A report on an introductory physics course telecast and color filmed at WQED-TV, Pittsburgh, Pa., as part of the Television Teaching Demonstration Program conducted in cooperation with the Pittsburgh Public Schools and the Allegheny County Schools during the school year 1956–57.

Fig. 1.

PHYSICS COURSE ON TV

By Harvey E. White

BECAUSE of the fact that the population of our nation is growing more rapidly today than ever before, the educational institutions throughout the country are confronted with increasingly difficult problems concerning the education of our youth. Not only are most of our physical plants overflowing with students, but there is a vital shortage of good teachers to teach them. Some have said, "Raise the teachers' wages and you'll fill your teacher needs." True, teachers' salaries are considerably below what they should be in comparison with many other professions, but raising their salaries alone will not solve the problem. It is certain that industry and government would raise their salaries to keep valuable men and lure them back from teaching.

The problem really confronting us today is clearly, "How can we use the teachers we have and those who are being properly trained and graduated from our colleges each year to the best advantage?"

If we are going to solve this problem, one thing appears certain. Whether we like it or not we are going to have to increase the student-teacher ratio throughout our educational institutions. How can we do this and at the same time maintain the high standards we have so jealously guarded in the past?

Over the past several years educators and administrators at the elementary, secondary, and college levels have met in large and small groups for the purpose of finding possible solutions to the teacher shortage problem. While various promising methods have been proposed and a number of constructive ideas have come forward, far too little has actually been done about it. Of the various proposals that have been made, the use of television and motion pictures appears to be among the most promising.

The fact that a number of educational TV stations are now telecasting and others plan to be in operation soon, is good evidence that these are worthwhile proposals. It is only natural, therefore, that with the acute physics teacher shortage we look to these new methods of communication for the teaching of physics.

The Project

THE original formulation of ideas for the teaching of high-school physics by television in Pittsburgh came about as a result of a luncheon engagement in December, 1955. Dr. Alvin C. Eurich, of the Fund for the Advancement of Education, Dr. E. A. Dimmick, Superintendent of Pittsburgh Public Schools, Dr. Alfred W. Beattie, Superintendent of Allegheny County Schools, Pennsylvania, and Mr. John F. White, General Manager of Educational Television Station, WQED in Pittsburgh, met for the purpose of selecting a year course of study at the secondary level that might be telecast daily to many high schools in the Pittsburgh area. This was to be an addition to a Television Teaching Demonstration program initiated by this group in 1955 and carried out at the elementary level during the succeeding year.

After several months of study, the subject of physics was selected and, because of the nationwide physics teacher shortage, it was agreed by all concerned that

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the lesson broadcasts should be filmed and made available for use in other metropolitan and rural areas. With this in mind and at the request of Dr. Eurich, the National Academy of Sciences was requested to select someone, preferably at the college level, who would undertake the teaching of such a course. In response to this request Dr. M. H. Trytten, Chairman of the Office of Scientific Personnel in the National Research Council, appointed the following committee, with himself as chairman, to select the person and to act in an advisory capacity for the project. Committee members were Dr. E. Hutchisson, now Director of the American Institute of Physics, Dr. Emerson Pugh, Professor of Physics at Carnegie Institute of Technology, Dr. Clarence Zener, Research Director of the Westinghouse Research Laboratories, Dr. Nathaniel Franck, Professor of Physics at the Massachusetts Institute of Technology, and Dr. Paul F. Brandwein, of Forest Hills High School, N. Y.

At the request of Dr. Eurich and with the consent of the Board of Directors and General Manager of WQED, Mr. M. B. Mitchell, President of Encyclopaedia Britannica Films, Inc., of Wilmette, Ill., was asked and agreed to film the daily lessons in color and make the films available to anyone.

The Teaching Problem

THE first I heard of the television teaching program for physics was in April, 1956, when I was requested by Dr. Trytten to visit the Pittsburgh project. Later by mutual agreement between Dr. Eurich and the University of California administration, I was released for one year to go to Pittsburgh and carry out the teaching of this course. Arriving in Pittsburgh on July 1 and with the first lesson scheduled for telecast on September 10, many hurried decisions had to be made. Suitable laboratory tables and sturdy blackboards that could be moved quickly and easily in and out of a television studio had to be designed and constructed. The tables were mounted on large rubber-tired casters and were equipped with gas, water, ac and dc outlets. Tank nitrogen was to serve for compressed air jets. (See Fig. 1.)

