REPORT RESUMES

ED 020 917 SE 004 920

PRODUCTION AND USE OF SINGLE CONCEPT FILMS IN PHYSICS TEACHING.

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PUB DATE SEP 67

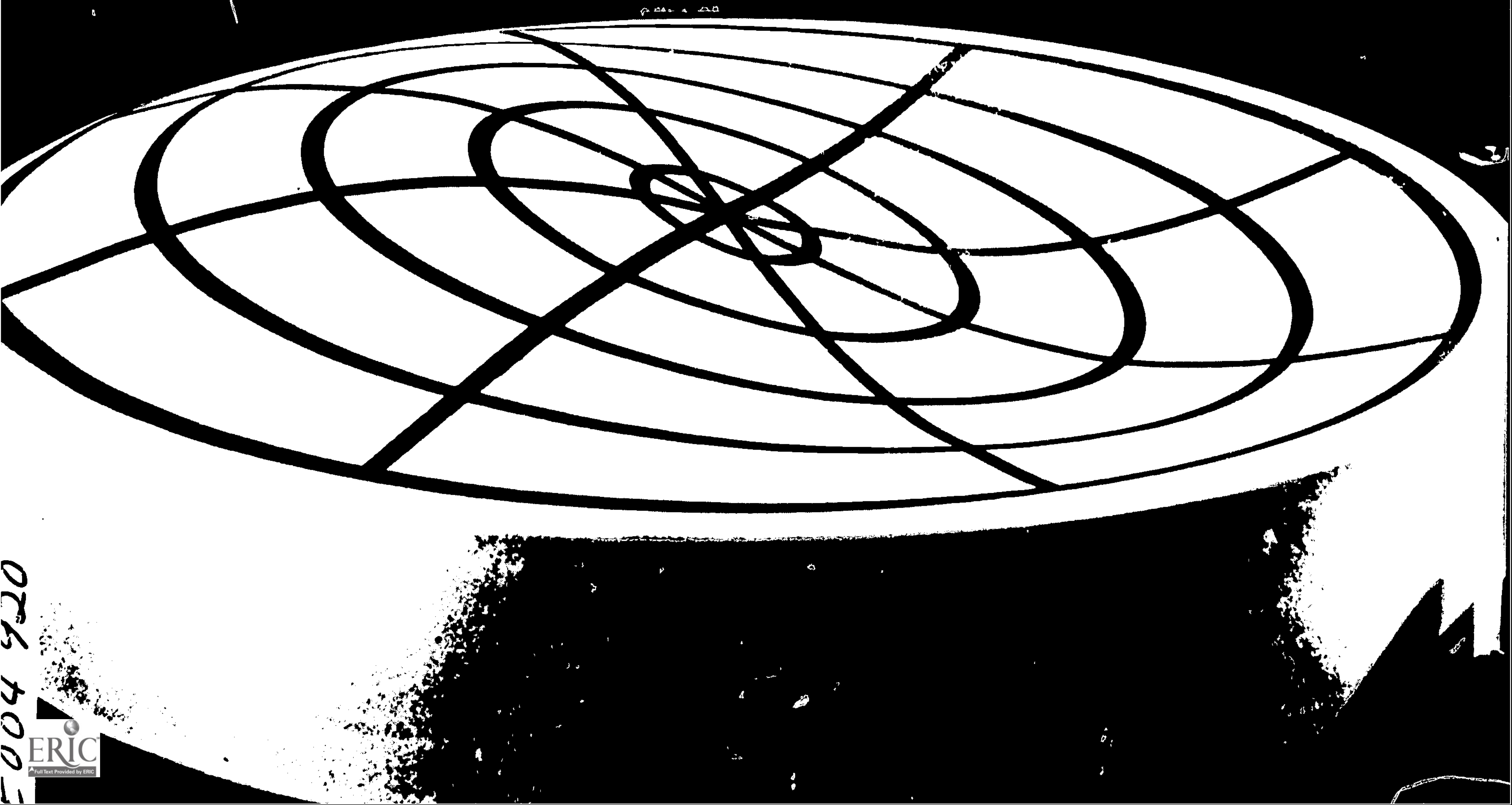
EDRS PRICE MF-$0.50 HC-$4.72 116P.

DESCRIPTORS- *AUDIOVISUAL AIDS, BIBLIOGRAPHIES, *COLLEGE SCIENCE, *INSTRUCTIONAL MATERIALS, *INSTRUCTIONAL FILMS, PHOTOGRAPHY, *PHYSICS, PROJECTION EQUIPMENT, SINGLE CONCEPT FILMS, CONFERENCES, FILMS, SCIENCE EQUIPMENT, COMMISSION ON COLLEGE PHYSICS,

BASED UPON THE CONFERENCE ON SINGLE CONCEPT FILMS IN COLLEGE PHYSICS TEACHING HELD AT RENSSELAER POLYTECHNIC INSTITUTE IN DECEMBER OF 1966, THIS REPORT ATTEMPTS TO (1) PRESENT CURRENTLY AVAILABLE TECHNOLOGICAL INFORMATION ON THE PRODUCTION, DISTRIBUTION, AND DISPLAY OF SINGLE CONCEPT FILMS IN PHYSICS, (2) TO ENCOURAGE INCREASED AND BROADER USE OF THESE SHORT FILMS IN COLLEGE PHYSICS TEACHING, AND (3) TO STIMULATE THEIR PRODUCTION IN COLLEGE PHYSICS DEPARTMENTS. THE REPORT IS ESSENTIALLY AN EXPANSION OF THE RESULTS OF THE WORKING SESSIONS OF THE CONFERENCE, AND DEALS WITH (1) THE USE OF SINGLE CONCEPT FILMS IN PHYSICS INSTRUCTION, COVERING THE AREAS OF CLASSROOM USE, LABORATORY INSTRUCTION, AND SELF-INSTRUCTIONAL USE, (2) FILM MAKING TECHNIQUES, INCLUDING LOCAL PRODUCTION OF PHYSICS FILMS, FILMING IN A PROFESSIONAL STUDIO, AND COMPUTER-ANIMATED FILM MAKING, AND (3) CAMERAS AND ACCESSORIES FOR AMATEUR SCIENTIFIC FILM MAKERS, INCLUDING FILMS, PROJECTORS, AND UTILIZATION OF PROJECT MATERIALS. THE APPENDIXES INCLUDE SECTIONS ON (1) CONFERENCE AGENDA, (2) FILM ANIMATED BY COMPUTER, (3) PRODUCING A FILM, (4) EQUIPMENT, (5) AUDIOVISUAL INSTRUCTION AT PURDUE, (6) LIST OF CONFERENCE PARTICIPANTS, AND (7) A BIBLIOGRAPHY. (DH)

COMMISSION ON COLLEGE PHYSICS

Production and Use of Single Concept Films in Physics Teaching



Front and rear cover illustrations

Still photographs from *Vibrations of a Drum* produced for Project Physics by the National Film Board of Canada. The pictures are made possible by a new high speed camera in which the camera speed can be varied while shooting to equal the vibrating frequency of the rubber skin. Designer of the demonstration: Alfred Leitner of Rensselaer Polytechnic Institute. (Courtesy of the National Film Board of Canada)

Production and Use of Single Concept Films in Physics Teaching

Commission on College Physics

Part of the report of the Conference on Single Concept Films in College Physics Teaching sponsored by the Commission on College Physics and held at Rensselaer Polytechnic Institute December 15-17, 1966.

The Commission on College Physics

The Commission on College Physics is a national organization established by the physics profession in 1960 to coordinate efforts to improve undergraduate physics instruction. The Commission's full-time professional staff consists of a Director and Staff Physicists who are typically academic physicists on leave for one- or two-year terms. Commission programs are guided and reviewed by the Commissioners, seventeen physicists elected from the physics profession or appointed by the Commission.

The Commission is engaged in the development of broad programs to identify and understand the problems of undergraduate physics teaching, to stimulate the search for solutions, to encourage innovation and experimentation, and to design mechanisms which will assure continued involvement of physicists in these tasks. The Commission offices are located in the Department of Physics and Astronomy at the University of Maryland. The activities of the Commission on College Physics are financed by a grant from the National Science Foundation.

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Acknowledgments

This report is based on the Conference on Single Concept Films in College Physics Teaching, held at Rensselaer Polytechnic Institute on December 15-17, 1966. First acknowledgment must go to the participants at that Conference (see Appendix F)—physicists, film makers, producers, etc., who braved a December snowstorm to contribute their knowledge, imagination and criticism to the Conference proceedings—as well as to the working group chairmen E. Leonard Jossem, Alan Holden, W. Thomas Joyner, and Kevin Smith, who so effectively mustered these talents and reported the results of their deliberations.

The first day of the Conference was made most useful by the invited speakers and panelists; among these, we must give special thanks to Shirley Clarke and Wheaton Galentine for bringing to us their stimulating glimpse of the film maker's art.

We must also thank those who were involved throughout in the planning of the Conference: Walter Eppenstein who first suggested it and who so ably handled local arrangements, and the Steering Committee of Walter Eppenstein, W. Thomas Joyner, Elwood Miller, Kevin Smith, and John M. Fowler who gave advice before, during and after the gathering.

The report itself elaborates and extends the working group reports; we were greatly assisted in this phase by several contributors who merit special thanks: Kevin Smith who gave generously of his time and know-how to provide the section on local film making techniques (including the production of a film and accompanying storyboard); Franklin Miller who was unable to attend the Conference but who contributed of his physicist's expertise in film making to produce the section on cameras and accessories and who read sections of the report; Jacques Parent who cheerfully advised us on problems of equipment and who wrote up the description of the professional's view of film production and read sections of the report.

We also wish to acknowledge the cooperation of E. E. Zajac, S. N. Postlethwait and David G. Husband, and John Vergis who allowed us to reprint materials on computer-animated film making, the Purdue botany course, and testing cameras and shooting sequences, respectively. We appreciate also the help of Gordon H. Tubbs of Kodak who read the equipment report.

The final choice of materials, design, editing, compilation of appendices, etc., is however our responsibility and we look forward to comments, additions, and criticism from the report's readers.

