PSSC: Instant Credibility for a Beginning High School Physics Teacher

by John W. Layman*

I began my high school teaching in 1958 just at the time that PSSC was emerging. Even though I had not encountered the materials prior to my teaching, I was immediately struck with the laboratory program, the complete outlines of proposed course scheduling, recommendations for limited coverage, and the availability of the carefully integrated ancillary materials. There was also a statement suggesting that "the most common use of the laboratory experiments is to introduce a topic or contribute to the early stages of its development". My students found that they could read and understand the textbook after they completed their lab work.

The Laboratory Program

I was so struck with the ripple tank that even though I had no budget for materials I scrounged old window sashes from my uncle's lumber yard and began using these after repairs for leakage.

The major feature of the labs was the informality of the text aimed at the users. There was no evidence of a formal laboratory procedure, just suggestions and questions with enough guidance to allow students a good start. The formal terminology of physics was used, but never in a tone of "this needs to be memorized." The "To Students" section began with "This Guide is designed to help you with your laboratory work." Other elements in the "To Students" section were the need for good working habits, keeping clear records, working with partners, and recognizing the need for additional experimentation, with the caveat of "It is up to you to decide what to do in each case."

The use of Slinkys (referred to as coiled springs in the lab guide) enabled us to move into the hallways to accomplish our physics as well as advertise PSSC. I had participated in the design of the physics space in the new high school, and we had a steel beam above the lecture table and one at right angles to its direction at the back of the classroom. We could string a cable between the two, with a number of Slinkys tied together to constitute a master Slinky to be used during class to resolve Slinky questions during class discussions and laboratory work. It also provided opportunities for genuflections as students entered the classroom, to recognize a small legacy of earlier pagan activities.

"Large Distances" allowed us to go to the athletic field, in clear view of students in other classes, to measure the distance from our hilltop to a radio station antenna in downtown Kansas City.

"Molecular Layers" allowed me to visit chemistry and other classes to advertise physics, guaranteeing students the opportunity to measure the height of a molecule with a meter stick, measure the mass of an electron, and guarantee them a C for just coming through the classroom door, and assuring them of wonderful physics activities that would enable them to then earn an A, B, a D or an F depending on their willingness to work. I had scaled the grading scheme in such a way that students doing the labs would achieve enough points to guarantee a C in the course.

Skate Wheel Carts

The skate wheeled carts with spring enclosed pushing rods were wonderful for calculating the energy stored in a spring by upending the cart, loading masses on the rod, and of course monitoring the resulting displacements due to Hooke and his law. We devised our own experiment to compare the potential energy stored in the spring with the kinetic energy acquired by the cart when the tube with the spring was forced against a stopping block C-clamped to the end of the table, released from a specific compression mark, and tracked with a ticker-tape timer. We stressed the fact that these were totally independent measurements of energy – the potential energy stored in the spring and the ultimate kinetic energy of the cart the moment the spring became uncompressed. Some noticed that the push rods moved beyond their compression points. What to do about that? Other characteristics within the experiments allowed students to create explanations that would help account for the observed potential and kinetic energy differences.

Successive Experiments

The laboratory program also provided wonderful sets of successive experiments ultimately enabling students to carry out a final fundamental measurement of something of great sophistication and significance using relative simple apparatus. One of the prime examples culminated in students being able to measure the mass of the electron. The series began with “The Magnetic Field of a Current”, enabling students to measure the influence of the number of turns of wire surrounding a compass, with a constant current in the wire. The second experiment “The Measurement of a Magnetic Field in Fundamental Units”, introduced the students to a coil of wire (now recognized as a solenoid) and a current balance to measure the magnetic field in the center of the coil. The culminating experiment involved using the solenoid to produce a uniform magnetic field in which was placed an electron tube or tuning eye, something our younger readers will not know about. In the absence of any magnetic field electrons emitted from a central cathode are deflected by an electrode to form straight-line shadows on the fluorescent surface of the anode where the electrons are collected at the end of their paths. Because of the anode’s curved surface, it intercepts on its lower edge the electrons that were closest to the cathode, while it intercepts on its upper curved surface the other electrons that traveled further from the cathode. With no magnetic field in the coil, the shadows produced by the deflecting electrode are straight lines. When a uniform magnetic field is applied, the uppermost emitted electrons, which traveled further to reach the surface, are deflected further around the circle of the curved path of the electrons in the magnetic field. The edge of the shadow is now curved. Students knew the strength of the uniform magnetic field as a function of the solenoid current, the strength of the electron accelerating voltage and the radius of the circular path of the accelerated and deflected electrons. Students used the field strength (B), the charge on an electron (q), its accelerating voltage (V) within the tube, and a manual measurement of the radius of curvature using a transparent disk with various curvature lines (R) to calculate the mass of an electron. $m=B^2q$[illegible]V

Total Internal Reflection: Water and Microwaves

My last example of a major contribution of one of the extraordinary PSSC laboratory experiment series harkens back to a contribution derived from the already mentioned ripple tank series. It is a contribution that strengthened an understanding of both the teacher (me) and my students, and is tied in with the Feynman Lectures on Physics.