For twenty-five years I have been teaching introductory physics at the freshman level at the University of California. Years ago I completed all of the Education courses required for a Secondary Teachers Credential for the state of California. While this experience gave me a good background for the teaching of an introductory course at the high-school level, I realized that there was much to be learned from those already engaged in teaching high-school physics.

Frequent consultations with Mr. Eugene Peckman, Science and Mathematics Supervisor for the Pittsburgh Public Schools, and visits to several of the high schools, gave a picture of widely differing school conditions.

From conversations with other secondary-school administrators and educators it was evident that these conditions are typical of those now existing in many areas of the country. Some schools, like those frequently found in residential areas, may have an excellent physics teacher, good equipment, and laboratory facilities, and students with a high average IQ, while other schools may have a poor teacher, little or no equipment or laboratory facilities, and students with a low average IQ.

In some high schools physics instruction is confined to five 40-minute periods a week, while in others there is an additional hour allotted on Tuesdays and Thursdays for laboratory practice. In a few schools two 40-minute periods are assigned to physics every day. While physics is taught in the senior year in most high schools, it is also offered in the junior year in some. In other instances, physics is even taught in the sophomore year.

With such widely varying student and teacher capabilities, the most difficult of all problems posed itself. *At what level should such a course be taught?* It is the opinion of some school administrators that physics in many high schools has become a General Science course and that something should be done about raising the general standards. A survey of a number of widely used high-school physics texts will confirm this. The use of mathematics in any form has been reduced to a point where it is practically negligible. Some say this is largely due to the suppression of mathematics in many primary and secondary schools. Often counselors, trained largely in Letters and Arts and with Education Degrees, having found mathematics difficult themselves, advise students to stay away from such subjects.

Another difficult question of considerable importance, yet one which had to be answered, was one concerning laboratory practice. In some schools, where good laboratory apparatus once existed, the absence of a physics trained teacher who knows what such equipment is for, and how it should be handled, has resulted in the deterioration of the apparatus through abuse and lack of proper care.

Whether an introductory course in physics is given to a group of students in their senior year in high school or to a group in their freshman year in college need make little difference as far as lecture demonstrations are concerned. Simple demonstrations as well as clear explanations of them can be understood equally well by both groups. What does make the difference between an easy course or a more difficult one at any level depends largely on the mathematics employed as well as the kinds of problems assigned the students as homework. Every physicist knows that principles and laws are represented by mathematical equations in one form or another and that it is possible to make up and assign as homework easy problems as well as hard ones.

With this in mind, I decided to confine the mathematics in the lessons to the simplest algebra and geometry and to introduce, by a special lesson, the sine, cosine, and tangent from trigonometry.

By leaving all homework and testing to the individual teachers, the question of level of instruction becomes one suited to student capabilities in each particular classroom. After consideration of the text book problem it seemed advisable to leave this decision also to the individual schools and periodically to distribute titles, dates, and brief outlines of lessons to come.

From the very beginning, I realized that the major problem confronting me throughout the year would be one involving the acquisition of apparatus and the necessary assistance needed in setting it up for daily demonstrations.

Through the cooperation of Dr. A. C. Helmholz and the Physics Department of the University of California, I was able to persuade one of the department's two experienced lecture room assistants, Mr. Wilson Flick, to accompany me to Pittsburgh and to assist in the project. At the same time arrangements were made for shipping about one third of the equipment I needed from Berkeley to Pittsburgh at the proper times and to return it immediately after its use.

Through the courtesy of Professor W. C. Kelly, Mr. G. W. Hoffman, and the Physics Department of the University of Pittsburgh, we were able to borrow considerable equipment locally. The remainder of the apparatus used was either purchased from scientific equipment supply houses or was built in the studio shop by Mr. Flick.