John M. Fowler, Director
Commission on College Physics

Barbara Z. Bluestone
Reports Editor

September 1967

Table of contents

I

Introduction

II

Uses of Single Concept Films in Physics Instruction

III

Film Making Techniques

IV

Equipment

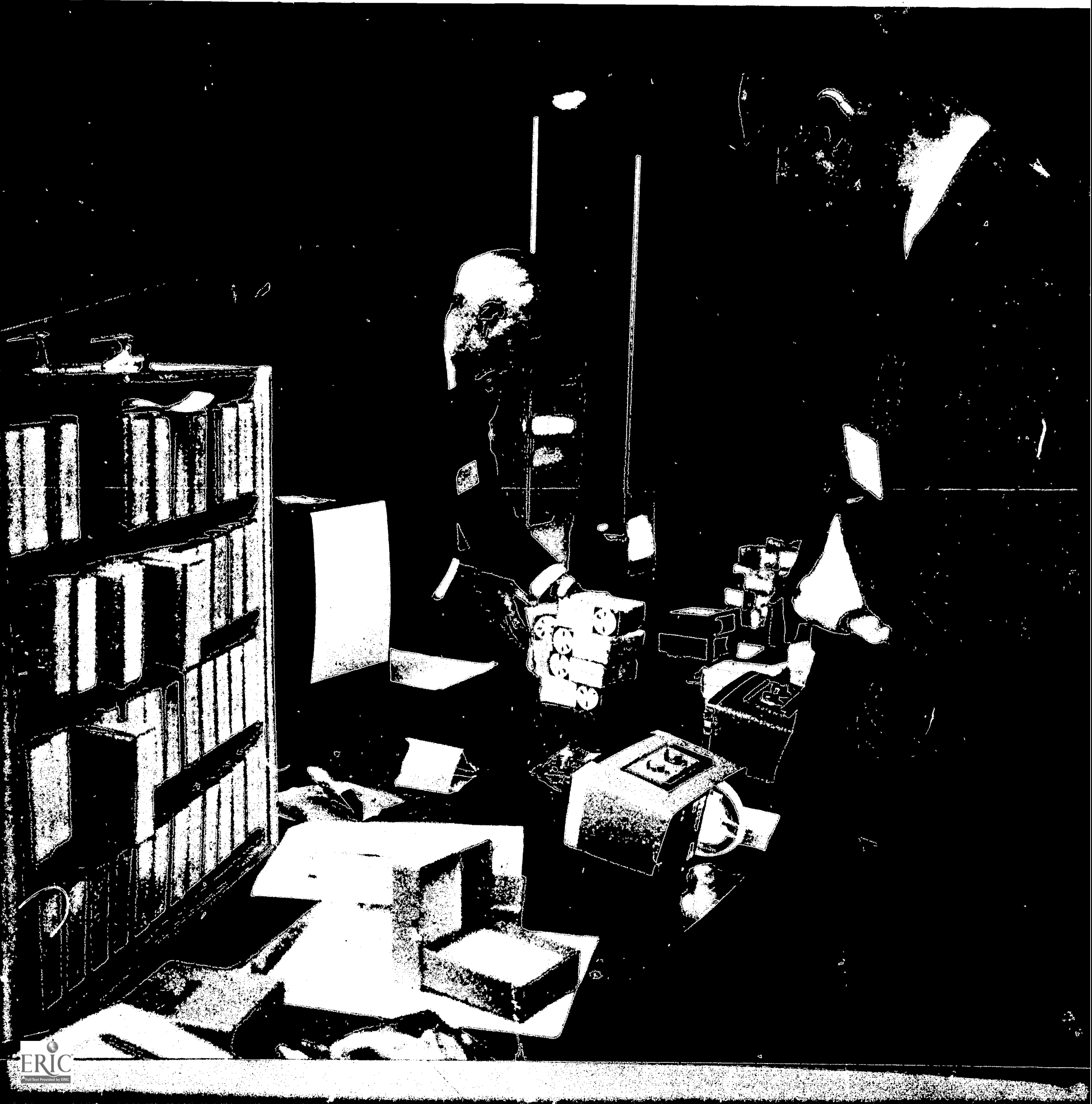
V

Conclusions

VI

Appendices

Part I Introduction



Introduction

The introduction of the 16mm film format and the rapid evolution of the theory of quantum mechanics both took place in the mid-1920's. Their impact on the teaching of physics at the introductory level was negligible, however, until the 1960's.

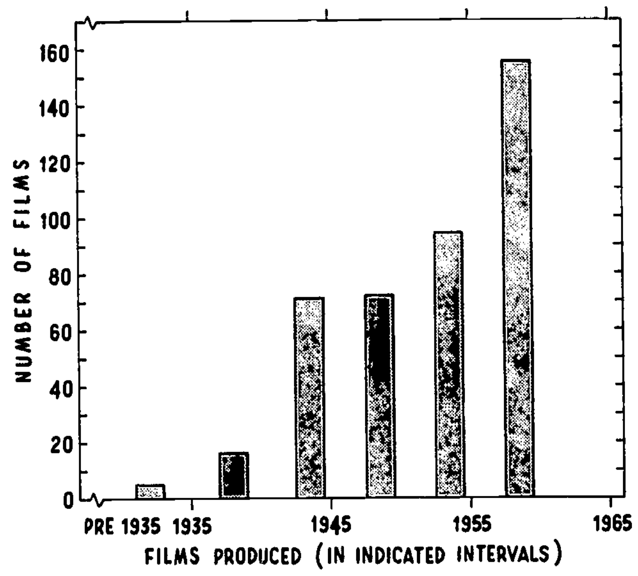
One cannot, of course, push the parallel much farther. The development and application of quantum mechanics provides an excellent example of what physicists do well—the determined effort to understand the fundamental properties of the universe. Film, on the other hand, is a little exploited technique whose application is in an area in which physicists do not do so well—explaining their understanding to others.

It is surely true that film has not been thoroughly or imaginatively exploited in the teaching of physics. One can measure the importance which physicists attach to the film medium in teaching by the absence of records as to how and how often films have been used in physics classes. No checklist of films for undergraduate instruction has ever been compiled to parallel the AIP's *Check List of Books and Periodicals for an Undergraduate Physics Library.* Thanks to Robert L. Weber's series of survey articles in the *American Journal of Physics,*[1] however, we do have some information on how many films had been produced in physics as of 1961. The graph in Figure 1 shows the steady increase in the number of films available to physics teachers between 1935 and 1961.

One has the feeling that such a representation of the *use* of film in physics teaching would not show the same upward slope. It is, for instance, difficult to think of a teaching film available in the 40's and 50's which would be universally known. A strong candidate might be *Bubble Model of a Crystal;*[2] its credentials are impressive. Made by Sir Lawrence Bragg, it uses a clever demonstration technique to capture some of the orderly beauty physicists see in crystal structure and at the same time provides a model useful in understanding the physical features of this structure. One can only guess at the fraction of physicists who have used this film in class and the guessed fraction would be small.

Many reasons can be found for the relative unimportance of the film medium in the teaching of physics. A study by the British Universities Film Council in 1960 gave as the reasons for non-use of films:

> **(1) lack of suitable films; (2) difficulty of locating suitable films; (3) lack of projection facilities; (4) difficulty of having to pre-plan**



Graph illustrates the steady growth of the number of physics films available since 1935 (based on Weber's film lists).

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[1] Am. J. Phys., 29, 222-233 (1961); 22, 54-59 (1953); 17, 408-412 (1948).

[2] *Bubble Model of a Crystal* by Sir Lawrence Bragg, distributed by Ealing Corporation.

> the speed of progression of a course because of the necessity of booking films well in advance. . . .[3]

Robert Weber in his first AJP article[4] makes essentially the same analysis:

> Despite these advantages, instructors who have used films in the teaching of college physics have noted chiefly their shortcomings. The inadequacy stems in part from the nature of the medium. A film presentation is usually inflexible, but need not be so. The realism of actual demonstrations is missing, the student is allowed little opportunity for reflection, questions, or the taking of notes. There is a lack of repetition and no opportunity for individual students to review and study the film.
>
> Other and more remediable inadequacies in the present use of instructional films in college are: (1) tht diffuseness and theatrical packing of films edited to catch the widest possible audience; (2) the limited effort of colleges and professional organizations to sponsor and edit films for specific teaching needs; (3) the difficulty of finding reliable critical appraisals of films; and (4) the inconvenience to the instructor of screening films in advance and fitting them effectively in the class room work.

Neither author has mentioned directly the cost of the film; this factor also finds its way into the decision to use or not to use. But whatever the reasons, the chief use of film in lecture has been as a filler for lecture time left vacant by traveling physicists.

There seem now to be two technological advances which are likely to change the pedagogical role of film. One of these, the cartridged film, is already upon us; the other, the new technology of 8mm film, is cresting to break. Together they should make filmed material as easily accessible as is supplementary reading material.

The movement to cartridged films and projectors to handle them comes in two steps: the idea of a continuous film loop which needs no rewinding and is ready for reshowing; and the cartridge which protects it (fairly well) from dust and grubby fingers.

John Heilemann of Ursinus College has been suggesting the usefulness of film loops in physics teaching for some time[5] and has provided examples of their applicability to the demonstration of wave motion.

The first examples of cartridges appeared in 1962. They are now available both in longer (20- to 30-minute) sound film[6] and the short (four-minute) silent films.[7] Their advantages as supplementary material stem from the simplicity of their use: they can be picked up from a library collection, slipped into the projector, looked at, and returned to the library. With self-contained screens, the cartridge-loading projectors provide access to information in a manner still more complicated than that offered by a book, but less complicated than, say, a microfilm reader.

Cartridge-loading projectors are relatively inexpensive.[8] The films range in price from $7.00 to $20.00 for a four-minute silent loop and from $18.00 to $160.00 for up to 30 minutes of sound loop. Their easy accessibility and low cost remove several of the objections noted above.

The cost should go down. The major industries connected with photography have finally recognized 8mm film as an item with big market potential and are turning their great resources toward its improvement. And the improvements are appearing. Eight millimeter sound film, both optical and magnetic, is already several years old. The new 8mm formats (see Part IV) produce brighter, sharper pictures when projected. New projectors, sound and silent, using cartridges or with simple automatically rewinding reel packages, are appearing. Equally exciting and necessary, laboratory facilities are being improved and fast printing systems, one of them producing 200 ft/min of printed film, are now being developed.

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[3] From "Film as a Teaching Aid," in *Films in Higher Education*, edited by Peter D. Groves (London: Pergamon Press, 1966), p. 98. The paraphrase is of a report by BUFC entitled "The Use of Film in Teaching and Research in British Universities, 1959," University Film Journal, 19, (1960).

[4] Am. J. Phys., 17, 408-409 (1948).

[5] Am. J. Phys., 20, 465 (1952); 23, 555 (1955); 26, 50 (1958).

[6] Fairchild MoviePak cartridges with magnetic sound track; Technicolor Magicartridges with optical sound track.

[7] Technicolor silent Magicartridges.

[8] See Part IV.

Eight millimeter film can now be economically presented to an audience as small as one or as large as 500.

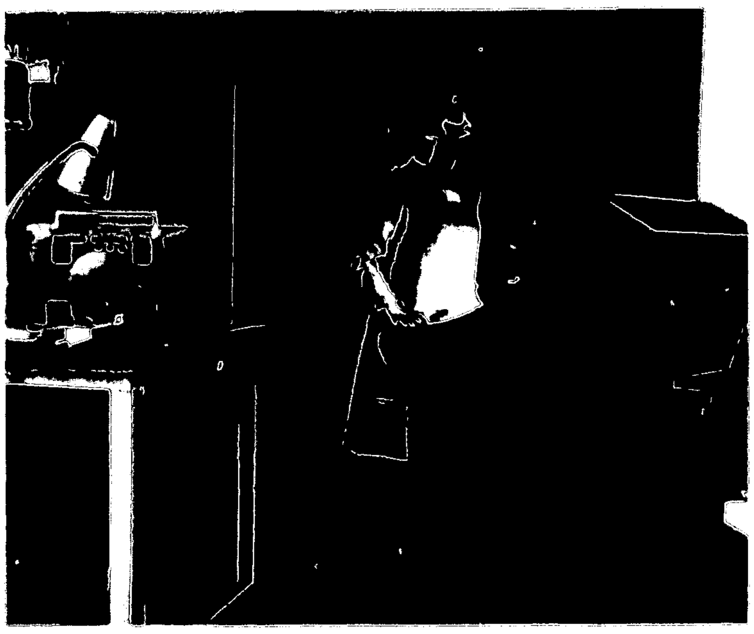
What is lacking still is quantity and quality—the other part of the set of difficulties referred to in the British list (1) and Weber's list (1) and (2). It was toward lessening these inadequacies that the CCP set up the Conference on Single Concept Films in College Physics Teaching.

The first formal suggestion of the need for such a conference was made in February of 1966 by Walter Eppenstein of Rensselaer Polytechnic Institute, then a member of the AAPT Visual Aids Committee. In his letter to the Commission he said:

> **I would like to make a suggestion for a possible conference I have not seen mentioned previously. I would like to see the use of Single Concept Teaching Films in Physics discussed in some detail with a report to be widely distributed. I believe that this type of film—usually in 8mm cartridges—is relatively new and has many possibilities not yet fully explored.**

W. Thomas Joyner, CCP Staff Physicist, began with Eppenstein the long planning that goes into a successful conference. A Steering Committee consisting of Kevin Smith (Education Development Center), Elwood Miller (Michigan State University), Walter Eppenstein, and Thomas Joyner and John M. Fowler of the CCP, met on September 30, 1966, to produce a complete Conference design.

The Conference had unique features. First of all, it was held in Troy, New York, in mid-December (clearly it was a working conference). In order to sample widely among the experience and opinions of the many types of professionals whose interests meet in film production, we invited physicists, photographers, film makers, producers, photographic technicians, representatives of film distributors and of film equipment companies and others. The presentations to the Conference on the first day thus varied in style and content from John Vergis' illustrations of how to use magic markers in title making to presentations of Shirley Clarke's impressionistic film *Bridges Go Round* and Wheaton Galentine's time-lapse studies of growing plants; from Jacques Parent's precision high-speed photography of a recoiling cannon to Wendell Slabaugh's garage-studio chemistry films. The mix was potent and each of us carried away more than we brought.