In our ripple tank work we could support a rectangular glass plate just beneath the water surface to create a shallow region surrounded by a deeper region. Plane waves approaching from the deep to shallow area normal to the shallow region, clearly passed on through, but more slowly with reduced wavelength, regaining their speed and wavelength as they passed back into deeper water beyond the opposite face. With a triangular plate, the plane waves coming into the side of the prism would change wavelength and arrive at the back surface at an angle of incidence greater than the critical angle, thus total internal reflection was clearly visible with the waves emerging from the opposite face, with none emerging beyond the longest side of the prism.

I had purchased a microwave source and had a number of diode detectors. We could do excellent single, double slit experiments as well as interferometer experiments. We had also studied both optical and ripple tank observations of total internal reflection but it was always a conundrum as to how a wave knew when to totally internally reflect (remain inside the denser medium), when there had been only a change in the angle of the incidence of the approaching wave. We surmised that somehow the wave had to sample the second medium to know that it should totally internally reflect.

In *The Feynman Lectures on Physics* I read that the wave had indeed to sample the second medium and in fact should be found in the second medium. It was pointed out that the wave intensity in the second medium would tail off within a single wavelength distance. I was reading this at home one evening and realized that we had used paraffin as a good medium for microwaves and were also dealing with microwave radiation with significant wavelength. When I got to school the next morning I immediately got some of my student assistants to fashion two right angle prisms made by stacking together some of the our ripple tank paraffin blocks. Two things happened when we sent microwaves in normal to one of the smaller sides of the prism. First, it was easy to detect the total internal reflection of the microwaves by placing a detector in front of the opposite small side. However, when we moved another detecting diode near the face of the prism where the total internal reflection was occurring, a signal could be detected close to this surface. The waves (microwaves in this case) were indeed sampling the medium outside the paraffin surface where the total internal reflection was occurring.

This was further evidenced when we moved a second right angle prism with its long face parallel to the long face of the first prism, closer to the first prism. When the separation of the second prism face became less than one microwave wavelength the total internal reflection within the first prism disappeared, and in fact the microwaves could now be detected coming through both prisms, without any total internal reflection. There were two detectors, one beyond the opposite face of the first prism providing evidence of microwaves emerging via total internal reflection, and beyond the second prism where no microwaves were detected. As the second prism was moved closer to the first, students could observe a gradual reduction in the total internally reflected waves and a strengthened emerging of waves from the opposite side of what became a cube of paraffin.

We had two sets of observations to support our supposition that the microwaves did indeed spend time sampling the air, so they knew it was all right to totally internally reflect from the first prism's longest face. This experiment remained in the repertoire of Oak Park High School for the rest of my high school teaching career, and I brought it to the University of Maryland when I changed levels of teaching.

The Science Study Series

The Science Study series played a major role in a strange required-but-not-graded physics assignment. During each semester I required one outside reading report per month, one of which had to be a book. We had many of the Science Study Series books as resources. The report consisted of one 3 by 5 card on which the student was to provide bibliographic information, a few sentences about the theme of the article or book, and finally a brief judgment of how and why the student liked or did not like it. I merely collected these and checked them as done. Lest you think that was a fairly thin expectation, I found that on the free response portions of the examinations students would often make reference to an article and its relevance to the topics that we were doing in the course. This increased as the year progressed and provided the students with personal evidence that our physics studies enabled them to increase their understanding of the books or articles. Some students read more than one book per semester, some not within the Science Study series. Scientific American and The Physics Teacher were also major resources.

Closing

I am struck with the philosophy and learning conditions and expectations visible within the PSSC program that mirror our present expectations bolstered by many additional years of research into learning and teaching. Phrases such as: "The student is expected to be an active participant in this course"; "Hence, the most common use of laboratory experiments is to introduce a topic or to contribute to the early stages of its development"; "To this end, the Physical Science Study Committee judged it wise to shift the emphasis in secondary-school physics away from technology toward a deeper exploration of the basic ideas of physics and the nature of inquiries that can lead to these ideas" and "Achieving these aims in a one-year course meant that coverage of the field of physics had to be sharply restricted in favor of a deeper development of ideas that are central to a comprehension of the fundamentals of contemporary physical thought."

PSSC was the single factor that got me off to a fine start in my early days of high school teaching.

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