The Course Plan

THE original plan as submitted to me by the Pittsburgh schools consisted of thirty-minute broadcasts of lecture material with demonstrations on Mondays, Wednesdays, and Fridays, and ten-minute broadcasts, developing the theory of laboratory experiments on Tuesdays and Thursdays. The proposed ten-minute sessions, correlating laboratory experiments with principles and laws developed in lecture periods, presented certain problems and limitations. First, many schools do not have laboratory equipment and facilities of any kind; second, available equipment in some schools differs widely from that in others; and third, many of the laboratory manuals or work books commonly used are devoid of experiments on kinematics, dynamics, and atomic physics.

After careful consideration of the widely varying conditions existing over the country as a whole, as well as the different text books and laboratory manuals in common use, I broadened the above plan by extending the Tuesday and Thursday broadcasts to thirty minutes each. This extension made possible not only carrying out the original proposed plan but performing each laboratory experiment during the lesson and carrying it through to completion. Not only did this provide laboratory instruction where none now exists but it put on film a more complete introductory course in physics. Furthermore, those students repeating the experiment in laboratories where the equipment is available would be able to proceed with greater confidence and experimental know how.

In setting up the course outline it seemed proper, for the benefit of schools on the semester system, to divide the work into two equal parts. Since the length of the school year varies from one school system to another, the total number of lessons was set at 162. These lessons were planned out and listed under the following twelve headings:

1st Semester

A.	Introduction	4	
B.	Special Lessons	3	
I	Mechanics	44	(18)*
II	Properties of Matter	15	(6)
III	Heat	15	(6)
	Total	81	(30)

2nd Semester

IV	Sound	11	(4)
V	Light	18	(7)
VI	Electricity and Magnetism	24	(9)
VII	Atomic Physics	9	(3)
VIII	Electronics	8	(3)
IX	Quantum Optics	4	
X	Nuclear Physics	7	(1)
	Total	81	(27)

* Parentheses give the number of lessons devoted to laboratory experiments in which class participation is requested.

The four introductory lessons are entitled "Introduction to Physics", "Optical Illusions", "Units of Measurement", and "A Laboratory Experiment on Measurement". The three special lessons are entitled "Algebra and Powers of Ten", "Learning to Use the Slide Rule", and "Elements of Trigonometry". They are designed to be inserted wherever convenient during the early part of Mechanics.

The general format of the daily lessons as they were broadcast live over WQED and simultaneously photographed in color by EBF is as follows: Each demonstration lecture includes a number of pre-drawn blackboard diagrams, at least one and often many demonstrations. Simple algebraic equations are presented wherever appropriate and problems are sometimes worked out.

The general procedure followed on each laboratory day calls for individual participation of the following kind. The first five to ten minutes are devoted to the theory of the experiment. In most instances this consists of a brief review of principles or laws previously treated and includes whatever algebraic formulas will be needed for calculating experimental results. Diagrams of apparatus are next shown and explained, followed by views of and my descriptions of apparatus itself.

At this point the students are instructed to prepare data sheets. This they do by first copying the *Title* of the experiment from a plaque, and then the *Object* of the experiment from a slowly moving drum scroll. The table to be used is then seen in close-up on the blackboard and sufficient time is allotted for them to copy the column headings.

The class then watches as I proceed with the experiment. By means of carefully planned close-ups, they observe and record measurements as I read them off. In the measurement of distance, for example, they see the individual millimeter marks on the meter stick. In the measurement of time everyone can see the hand of

Fig. 2. Photograph of a cameraman with a Tele-Cam unit on a counter-weighted dolly.

the stopwatch and read the time interval to fifths of a second, and in the measurement of mass they can all see the small weights as they are placed on the platform of a beam balance, as well as the rider as it is moved along its scale.

Upon completion of the measurements a close-up of the recorded data, simultaneously recorded by my assistant on the blackboard, is shown for student comparison. The students are then instructed on how to calculate their results and, where pertinent, to plot a graph. In the first few minutes of the demonstration lecture immediately following each laboratory lesson, the results I have obtained are shown in detail so that students may make direct comparison with their own. Where a graph is called for, they see my plotted points and hear my interpretation of the drawn curve.