Shirley Clarke gives the Conference a look at the professional film maker's art.

But after the shock of *Sleep*[9] had worn off, what did the Conference accomplish? The pre-Conference statement of purpose was:

> **The goals of this conference are: (1) To gather in one report the presently available technological information on the production, distribution, and display of single concept films in physics; (2) To encourage increased and broader *use* of these short films in college physics teaching; and (3) To stimulate their *production* in college physics departments.**
>
> **To this end the conference will be a working conference, and the report will carry a summary of present uses and suggestions for future experimentation, a survey of different film making techniques and of the equipment for filming and projection; it should also suggest a mechanism or mechanisms for distribution suitable to the increased use which is foreseen.**

The Conference agenda forms Appendix A. The input of the first day concentrated on what had been and what could be done with film. The second day's working sessions considered what should be done in physics. The Report which follows is an expansion of the results of these working sessions.

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[9] *Sleep* by Andy Warhol, perhaps the ultimate in a single concept film, several minutes of which was shown by Shirley Clarke.

Part II Use of Single Concept Films in Physics Instruction

Use of single concept films in class[1]

In keeping with the theme of the Conference—to encourage the production and use of "single concept" films in physics—this working group chose to concentrate its attention on how films *could* be used in physics classrooms rather than how they *are* being used. They accepted as a working hypothesis that cartridge or other automatic projectors suitable even for large lecture halls are available and that they impose no arbitrary restriction on film length.

The report of the Working Group on Self-Instructional Uses of Single Concept Films (see pp. 17-21) establishes that the availability of inexpensive, accessible film will be an important part of the advance of educational technology and will make possible radical experimentation in the nature of instruction and the development of alternatives to the lecture-dominated mode which has endured so long. It is also evident, however, that changes, if they occur at all, will be long in coming and that, in the expectation of a healthy future for the classroom lecture, the consideration of the role of films in this setting is no idle exercise.

TYPES OF USES

Demonstration

The most obvious use of film in the classroom is to demonstrate phenomena. While most of the longer films (for example, those produced by EDC for high school and college) are of demonstrations, their length, and the inflexibility of presentation caused by their accompanying sound track, have made them compete to disadvantage for lecture time. The short, silent film is a much more attractive modular unit and more obviously an aid to the lecturer than his replacement.

Because physics is a subject in which abstraction and the concreteness of experimentation and observation are strongly linked, some see the use of filmed demonstration as a regrettable retreat from the real world. It is a fact of academic life, however, that the use of live demonstrations is not always possible; their construction competes with higher priority research time and shop time, and their arrangement for other valuable time. A filmed demonstration, once in the can or cartridge, is always ready and quickly available. And even the most dedicated demonstrator will agree that there are demonstrations which are better handled on film than live. Proceeding from the question "Is a film necessary for this demonstration" rather than "Can this demonstration be filmed," Franklin Miller[2] supports the filming of demonstrations in the following cases (the examples are from his film series):

1. **The action is too slow or too fast for convenient study *(Radioactive Decay);***
2. **The experiment is dangerous *(Critical Temperature);***
3. **The experiment is uncertain or requires a difficult or critical adjustment *(Coupled Oscillators);***
4. **The experiment requires apparatus or supplies which are expensive or not readily available *(Paramagnetism of Liquid Oxygen)*;**

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[1] W. T. Joyner (Chairman). George Carr, Thomas Norton, Jacques Parent, N. MacGregor Rugheimer, Joseph Straley, F. W. Van Name, Jr., Frederick W. Zurheide (members). Forrest I. Boley, John Fitch, Ross Gortner, Jr., Robert Resnick, John Fowler (visitors).

[2] Am. J. Phys., 33, 806 (1965).

5. **It is an optical demonstration which cannot be projected because of weak light *(Resolving Power)*;**
6. **The experiment is too small to demonstrate in a classroom *(Ferromagnetic Domain Wall Motion)*;**
7. **The experiment is too large to demonstrate in a classroom *(Inertial Forces)*;**
8. **The presentation is clarified by superposition of graphics or legends over live-action photography *(Michelson Interferometer)*;**
9. **The film records a rare or one-time event *(Tacoma Narrows Bridge Collapse)*.**

The number of short demonstration films meeting these criteria is growing steadily (as is the number of films which fail to meet them) and their increasing use seems assured. More films are needed, however, in order to bring to as many students as possible the most compelling demonstrations of physics that inventive physics teachers have produced.

There is, of course, a deep reservoir of short film materials in the film libraries of industry and government. NASA, for example, has 8×10^6 feet of film. While the problem of searching these large amounts of film for short sequences which can be excerpted is a formidable one, the introduction into classes of some of the applications and illustrations of physics in space exploration may make it worth while. NASA, in particular, is eager to see its films used, and is engaged in the massive task of producing microfilm descriptions of their films, which will carry representative frames as well as written abstracts. Surely a summer spent by some physics teacher in these archives could have fruitful results for physics instruction.

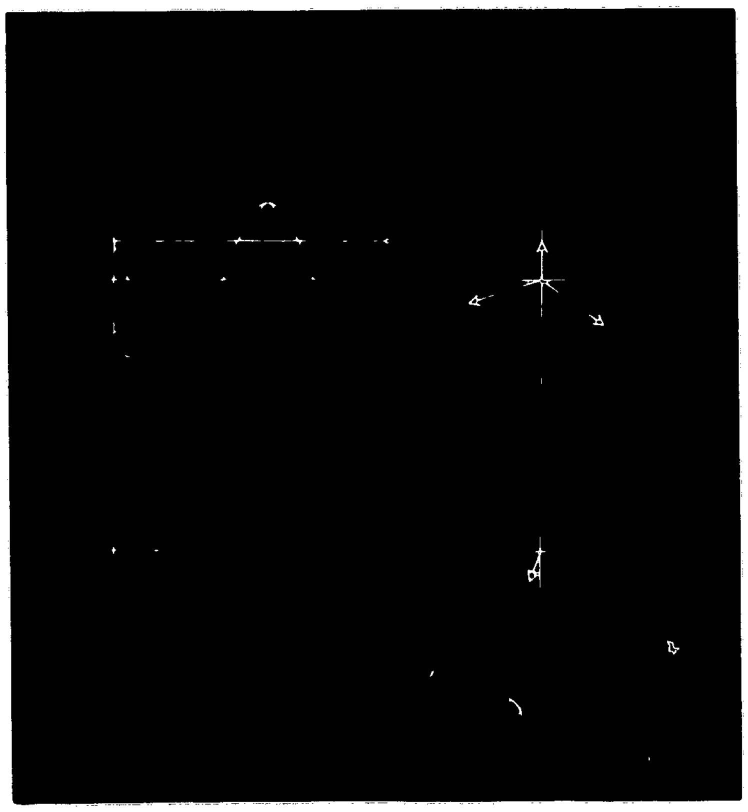
Even with a great variety of films in hand, however, there are many questions which must be answered before film can be used to full advantage. Serious studies should be made of the importance of the length of films (how long a segment can the student hold in memory and discuss fruitfully afterward?) and of their effectiveness as teaching aids compared with live demonstrations; and teachers will have to be encouraged to experiment further with instructor-applied sound tracks, etc.

Definitions

In physics, words, accompanied by limited, imperfect artistry in the static, two-dimensional representation of the blackboard, are often inadequate to clear definition of physical concepts. Film has obvious advantages; it is dynamic and the necessary art can be supplied in uniform high quality.

Suggestions for useful "definition films" are easy to come by. The concept of reference frames, the center-of-mass frame of colliding objects, or the rotating reference frame so useful in describing many wave phenomena, lend themselves to dynamic illustration. One can envisage films "explaining" phase space, symmetry operations, and so on.

There is also a need for films which link abstract concepts to real phenomena. It would be valuable to have, for example, a collision photographed in slow motion and compared on film with the representation of that collision in momentum space, or actual motion compared with its space-time representation, or to superimpose a probability distribution on a time-lapse photograph of the growth of an electron diffraction pattern. The techniques of superposition of images, of combined live and animated action, etc., are all available to enhance the visual presentation of ideas.



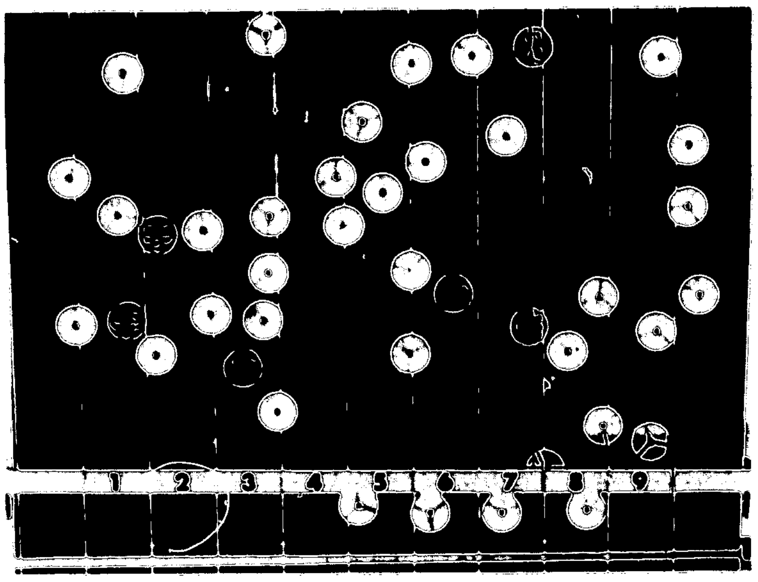
The superposition on sinusoids of different phase and amplitudes is shown in the computer-animated film *Harmonic Phasors*.

Model Building

Related to the definition film is the film displaying mathematical models which are useful approximations of the real situation. Again, where possible one should use a real model, for example, the two-dimensional gas model of Harold Daw's frictionless puck table[8] or the one-dimensional wave medium constructed by John Stull on a linear air track[4] or by Fowler, et al.[5] However, for the case where the actual building of such models is ruled out by expense or time, films could serve as useful intermediaries, connecting words and actions.

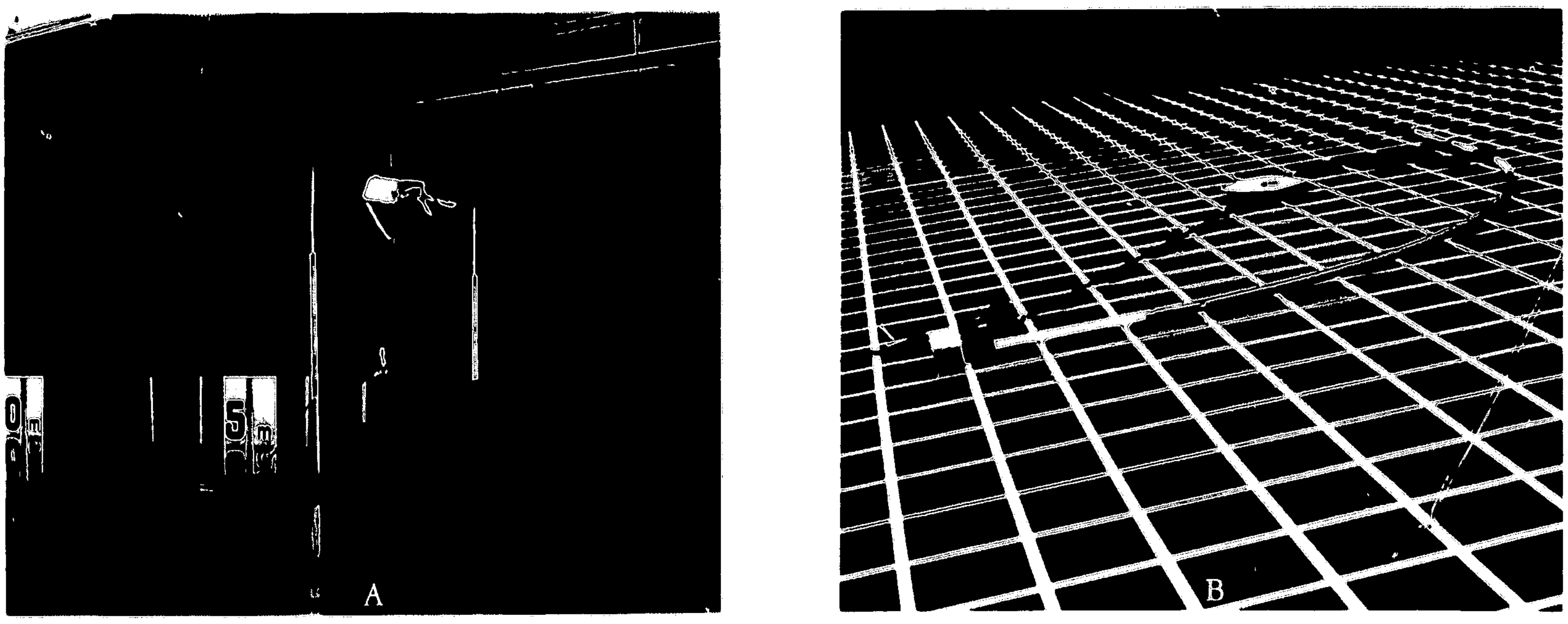
Examinations and Problems

As film becomes increasingly inexpensive and accessible (and since imagination is always in good supply), the examination might also be liberated from the printed sheet. Film can be used to set both qualitative and quantitative problems before a class, in the same way that the "situation film" is gaining use in the social sciences.



