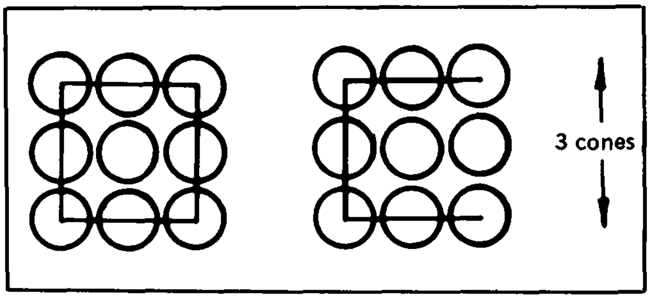


Fig. 2a. Part of the letter P. **Fig. 2b.** Part of the letter F.

indicates that the limit of visual acuity is approximately 20/10. It is interesting to allow the students to test each other. From time to time a case of about 20/10 vision will be found.

The limit of resolution based on diffraction can be found using the Rayleigh criterion

$$x_d = 1.22\frac{\lambda}{d}f = 1.22\ \frac{(500\ \text{nm})}{2\ \text{mm}}\ (30\ \text{mm}) = 9\mu$$

using a wavelength of 500 nm (green light) and a pupil diameter of 2 mm (small opening for high light level). This surprisingly spans 3 cones. It is remarkable that the limit for visual acuity corresponds to the limit of resolution obtained from diffraction arguments.

The author is indebted to David S. Falk for sharing his ideas on resolution of the human eye and diffraction which he discusses in a very popular nonscience course "Light, Photography, Perception, and Visual Phenomena" at the University of Maryland. The author would also like to thank Mark Clark (MD) of Anderson, South Carolina for discussions on the physiology of the eye and visual acuity from a medical viewpoint.

Reference

1. Cat. No. 3539. Sargent-Welch Scientific Company, 7300 N. Linder Avenue, Skokie, IL 60077.

Feeling the Coriolis force

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We frequently talk about the Coriolis effect in physics and earth–science courses citing its effects on air and ocean currents and on projectiles as evidence that the earth is turning on its axis. In teaching physics we deal with it as an example of fictitious forces which arise in rotating or otherwise accelerated reference frames.

There are several lecture demonstrations that show this effect. However, one day it occurred to me that the "experiment" described below ought to work, so I went to an amusement park and tried it on the appropriate piece of apparatus. It works beautifully.

If you really want to *feel* the Coriolis effect, find the nearest merry-go-round. Invest the fare and take a ride, but instead of mounting one of the horses, do what the ticket taker does; walk on the carousel while it is in motion. Try to walk briskly from a point on the outer rim straight in to the corresponding point on the inner rim. You will be walking from a part of the platform that has a certain tangential velocity to your right (based on the usual direction of motion of carousels in this country) to a point which has a lower tangential velocity since the radius is less, and the angular velocity is the same. (This is analogous