TV and Color Filming

THE original plan for filming the daily lessons called for 16 mm black and white film made by the television process called *kinescoping*. Fortunately, a new device called TELE–CAM, developed in Pittsburgh by Warren Smith, Inc., and completed for testing and operation only three days before the first telecast, was made available for use on the project. TELE–CAM is a mechanical-optical system which unites a standard TV camera with a motion picture camera, using a common lens system permitting direct black and white or color filming during actual telecast. Being a direct film system it has none of the quality limitations of kinescoping. Because of the great importance of this new device to the motion picture industry in general, and because it was designed by a physics student while still in college at the Carnegie Institute of Technology, Mr. Robert Ferber, its principles and operation will be briefly described. (See Fig. 2.)

A standard 16 mm moving picture camera, electrically driven and capable of handling 1000-foot reels of film, is mounted on one side of the TV camera as shown in the photograph. By means of a thin mirror, partially coated and mounted just behind the lens turret, the converging image light is split into two parts, about 25 percent going to form an image on the photocathode of the TV Image Orthicon, and the remainder going to form an identical image on the face of a field lens. (See Fig. 3.) The latter image is then filmed by focusing the moving picture camera on this lens face.

Kodachrome film was selected for original recording because of its fine grain characteristics. Because of its relatively low film speed, however, the physics staging had to be uniformly illuminated with about 1100 foot-candles. Two complete TELE–CAM units were used throughout all lessons, one for what are called "close-ups" and the other for what are called "wide shots". Simultaneously with the telecasts a 16 mm kinescope film was made in black and white and two separate magnetic sound tracks were made from the sound picked up by a chest microphone hidden under my tie.

The physics stage setting consisted of three matching tables with paneled fronts, which could be joined together to form a single working surface 3 feet by 18 feet. Four feet behind these were three green-surfaced magnetic chalk boards. At times these were not all used. (See Fig. 1.)

In general, all diagrams and equations were carefully drawn on the chalk boards ahead of time. The two to three hours spent each day on this work was well-spent, however, for it made it possible to cover in thirty minutes what, in the normal classroom, would require at least 45 minutes. In making use of colored chalk to bring out desired details care had to be exercised in the choice of colors. Some combinations that accentuate important details when seen on color film may give identical gray tones on TV and black and white film, thereby losing the desired effects.

Because of keystoning effects and focusing problems of the apparatus being photographed when lying on the table top, considerable thought and effort were devoted to the design and construction of new apparatus that could be mounted on a vertical surface. Many of the principles in mechanics, for example, lend themselves

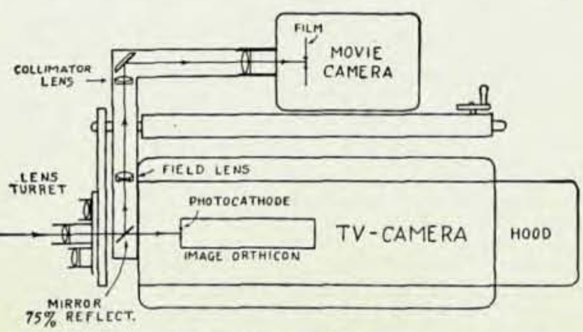

Fig. 3. "Tele-Cam", the TV and motion picture camera combination used on this project for the simultaneous telecasting and color filming of the daily lessons.

to a vertical wall display and it is surprising how little time is required to make such demonstrations out of wood, cardboard, pulleys, string, and a little paint. Rubber base paints of the kind used for inside wall coverings dry quickly and give a desirable matte finish.

The studio became available to our use each day at 11 AM. At this time the tables, chalk boards, and demonstration equipment were moved into place and the utilities connected by my assistant, Mr. Wilson Flick, and the floorman, Mr. Richard Price. At 11:30 AM the director, Mr. Samuel Silberman, and the film producer, Mr. David Ridgway, arrived and together the five of us talked over the lesson. By my explanations of what I wanted to show, the director worked out the best camera shots. With the entire crew in place at 12 noon, rehearsal began, and at 1 PM we were "on the air".

The crew consisted of twelve people. They included my assistant, the floorman, two cameramen, the director, the film producer and his secretary, the audio engineer, the video engineer, the kinescope recorder, the master control director, and myself. The television director, watching the two camera monitors from the control room, directed the cameramen and floorman on their various moves by means of an intercommunications system and at the same time switched electrically from one camera to the other, choosing the picture he desired to be broadcast.