The random motion of molecules is simulated in this two-dimensional model of a gas developed by Harold Daw. The flat plastic cylinders are supported by air jets in the table top and put into motion by a vibrating mechanism. (Courtesy of The Ealing Corporation)

Such films take advantage both of the ability to show motion and of the inherent high information content of the visual medium. One would no longer face the danger of leaving out some vital element in the description of a situation on which the student is to be questioned; film can present the entire situation, in slow motion or time-lapse, in close up and from all angles, in color or black and white. The student could then be left to gather and organize his observations in a way which is meaningful to him.



In this film of a pole vaulter made for Project Physics, students can use frame counts to obtain the vaulter's speed on approach; the height he clears (a) provides a check on the conversion of kinetic to potential energy. In an earlier sequence, the energy stored in the bent pole (b) is found to be the difference between the total energy and the vaulter's gravitational potential energy. (Courtesy of the National Film Board of Canada)

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[3] "Kinetic Theory on an Air Table," a series of six films produced by Ealing Corporation.

[4] "Linear Air Track" series, nine films on Newtonian mechanics produced by Ealing Corporation.

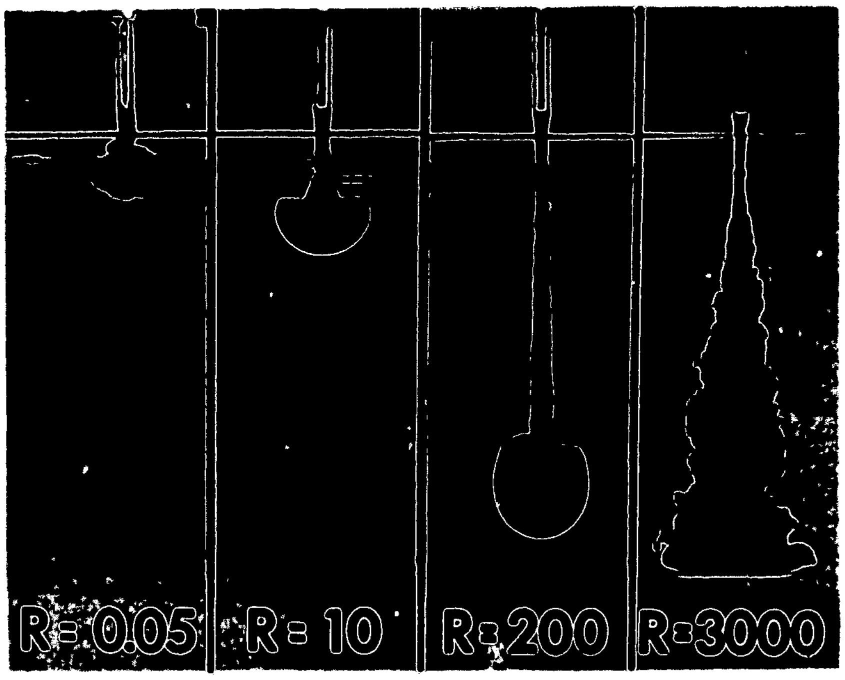
[5] J. M. Fowler, E. D. Lambe, J. T. Brooks, "One-Dimensional Wave Medium," to be published in the *American Journal of Physics* (November 1967).

One could pose qualitative problems in which a student is shown the initial state (of a collision, for example) and is asked to predict, and to justify his prediction of, the final state. Quantitative problems from which data could be taken or for which data were available would also be possible and could be used for either in-class examining or for outside assignment. Project Physics,[6] in cooperation with the National Film Board of Canada, is producing excellent films for this latter use. We should point out here, however, that for examination, problem assignments, etc., particularly those of a qualitative nature, the inexpensive local production being emphasized in this report has the natural advantages of individualization.

An example of film used to study fast action, in this case, the vibration of a drum head. (Courtesy of the National Film Board of Canada)

Background

Many lecturers would like to enrich the background against which physics is presented to their students. Film allows a compression of time and space and an organization of presentation which could bring to the classroom glimpses of the applications of physics to the other sciences and to industry; it could also provide a guided tour through inaccessible research facilities and allow students to look over the shoulders of the research practitioner.



Comparing the penetrations of the first three jets demonstrates the relative importance of inertial and viscous forces for increasing Reynolds number (R) in fluid mechanics. Fourth jet is turbulent. (From *Low Reynolds Number Flows* courtesy of the National Committee for Fluid Mechanics Films)

One would also hope that film would be used to humanize physics by presenting physics in connection with the men who have made and are making the contributions: Dirac talking about "The Evolution of Physical Ideas,"[7] Feynman[8] or Morrison[9] on BBC. A careful historical treatment of a giant in physics, such as Project Physics plans to do on Fermi,[10] would also be much desired for in-class showing by many lecturers.

These "background films" would in most cases surely be longer films and the justification of their use in the classroom would come harder than that of the short loops, but their auxiliary usefulness is so obvious that it deserves to be mentioned.

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[6] A project for the development of a new physics course for high schools and junior colleges, co-directed by Gerald Holton, F. James Rutherford, and Fletcher G. Watson of Harvard University.

[7] Available from Robert Carlisle, Director, SUNY Education Television Office, 60 East 42nd Street, New York, New York 10017.

[8] "The Character of Physical Law," a series of seven filmed lectures by Richard Feynman, available from EDC.

[9] "The Nature of the Atom," a series of filmed lectures by Philip Morrison, available from the BBC.

[10] "The World of Enrico Fermi."

GENERAL AND SPECIFIC PLEAS

Unifying Concepts

The working group recognized a possible weakness in single concept film making, particularly in the production of short demonstration films. One of the most promising trends in physics instruction today is toward emphasis on such major unifying concepts as symmetry, fields, and conservation laws which underlie all of physics. The phenomenon-by-phenomenon approach to film making runs counter to this trend and could in the long run serve to weaken it. Film makers are urged, therefore, rather than to see their films only as filling in a vertical checklist of subject-matter items, to consider a two-dimensional matrix in which the second axis is labelled by these unifying concepts. We prepared as a sample the matrix of Table II-1 to demonstrate how phenomena chosen from one subject-matter area can serve to illustrate these concepts.

It would be instructive to fit existing films into such a matrix in order to identify areas which have not yet been treated on film. There are no plans to

◀ UNIFYING CONCEPTS ▶

	Symmetry	Conservation	Wave Motion	Fields	Etc.
Mechanics	Translations, rotations, space and time inversions	Energy, momentum . . .	Springs, gravitational waves . . .	Celestial mechanics . . .	. . .
Sound					
Heat					
Light					
Electricity and Magnetism	Fields about symmetrical objects, circuit theory . . .	Charge, momentum in radiation . . .	Radiation . . .	Electrostatic, magnetic . . .	. . .
Atomic	Solutions of wave equations . . .	Quantization and energy conservation . . .	Effect of boundary conditions . . .	Interaction with E and M fields . . .	. . .
Nuclear					
Etc.					

▲ PHENOMENA ORDERED BY SUBJECT MATTER ▼

Table II-1

The working group prepared a sample matrix, far from complete, which would hopefully direct the attention of physicist-film makers undertaking new films on physics phenomena to the possibility of tying these phenomena to one or several unifying concepts in physics rather than presenting them as isolated occurences. The table has been sketchily filled in for the purpose of example; a complete matrix would require many more divisions and entries.

attempt such a major cross-listing in the film catalog which is being prepared as a part of this report. The working group does, however, make a plea to prospective film makers to consider both axes of the matrix when deciding on film topics.

Advanced Topics

It is a predominant pattern of the physics major's progression through the undergraduate years that although he may see some demonstrations in his introductory classes, he sees them in almost none of his advanced courses. This is in spite of the obvious fact that the physical examples he considers in his upperclass and graduate courses are farther removed from his experience than those demonstrated to him in the beginning courses.

Some of the flavor of abstraction is removed in the laboratories which usually form a part of the upperclass curriculum, but there seems to us to be a great need for more demonstrations to support the study of advanced topics, particularly in the modern physics course; some of these could be on film. Examples from quantum mechanics, from atomic, nuclear, high energy, and solid state physics, as well as from electricity and magnetism, advanced mechanics, and thermodynamics, should immediately suggest themselves to the experienced lecturer.

Examples of such films do exist — Miller's *Ferromagnetic Domain Wall Motion* and *Critical Temperature,* for example; or Goldberg, Shey, and Schwartz's *Scattering of Quantum Mechanical Wave Packets from Potential Well and Barrier.*[11] The utility of the techniques of computer animation have already been demonstrated and will surely be important for advanced topics films in which time-dependent solutions or other difficult-to-present graphics are involved.[12] The list of computer-animated films which now are available shows what can be done and should provide stimulus for further production.[13]

We look forward to the early addition of this visual dimension to our advanced classes which would allow students to "see" wave packets expanding in time or phonons resonating in a solid; the gain in efficiency of teaching and quickness of understanding should be significant.

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[11] See "New Animation for Physics," CCP *Newsletter* #11 (October 1966).

[12] Part III of the report on film making techniques gives a detailed description of computer-animated film making.

[13] See Appendix III of *Short Films for Physics Teaching,* available from the Commission office.

Use of single concept films in laboratory instruction[1]

This working group agreed that a discussion limited to one day could be incisive only if it were bounded at its outset by a few limiting propositions. The most important of these was that since physics is about the external world, and since the laboratory is the only part of the physics course in which a student makes direct formal contact with that world, film should be used in a laboratory only when and where direct student involvement with phenomena and apparatus is not feasible. The group also agreed that it would be profitable to discuss only traditionally structured courses, not such radically restructured courses as Joseph Novak described in his presentation to the Conference of the Purdue University botany course.[2]

FILM AS LABORATORY AID

Within these limitations, two major uses for single concept films seemed clear. The first use is in displaying to a student the apparatus that he is about to use —how its parts are related, what sequence of operations is appropriate to it, and what precautions the student should observe. An example for an elementary laboratory is Wendell Slabaugh's film on the proper use of a chemical balance,[3] which he says has reduced damage to the balances in his laboratory. Films showing the use of the slide rule, and the micrometer and the vernier in general are already available. It is easy to see the extension to more sophisticated ideas. In a more advanced laboratory films on the use of the oscilloscope, the lining up of a spectroscope, etc., would find much use.

One way to think of such films is as filmed instruction booklets, supplementary to written instructions. Pursuing this way of thinking, it seems clear that apparatus manufacturers might be encouraged to produce such films as adjuncts to their instruction manuals. The CCP could bring this possibility to the attention of apparatus manufacturers.

When the apparatus is "home-made" it is correspondingly appropriate that the film be made locally via a "shoe-string" operation. Such films would serve as valuable aids, and would in some cases even replace the work of graduate assistants in the laboratory.

FILMED EXPERIMENTS

The second major use for film in the laboratory is to provide filmed experiments from which data can be taken. An elementary example is provided by a swinging pendulum, whose instantaneous displacement, velocity, and acceleration are difficult to measure directly, but easy to measure on a filmed record.[4] Harold Daw's pucks on an air table with agitated walls furnish a more advanced example.[5]

Daw has made extensive use of his filmed demonstrations of the random motions of many colliding

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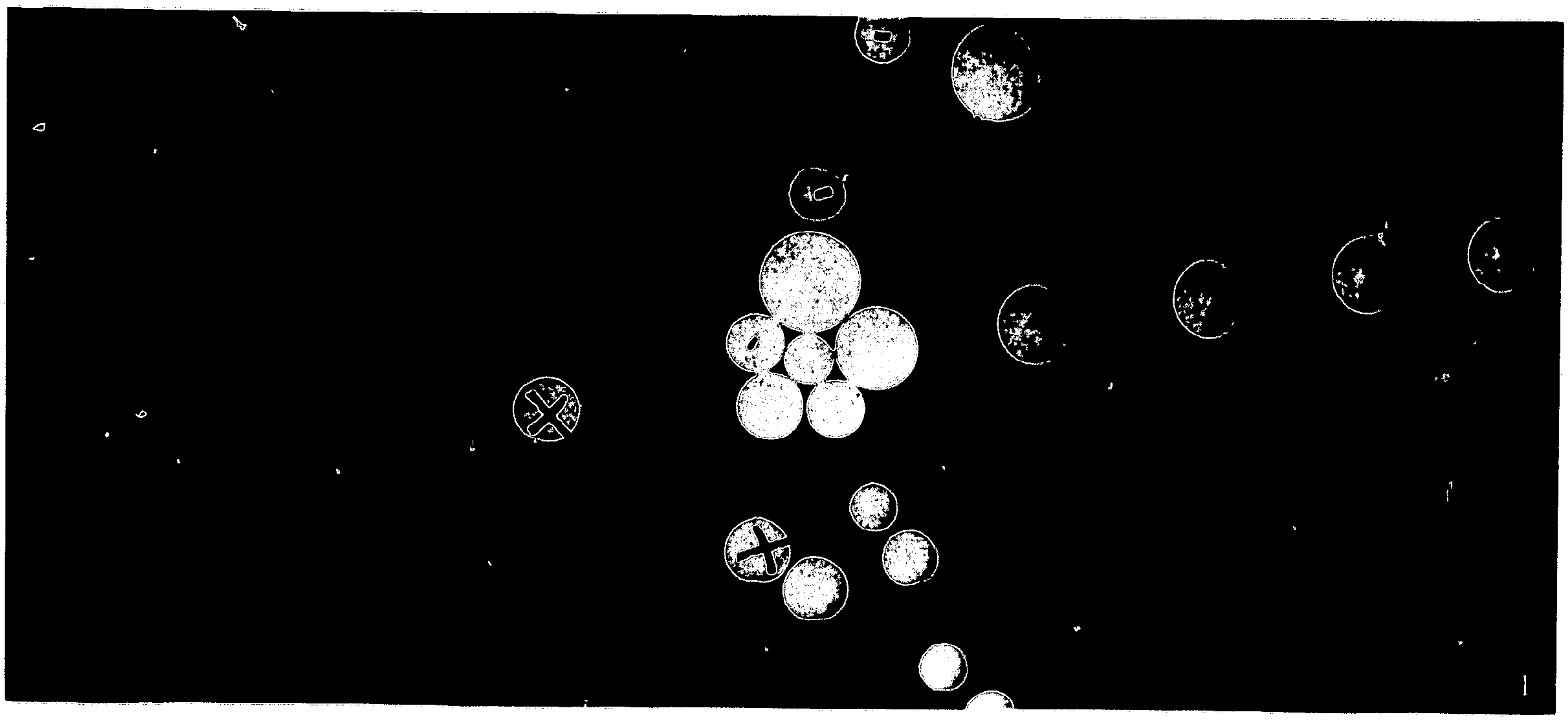
[1] Alan Holden (Chairman). Phillip Alley, David G. Barry, Ronald Blum, A. W. Burger, James L. Burkhardt, James E. Henderson, Guenter Schwarz, James Strickland, John L. Stull, Elizabeth A. Wood (members).

[2] See Appendix E, "Audio Visual Instruction at Purdue University."

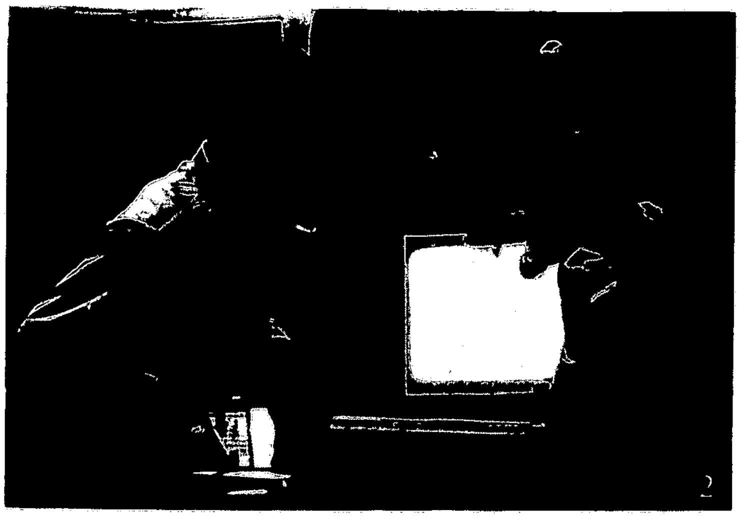
[3] *Operation of the Mettler Balance,* available from the Advisory Council on College Chemistry.

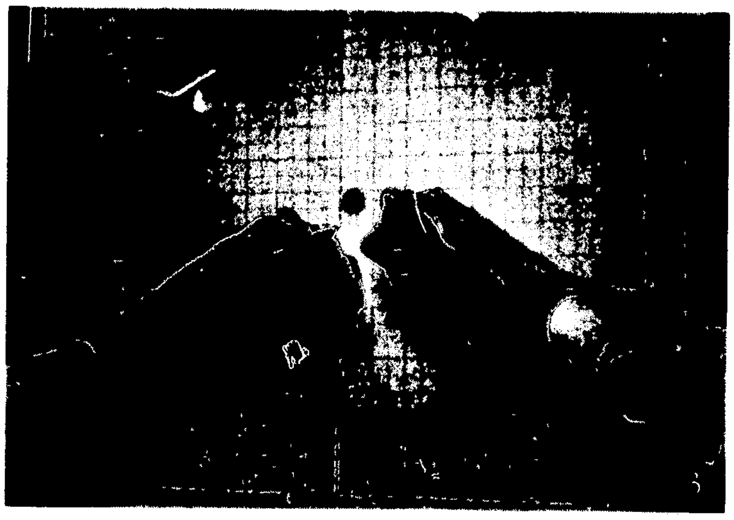
[4] See the "Coupled Oscillator" series (Alan Holden, collaborator) and the "Behavior of Pendula" series (Alan Holden and Judith Bregman, collaborators) produced by Education Development Center, Inc.

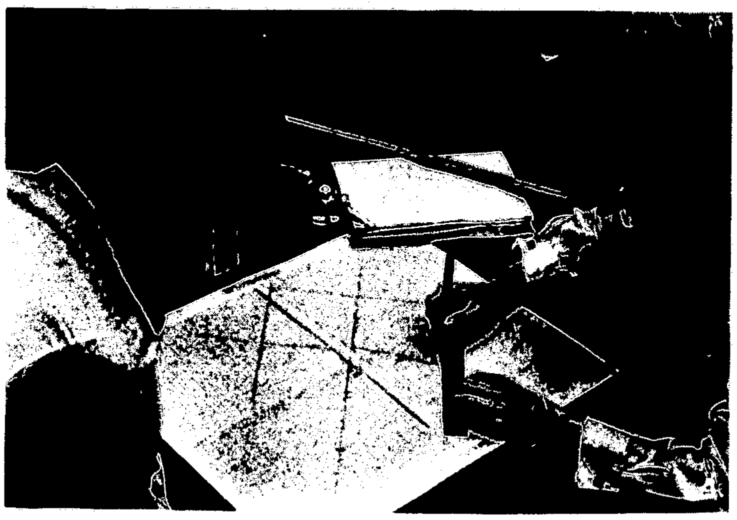
[5] "Kinetic Theory on an Air Table," a series of six films produced by the Ealing Corporation.

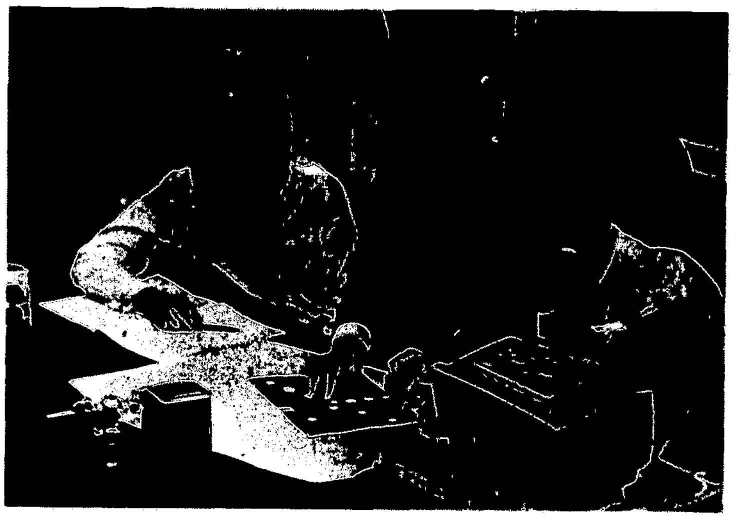


Stroboscopic photograph (at 2,000 fps) of a fast-moving projectile (marked X) scattering a cluster of six balls from *Scattering of a Cluster of Objects* (1). Students first view the film, then set up graphed screen (2) and rerun film marking positions of the balls (3) and establishing their trajectories (4). In the third running, students time the balls between two predetermined marks. Their finished product is then compared with the stroboscopic photograph of the collision (5). (Courtesy of the National Film Board of Canada)



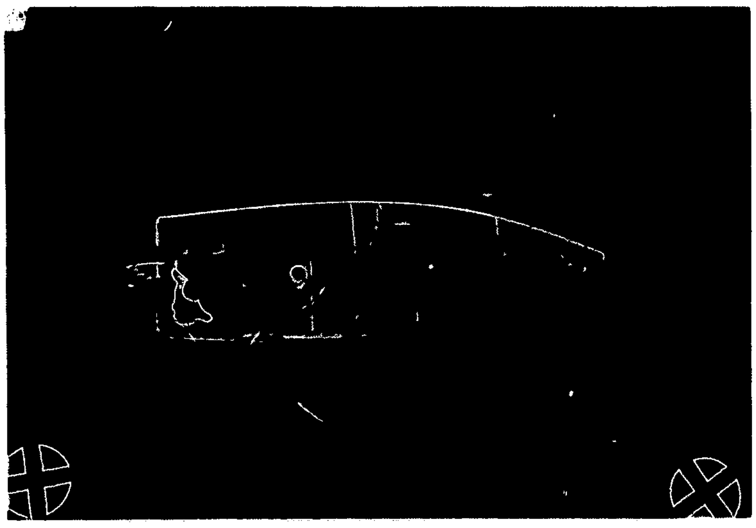






frictionless pucks in his laboratory classes. The film is projected frame by frame through a microfilm reader; students can plot the position of the pucks and obtain velocity distributions, mean free paths, etc.

Project Physics is also producing a large number of film loops which are designed to be used as sources of data for student analysis.[6] These range from a variety of collision experiments to the retrograde motion of a planet.