Since each kinescope film shows exactly what went out "over the air", the film producer and I reviewed each lesson, in kinescope form, to check for errors in sound and picture. If for one reason or another an experiment failed to work, or better close-ups were indicated, the experiment was refilmed to our satisfaction, and the new film cut in. Whenever sound errors were observed, corrections were also made and spliced into the original sound track. The various steps involved in the production of final film prints are shown by a block diagram in Fig. 4.

Once, before the opening of classes in September, and twice later, teachers who had classes participating in the program were brought together to discuss with me their problems as well as the students' general reaction. Additional "feed back" of information came as the result of classroom visitation at various times by Mrs. H. E. White and Mrs. David Ridgway, both of whom have had teaching experience.

At the opening of the school year twelve city and county high schools were signed up for participation in the program. Twelve additional schools began using the TV broadcasts in September and by spring a total of forty-four high schools, including eleven parochial schools, were watching the programs. Participation of a school involved the maintenance of a control class for a later comparison with the TV class. All of these classes were given the same "Dunning Physics Test" in September to find out what they already knew, and a similar test at the end of the school year for progress measurement and comparison purposes. Control classes are to be compared only with TV classes of the same average IQ. A report on the results will soon be made.

Personally I have little faith in any one such test for, as so often happens, long range conclusions are inclined to be drawn from their results. As we all know there are intangibles in education that are difficult to measure by testing methods. Has a student, for example, learned how to handle a piece of equipment or to perform an experiment better by watching a trained person first? Has a student turned in a neater and better report than he would otherwise have done because he has seen how carefully and neatly a trained instructor has made certain measurements and recorded the data? What influence have the instructor's methods had upon any one pupil that will redirect his general interests and thereby markedly affect his whole life's work?

Advantages of TV and Film

FROM the beginning of this project I had hoped that satisfactory answers could be found to two all-important questions: one, can TV and/or films make physics demonstrations visible to those sitting in the back of a large classroom; and two, what is it that attracts and retains the undivided attention of pupils to a TV or motion picture screen?

Now at the completion of the filming stage of this project I feel that we at least know some of the answers to these questions. It will be worthwhile noting with care the following answers for they clearly indi-

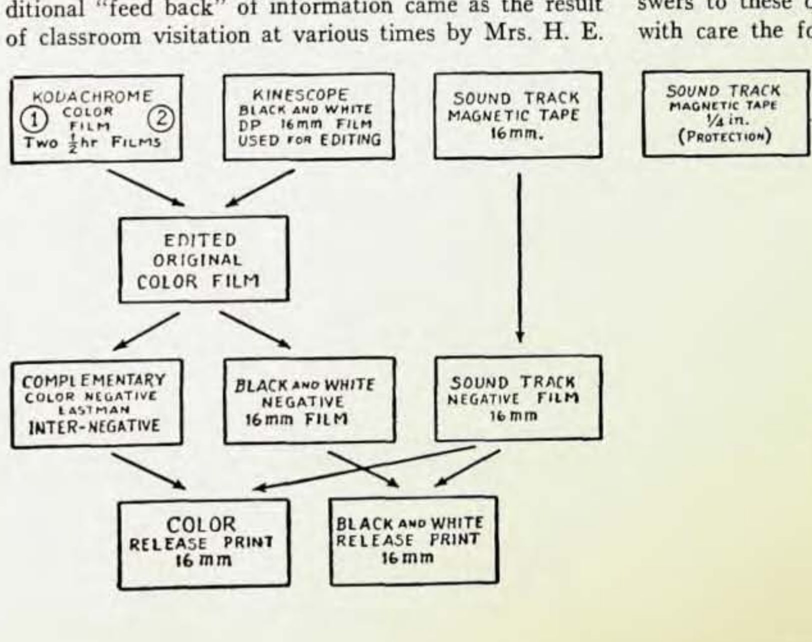

Fig. 4. Block diagram showing the number of film reels and magnetic tapes required in the production of release prints for every lesson.

cate that we now have within our grasp powerful new implements of communication.