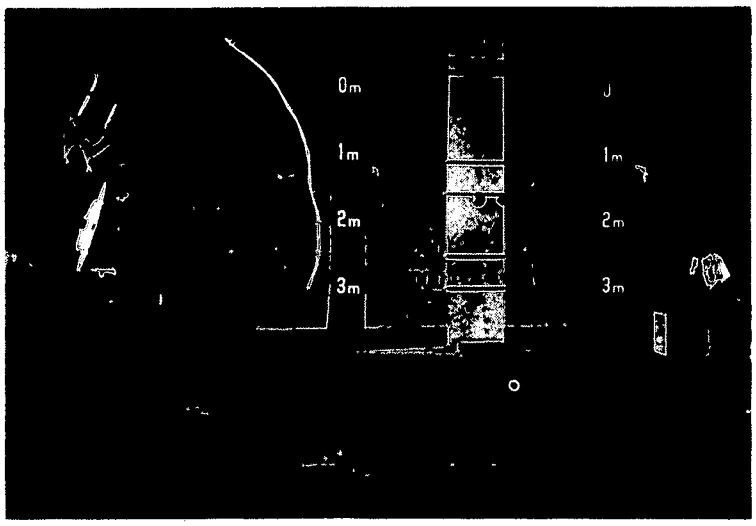
A motorboat heads across a river and is photographed in such a way that students can measure all three velocities—boat relative to the ground, water relative to the ground, and boat relative to the water (floats are placed alongside boat) and confirm the vector addition law. (Courtesy of the National Film Board of Canada)

In most cases requiring use of film for quantitative purposes, the film must be stopped at several frames to allow reading of data, and should be projected on a screen that carries a coordinate frame or other fiduciary marks. Thus such a potential use suggests the importance of developing film-projecting equipment with stop-frame and reversing facilities, as well as special screens for data taking.

Clearly these uses can be expanded and generalized in several directions. They can be made the basis of a self-instruction laboratory, and can even be used for an entire "laboratory" experience in institutions without the funds to provide space or staff for the more usual laboratories. Retreating from that extreme, film, printed instructions, and tape-recorded remarks can be provided along with laboratory apparatus to enable a student to do laboratory work at his own convenience, or at times when the laboratory is unstaffed, and in general to move the laboratory more toward its proper mode as an aid to learning rather than as a vehicle for teaching. Such laboratories are in existence in several sciences[7] and experimentation with them should be encouraged in physics.

OTHER LABORATORY-ASSOCIATED USES

Apart from these two primary uses of film in the laboratory, many subsidiary uses can be imagined. A film can, for instance, display a more sophisticated form of an experiment than is being performed: a simple scattering experiment could be followed by a film tour of the scattering experiment at a BeV accelerator or the half-life of silver experiment could be compared with a film of the measurement of very short half-lives in a "hot-chemistry" laboratory.



A scene from the National Film Board of Canada's film for Project Physics, *Acceleration Due to Gravity —Method I.* Care is taken to present the experiment in a manner which facilitates student data taking.

Film can exhibit examples which parallel experiments performed in the laboratory. It can show occurrences in which the principle examined in the laboratory is embodied in the external world—for example, the Tacoma Narrows Bridge collapse, in connection

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[6] See *Short Films for Physics Teaching,* available from the Commission office, for detailed descriptions.

[7] See Appendix E on the Purdue botany course; experiments are also underway in geology (Principia College), agronomy (Ohio State University and Iowa State University), biology (Orange Coast Community College, La Cross College, Merrimac Junior College, Kansas State Teachers College and others), geography (Carroll College) and in other areas. See Advisory Council on College Chemistry *Newsletter* #10 for information on experiments in chemistry.

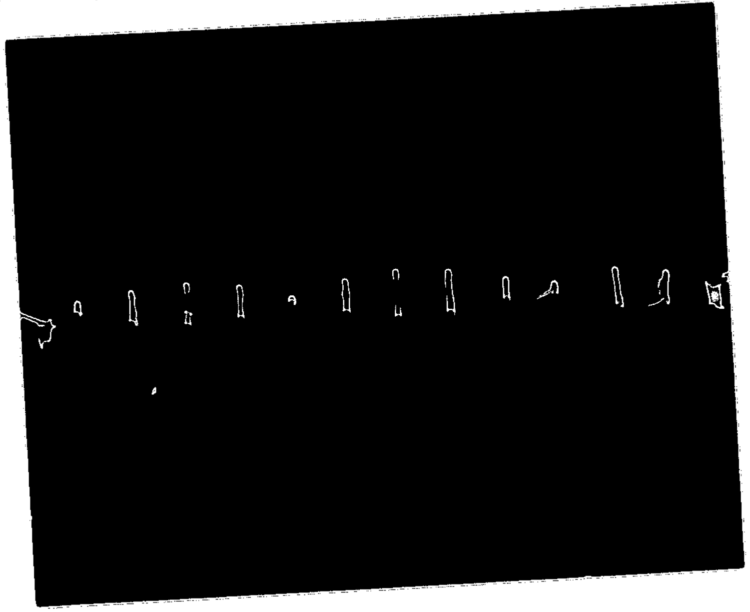
with an experiment on resonance. It can stimulate the construction of embodiments of a principle—for example, the construction of other systems of coupled mechanical oscillators after showing several such systems. It can provide a review of an experiment just performed, especially useful if the student makes a mistake which nullifies the experiment, leaving him with no useful observations or data.

Film might also provide a useful tool in laboratory examinations, even when film is not otherwise a part of the laboratory. For instance, a film can be used as the central basis for such questions as: (1) what is being done wrong in this procedure; (2) why is this particular thing being done; (3) what must have happened next (when the filming of an experiment is not completed).

There was some belief that viewing a film may not be too seriously defective a substitute for actually handling equipment, especially in an advanced laboratory, in light of the fact that in modern physical experiments the data characteristically appears as meter readings and traces on oscilloscopes. But there was also some agreement that a danger in the usual design of a single concept film lurks in the removal of all evidence that a *person* is associated with an experiment, thus contributing still further to the growing impression that science is a humanly disembodied pursuit.

In summary, film should be used in the laboratory only to the end of assisting and enriching that direct contact between the student and the physical world which is the heart of the laboratory experience.

Close-up view of an experiment on the electrolysis of sodium. (Courtesy of the National Film Board of Canada)



A standing wave on a line of coupled pendula (viewed from below) from the "Behavior of Pendula" series.

Self-instructional uses of film[1]

The cartridged film is by its nature self-instructional. The ease with which it can be handled and its inexpensiveness allow it to be made available to a student when he wants to see it rather than when a lecturer wants him to. This single factor should in itself make a large difference in the motivation to learn and the efficiency of learning.

From this point of view any film which is cartridged is potentially usable as a self-instructional film. Then there is a 100 percent overlap in theory between the class of films being considered by this working group and those considered by the group studying "in class" and "laboratory" uses. We will, however, confine our attention to two classes of films: (1) those which are to accompany a course of standard format—three lectures and one laboratory per week—and which are deliberately designed to supplement the main presentation of ideas; and (2) films which are to be part of a course structured around individual study (an example in a sister discipline is provided by the Purdue botany course, described in Appendix E).

ANCILLARY USE WITH STANDARD COURSES

Demonstration

Just as the most obvious in-class use of short films will be to demonstrate phenomena, their use as student-accessed material will also be, at least for the present, predominantly of this nature. It is also obvious that the physicist-film maker will not in most cases have to decide in advance for which of these uses he is designing. This latter assertion carries the built-in assumption that the filming of phenomena will always aim at completeness of visual description and that these films will not be deliberately designed to depend upon an accompanying lecture.

If, however, the film maker keeps before him the wider audience by considering each student individually rather than students as groups, the classes of demonstration films become much broader. We will consider more of these differing uses below:

1. ***Repetition***
   The availability of demonstrations on film has natural application to the numerically significant group of students who miss or want to see again a lecture demonstration. When the demonstration itself is on film, there is no problem. In the case of important live demonstrations repeated each year, local filming (perhaps by students) makes an attractive project and would provide a growing source of study films.
2. ***Enrichment***
   The number of demonstration films available is already larger than will be accommodated in any given lecture. If the projected goals of accessibility and inexpensiveness are reached, physics libraries can be expected to house large collections of films which can be assigned in the manner of outside reading.[2] One would want to

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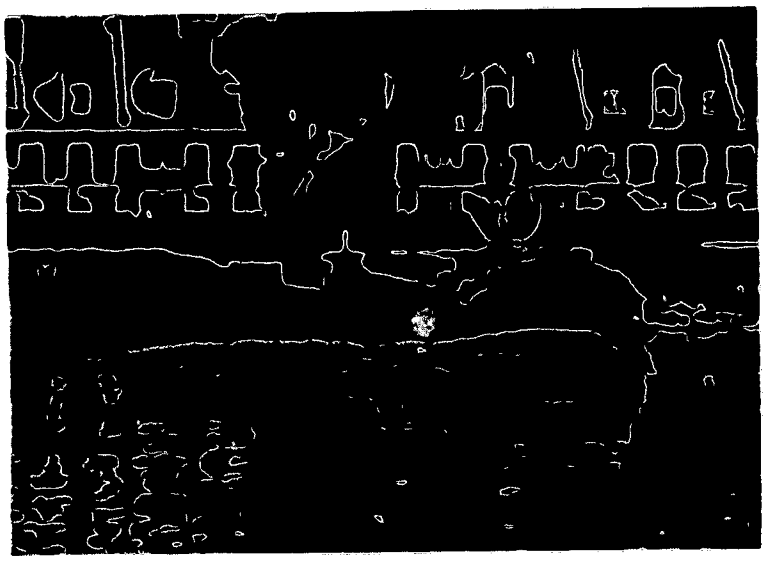
[1] E. Leonard Jossem (Chairman). Ludwig Braun, Judith Bregman, Louis Forsdale, R. E. Grove, Richard Hartzell, Robert Stearns, Walter E. Whitaker, William Whitesell (members). John M. Fowler, Ross Gortner, Jr., Robert Kreiman, David Lutyens, Frank Sinden (visitors).

[2] For example, the Physics Department of Cornell University has instituted a film loop collection in its library. A projector is available for student use during library hours and loops are signed out in the same manner as reserve books. In six months, the 37 loops in the collection were used more than 350 times. The program has been so successful that the library has taken it over as a responsibility; new loops are acquired with library funds upon request by any faculty member.

provide many different demonstrations of similar phenomena. Franklin Miller's *Tacoma Narrows Bridge Collapse* would supplement a more traditional in-class demonstration of resonance or his *Nonrecurrent Wavefronts* would provide an interesting parallel to waves as is commonly demonstrated with rubber tubing.

Phenomena from outside of physics which illustrate the application of physical principles would serve to make those multiple connections which are desirable between physics and the student's special interest. The Fluid Mechanics film series,[3] and the growing number of good films in astronomy, geology, etc., are pertinent examples.



A tidal wavefront is one of the examples used in Franklin Miller's film, *Nonrecurrent Wavefronts.* (Courtesy of the Ealing Corporation)

Large amplitude wave overtaking small amplitude wave in a water channel. (From *Waves in Fluids,* courtesy of the National Committee for Fluid Mechanics Films)

Students at Massachusetts Institute of Technology can view selected film loops at installations such as the one shown above in the corridors.

The MIT Education Research Center has used a somewhat different approach with its corridor displays, one of which is pictured below.

The modification of rear screen makes viewing in a lighted room possible.

We would hope that a film library would serve to blur the distinction between film as ancillary course material and film as intellectual entertainment, a way for students to see some of the things of delight and wonder which are so much a part of the joy of science. The film *Symmetry*[4] which will surely become available in sound cartridge, is a prime example of one such film, as are the Japanese-made film on ice crystals[5] and Alan Holden's Lissajous figures with a sand

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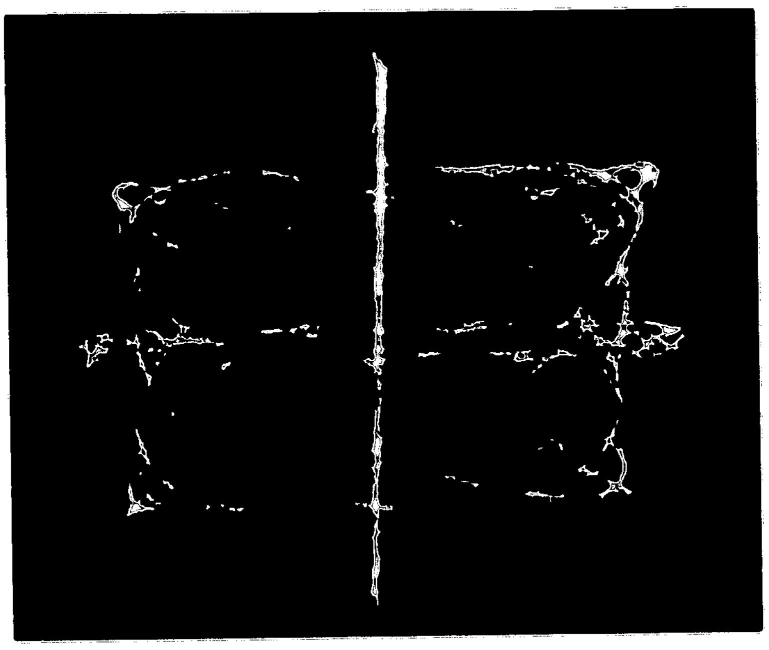
[3] Produced by the National Committee on Fluid Mechanics Films and Education Development Center, Inc.; available from Encyclopedia Britannica Films.

[4] *An Animated Film on Symmetry* by Alan Holden, Judith Bregman, and Richard Davisson (physicists); and Philip Stapp (film maker); available from Contemporary Films. See CCP *Newsletter* #14 for discussion of the film.

[5] *On the Variation of Ice Crystal Habit with Temperature* by T. Kobayashi of the Institute of Low Temperature Science, Hakkaido University, Sapporo, Japan. The film is available for $280.00 (including shipping charges) from Ginza Sakuraya Co., Ltd., No. 5, 2-chrome, Ginza Nishi, Chuo-ku, Tokyo, Japan. Efforts are now being made to make sections of the film into cartridged loops.



Two superimposed patterns from the film *Sand Pendulum II—Saddle Suspension*. Many different figures can be obtained by varying the starting conditions and the suspension.

pendulum in the film *Sand Pendulum II—Saddle Suspension*.[6]

3. ***Remedial-tutorial***

Some of the demonstration films can have a remedial use; that is, they can introduce students with weak or non-existent backgrounds to phenomena already familiar to other students. This is particularly true of the films which accompany the various high school courses.

Mathematics films can help students to review rusty concepts. Specific examples of such films are: *Cosine Function, Sine Function*, and *Pythagoras*, produced by the National Film Board of Canada, as well as some of the British film loops such as *The Ellipse, The Hyperbole, Vectors*, etc. produced by Halas and Batchelor.[7] Other examples are to be found in CCP film catalog. *Short Films for Physics Teaching.*

The films described in the section of this report on "In Class Uses" as "definition films" also have immediate and obvious self-instructional and remedial applications.

There is increasing experimentation with computer-assisted instruction in the tutorial-remedial mode[8]. Whereas in the present experimentation dialog is, for the most part, in printed form supplemented by slides, it is easy to see how the machine-presented material could be made much richer by incorporating short filmed segments where students' responses indicate that they would be useful. For instance, a student having trouble understanding momentum conservation could be shown a slow-motion collision sequence. This technique will require a projector providing quick and random access to any sequence on the reel. There is evidence that projector manufacturers are working toward this goal.

We also look forward to experimentation with cartridged films on illustrated problem solving. Much of the routine work now being done by graduate students in "help sessions" could be reproduced on sound cartridges and available to students on request. Such films could be enriched by cuts to the actual physical situation being studied, by animation, and by other techniques, to make them even more valuable.

Techniques

There are many things a physicist, particularly an experimentalist, needs to know how to do, from operating an oscilloscope to glass blowing. The high information content, the accessibility, and the repeatability of film recommend it for a class of usage as yet unexploited in physics. We here rather arbitrarily distinguish between general experimental techniques and shop techniques. It is clear that a professor working directly with a student will instruct by example and demonstration, and there is no suggestion here that this vital part of teaching be replaced by film. One can, however, without overworking the imagination, think of many experimental tasks which are sufficiently complex that a film reference would prove worthwhile.

1. ***General experimental***

The series of film loops on solder glass or the longer 16mm film with sound and color on the

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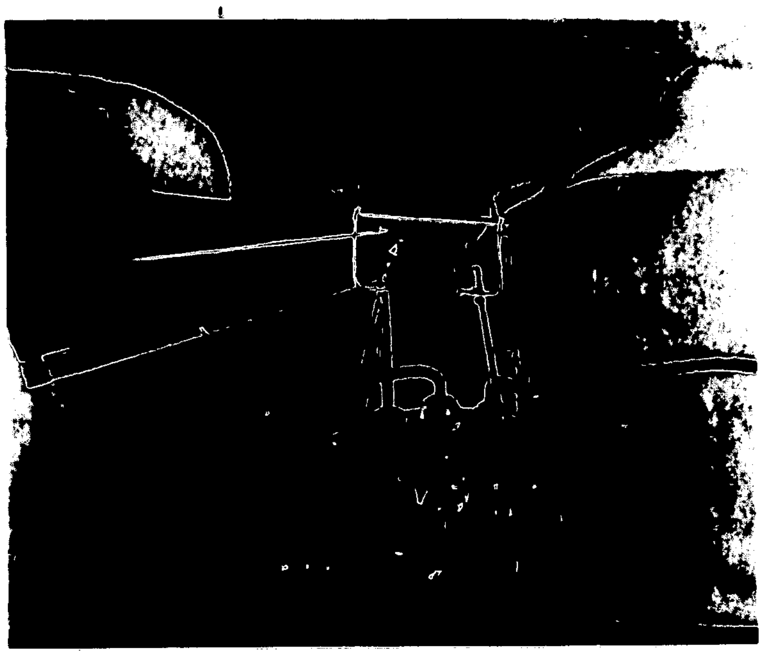
[6] One of four sand pendulum films begun during summer 1965 at the Conference on New Instructional Materials in Physics co-sponsored by the CCP and the University of Washington. See CCP film catalog for descriptions and information.

[7] See CCP film catalog for further information.

[8] See *The Computer in Physics Instruction*, available from the CCP.

the same subject[9] are perhaps the best examples at present in this area. From these films we can be instructed through sharp close-up photography on preparing the getters, preparing and baking a solder glass seal, etc. Written instructions can accomplish the same purpose, but few will argue with the greater depth and flexibility of visual presentation.



A scene from the film ***Preparing the Getter Header*** **showing the details of wiring the header. (Courtesy of Education Development Center)**

The physicist who is not afraid to take camera in hand can provide filmed instruction of, for instance, the sequence of turning on complicated equipment, the preparation of experimental materials, the lining up of equipment which will save him time and perhaps expense, and save his students embarrassment.

2. *Shop techniques*

Many of us have had the experience of having a kindly machinist from the physics shop check us out on proper use of, for instance, a milling machine, only to discover on the next use six months later that faulty memory has lost some vital details. A student shop equipped with a cartridge projector and several instructional loops would be a more useful shop, a more used shop, and one in which the damage to equipment might be significantly lowered.

There are, for instance, series of British films on shop techniques (see Table II-2 below) which should be evaluated. The CCP would be interested in working with a physics department to try out this kind of shop instruction film, either with some of these British films or with a set of loops put together by a knowledgeable technician from the departmental shop.

Title	Producer
Surface Finishes Produced by Lathe Tools	Eothen
Off-Hand Grinding—Basic Principles	Eothen
Shaper and Lathe Tools—Basics of Off-Hand Grinding	Eothen
Drills—Basic Features and Off-Hand Grinding	Eothen
Basic Movements of Knee Type Milling Machine	Marish
Procedure in Mounting the Arbor	Marish
Principle of the Backlash Eliminator	Marish
Up-Cut Versus Down-Cut Milling	Marish
Basic Operations of the Horizontal Milling Machine	Marish
Principle of the Milling Cutter	Marish
Cutting a Thread	St. Paul's
Tapping	St. Paul's
Soft Soldering	St. Paul's
Drilling	St. Paul's

Table II-2

Eothen Films, Marish Films, and St. Paul's Films, three British film producers, have produced series of cartridged shop films designed to instruct secondary level and technical college students on the use of equipment or to teach them a special skill. The list above is a sample of such loops (see OECD publication, ***Catalogue of Technical and Scientific Films,*** **for more complete list).**

The extension to soldering, glass blowing, printed circuitry, key punching, input-output computery, and other exotic but necessary skills would be expected to provide proof of its usefulness.

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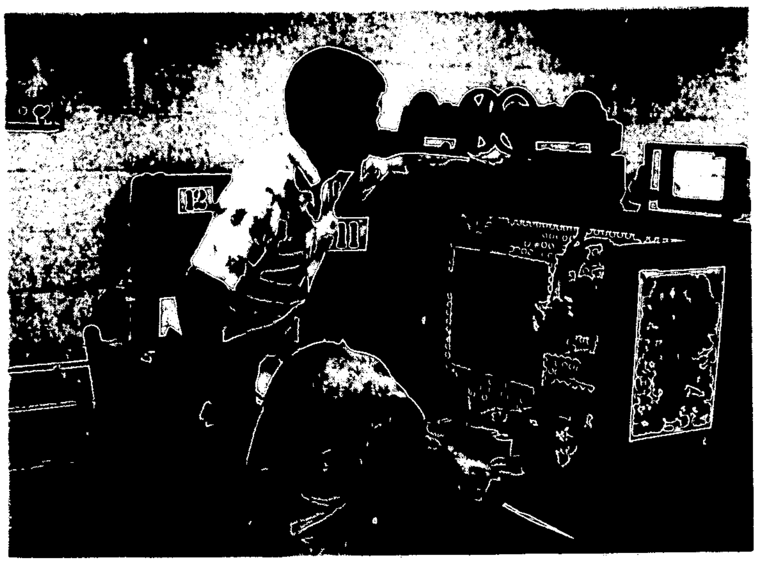
[9] The "Solder Glass Demonstration" series, a series of seven 8mm film loops made from the longer 16mm film, *Solder Glass Techniques,* by Jan Orsula, produced by Education Development Center, Inc. See CCP film catalog for more detailed information.

UNCONVENTIONAL COURSE STRUCTURES

The many relatively recent improvements in communications technology combined with the pressures which increasingly large student bodies are bringing to bear on the traditional lecture, recitation, and laboratory course structure have led to interesting innovations. One of the most radical of these is the botany course which S. N. Postlethwait has been developing at Purdue University since 1961. A full description of this course forms Appendix E, but we will comment on some of its features here.

In this course the student's activities are paced by his responses to a pre-recorded audio tape which carries lecture material as well as directions to the student to carry out various laboratory experiments. Extensive use is made of film loops as a means of illustrating laboratory procedures and for presenting auxiliary visual materials, particularly those in which motion plays an important role.



Students in Purdue botany course watch a film while studying in a carrel equipped with 16mm and 8mm projectors, tape recorder and laboratory specimens. (Courtesy of S. N. Postlethwait)

Any advantage which this or similar courses have over the traditional format—and Postlethwait reports considerable gains in the amount of material covered and in student performance—is associated with two major differences: first, the real integration of learning with lecture, text, demonstration, and experiment which is achieved; and second, the shifting to the student of the decision to choose the time when he will learn.

While it seems clear that it will not be possible to make a one-to-one correspondence between Postlethwait's design of a course in a descriptive science such as botany and an introductory physics course, it seems equally clear that there is much to learn from similar experiments in physics instruction. In any such experimentation, short and long films, some of which now exist and perhaps some of which will be made under the inspiration of this Report, will surely be important elements. The CCP should work to stimulate such experimentation which will itself suggest additional topics for films.

OTHER SELF-INSTRUCTIONAL USES

The working group noted other advantages for film outside of the regular classroom. The actual production of film loops by students may be an interesting pedagogical tactic. For a student or group of students to produce a good film loop, they have had necessarily to consider carefully what the essential points of the experiment are and how to present them effectively in three or four minutes. They have also to be able to make the apparatus work reliably and well. Such production has the additional advantage of involving students in physics in a manner more analogous to the research environment.

Finally, the prospective teacher will surely profit by learning about film (and other products of educational technology) for it will undoubtedly be an important instructional tool for his future use.