Close-up views of small things can be made so large and clear that everyone, even in the largest room can see necessary detail. As someone has said, "It gives every student a front row seat." I say it does better than that. It brings the visual aids and demonstration pieces right up to within touching distance. Furthermore, apparatus can now be made smaller than before, rather than larger, and to good advantage. Small things are usually easier and less costly to make, they lend themselves to better camera pickup, and the storage space is no longer a major problem.

The student sees only what is presented on the screen and is not distracted by other things in the room or on the lecture table. Undivided attention is the result, and the student is not wondering when the teacher is going to get to "that piece of apparatus over on the end of the table".

All pupils watching a TV or motion picture film observe and feel that the teacher is looking directly at, and therefore talking directly to, them. (Look at any picture of a person who is looking straightforward and wherever you stand, he seems to be looking at you.) In essence, this gives rise to the most effective of all communications situations—the teacher and one pupil alone with no one to interrupt. It approximates the Mark Hopkins ideal of a teacher at one end of a log and his student at the other.

A teacher, whether excellent or mediocre, whether experienced or a beginner, has an opportunity to observe throughout an entire year the teaching methods and demonstration experiments developed and employed by another teacher. No matter how good each of us may think he is, we can always learn new and often better ways of presenting subjects by watching and listening to others of our own profession. The dissemination of one teacher's pedagogical methods and knowledge among other teachers has never before been possible under such ideal conditions.

While there are a number of minor disadvantages to TV and films, I am now convinced that the positive values far outweigh the negative aspects. As with anything else that is going through its earliest developmental stages, difficulties are bound to arise. Careful consideration of the various disadvantages shows that most of them are easily remedied. Apparently the problem that disturbs teachers the most is the one referred to as "feedback". How can the students ask questions and obtain suitable answers?

The large universities have of necessity been using mass education methods for years. Questions are not permitted in large lecture halls, but the students are divided into small classes that meet at later times for discussion and answer periods.

For this introductory physics course at the high-school or college level, I therefore propose the following: film projection or telecast of the daily lessons, followed by an adequate and properly conducted discussion period each day.

Where a competent physics teacher is not available these discussion periods can be directed by any well-trained teacher. As a rule, discussions among students develop satisfactory answers to 80 percent of the questions raised by others within the class and most of the remaining questions can be found in the text books.

Use of Films

STARTING in February, 1957, Chicago's Educational TV Station, WTTW, began the daily telecasting of these physics films to 20 public high schools in that area. The second semester's lessons will be seen during the summer months. Many secondary school systems in other metropolitan areas, as well as some universities, are planning similar uses of the films beginning in September. Telecasts during evening hours are also planned in some localities for adult education purposes with signed enrollment and high-school credit available at the completion of a written examination.

One state is already making extensive plans for the use of films in rural schools. In this instance several sets of films will be used and circulation systems are being worked out so that each school will see the lessons in their proper order.

Several large industrial research laboratories are acquiring films for on-the-job training purposes, thereby reducing the transportation time for those selected for further training and education in the basic sciences.

One of the major problems encountered in the telecasting of daily lessons is the scheduling of classes. Time schedules vary from school to school, due to many circumstances, and to find a common time when a large number of schools in any one area can schedule any particular course appears to be difficult.

The second major problem concerns the total time available for physics alone. With 30 minutes set aside each day for a film or telecast there is insufficient time left for a discussion and answer period or a laboratory experiment.

It would appear then that where schools are to be reached by telecasting the following plan could solve most of the difficulties. All physics classes meet from 8:30 to 9 AM to observe telecasts. (Most schools begin at 9 AM.) Each physics class then meets at its regularly assigned period and uses the time for discussion or laboratory sessions.

The most effective use of the lessons can be made by employing classroom projection methods. All physics classes within any school can either see the films at the same time in the school auditorium or can see them separately at different hours and thereby solve the schedule problem. Because of the high cost of films, multiple use plans have been worked out so that as many as twenty schools can use the same set. A film used by one school one day can be passed on to the next school by messenger service set up between school busses and/or pupils. Such usage in metropolitan as well as rural areas all over the country can bring physics instruction to the hundreds of schools where none now exists.