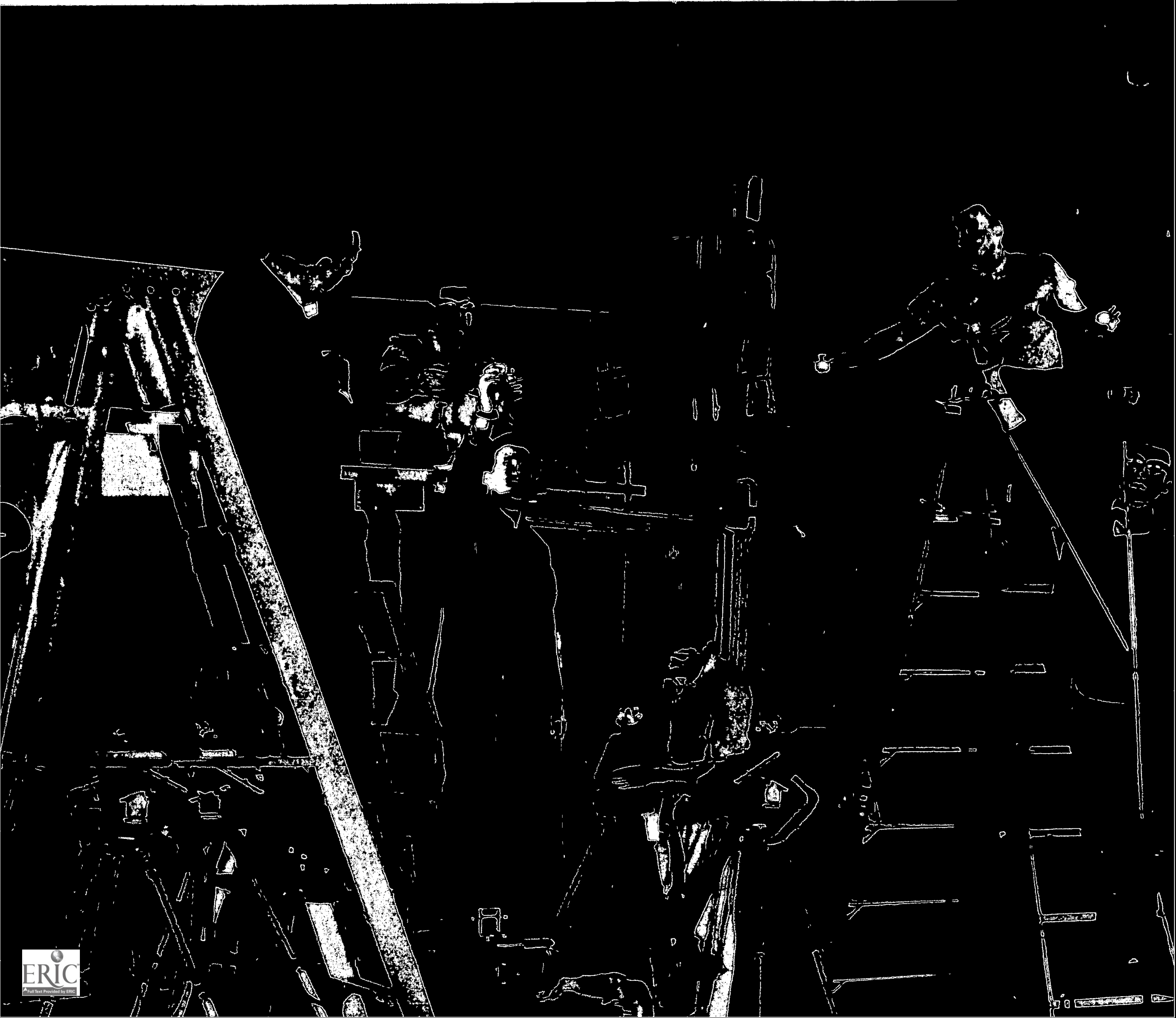
CONCLUSION

Cartridged films appear to have a very large potential as self-instructional devices and their use in this connection should be actively explored in both conventional and unconventional courses.

Films intended for self-instruction should, wherever possible, be designed to involve the student actively with what is going on in the film. One should try to avoid making the student merely a passive viewer.

The extensive use of film as a self-instructional device will require the development of projection equipment of very high reliability. Stop-frame and random access features would also be highly desirable. Two other needs in the equipment area are inexpensive "personal" viewers and inexpensive "paperback films" which will permit and encourage the collection of personal student libraries of visual materials.

Part III Film Making Techniques



Film making techniques[1]

This section deals with the second of the two goals of the Conference: the production physics films. We have chosen to describe three different ways in which film can be made: by the physicist in his own environment; by the physicist in collaboration with a professional film making team at a well-equipped studio; and, for a smaller but extremely important class of films, by the physicist on a computer. Which of these techniques is used depends on many things, but most decisive is the nature of the material to be filmed.

Local film production by a physicist with inexpensive equipment is limited to the straight-forward recording of a demonstration, a set of visual instructions, a problem solution, etc. One can look for little in the way of artistry. Techniques will be relatively unsophisticated: many esoteric possibilities of the film medium—the combination of animation with live action, very fast or very slow motion, etc.—will not be called into use. If technical excellence were the primary goal of instructional films, one would argue that all films should be made at professional studios. There are, however, overriding arguments for local production. Many of the uses contemplated in the section on "Uses of Single Concept Films in Class" have great specificity and their appropriateness will vary from school to school and even from class to class. In fact, much of the expected strength of these films will be in the ability to tailor film to instructional need. Furthermore, the careful thought and step-by-step design of an experiment and its filming will greatly benefit both the physicist-film maker and his student helpers.

Many formulae can be found for local film making; we have chosen to concentrate on the technically simplest method—"in-camera editing"—for this puts the lightest burden on the film-making ability of a physicist and the heaviest burden on his ability to design the experiment and its pedagogy.

The reports that follow have been written at our request by two film experts to the specifications requested by the Working Group on Film Making Techniques.

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[1] Kevin Smith (Chairman). Alfred Leitner, Harry Meiners, Donald Perrin, David Ridgway, Judah Schwartz, Wendell Slabaugh, Malcolm Smith, John P. Vergis, Edward E. Zajac (members).

LOCAL PRODUCTION OF PHYSICS FILMS

This "how to do it" material was written by Kevin Smith, Executive Producer of Education Development Center's Film Studio, an accomplished professional film maker, but one who has worked with enough physicists and filmed enough physics to understand why and how a physicist might produce his own films.

His article is intended to establish initial guidelines for physicists and physics students who wish to record on film experiments and experimental data for instructional use in and out of the classroom. He has assumed throughout that the reader is no more experienced in photography than the average person who keeps a growth record of his children through the use of still or motion pictures.

Mr. Smith has drawn his material from the actual production of a film, Two Fluids in a Box, *which he made specifically for this report under simulated "local conditions" in the Super 8 format, using in-camera editing techniques. In order to make this experience as complete as possible for the reader, Appendix C includes the actual "storyboard" for the film; we also have available on loan from the Commission office the finished film in a Technicolor Super 8 cartridge.*

Eight millimeter motion picture film as a supporting medium for education has gained wide popularity over the past five years. Extreme portability and relatively low cost of both projection equipment and release prints make this format ideal for instructional use. Although significant advances have been made in the development of high-quality sound tracks and ingenious cartridge-loaded projectors of various kinds, a major impact on education was made with the development of the Technicolor 800 projector series which takes a cassette loaded with up to 50 feet of either Regular 8 or Super 8 silent film in an endless loop which has a maximum running time of about four minutes. Many producers have made series of these "loops" on a myriad of subjects which are presently being used by schools and colleges across the country. The original photography for these materials is always done on either 16mm or 35mm film. Eight millimeter copies are made by various optical reduction processes. This sort of production requires fully professional attention and can be quite expensive.

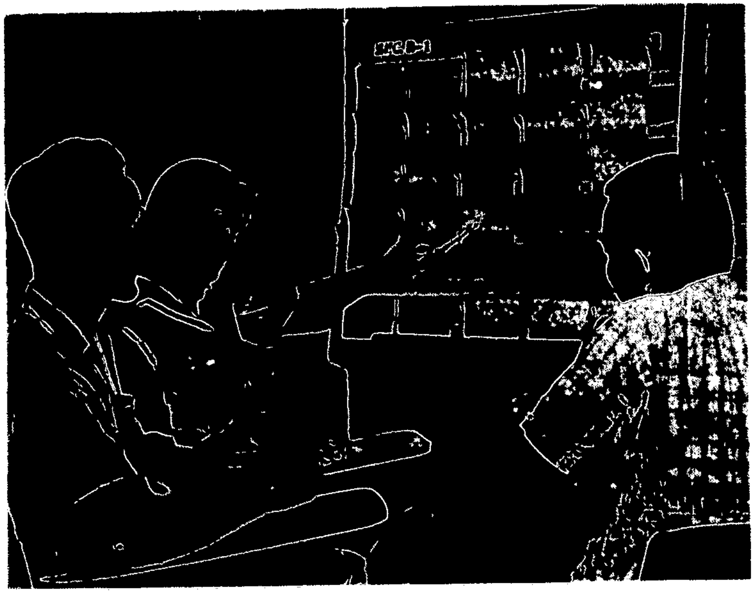
This section of the report is addressed to the problems faced by a physicist who wishes to produce short, silent films for use within his own department or institution. These guidelines should be helpful, however, in similar situations regardless of subject matter.

No matter what the motivation, the uninitiated cinematographer is almost always tempted to begin by investing immediately in cameras, tripods, lights, etc. While this is attractive and easy, it should be resisted. The effective use of motion pictures in education requires the development of an overall strategy which incorporates film only when it is most effective: the initial efforts of a beginner should be on planning.

Let us say, for example, that the motivation for a professor of physics is the existence of a difficult and hard-to-repeat experiment, the use of which would, in his view, give the student an immediate understanding of a concept not easily gained otherwise. The experiment is, at this moment, set up and running in his laboratory. Since the experiment has come to his attention only because it has been delivering good and effective data and since the graduate student who ran the experiment is through with it, the photography should be accomplished immediately. Rather than rushing into "production," the physicist should better sit down with the graduate student and another colleague to explore the details of a presentation which in four minutes or less will give the student the same intellectual stimulation which motivated the professor to film the experment. This discussion will undoubtedly range from the experiment at hand to the theory of physics pedagogy and back.

The Storyboard

The professor should then prepare a detailed outline (shooting script). This "storyboard" can be in any form which is easily understood by everyone involved and should be varied to suit the situation. One effective way to prepare such an outline is to use a succession of cards containing detailed descriptions and a rough sketch of each scene to be photographed. Storyboards prepared from memory lose in translation: it would be best to prepare the outline in the laboratory while viewing the experiment or phenomenon to be photographed, either through the viewfinder on the camera or a rectangular hole cut in a piece of card. The storyboard should include all titles and descriptive panels that are to be included in the final film.[2]



Students at Arizona State University discuss storyboard set up so that each sequence follows logically, as it will in the finished film. (Courtesy of John Vergis)

During the preparation of the detailed outline, decisions are made which influence the shooting procedures, techniques, and, therefore, the type of equipment which will be necessary. The decision on equipment will be influenced by a number of considerations. Many colleges and universities maintain some sort of film department which is generally equipped with 16mm cameras, sound recorders, etc., and may, indeed, in certain cases be very helpful in this kind of production. If, however, the effort is being financed from the limited funds available to the physics department, the costs involved in 16mm production should be looked at carefully. The shooting itself will not appear to be very expensive; however, the editing and optical reproduction of final prints may be too costly in both time and money.

Let us assume that the physics department in question can allocate limited funds to a filming project, that the subject matter in question lends itself to silent presentation and can be arranged in segments of not more than four minutes duration and, further, that the initial planning discussions uncover several other possible subjects for similar treatment.

The physicist and his group weigh the pros and cons of several systems and decide to shoot the project using Super 8 color film. In making this decision the physicist, of course, looked at each shot on his storyboard and ascertained that it could be illuminated so as to fully expose a film stock with an ASA rating of 40. Had this not been possible, he would have had to reexamine his storyboard from this viewpoint or to search for a stock with an appropriate exposure rating.

Editing In Camera

Having decided on the system to be used, he can concentrate on the problems of production. He must decide what camera and lighting equipment to purchase, but need not make up his mind about a projector yet, inasmuch as the local camera store will be glad to project his "rushes" for critical viewing by himself and his colleagues. He now faces another major problem, that of editing. Super 8 film can be edited and simple equipment for this process is available. However, editing requires some skill and is tortuous at best. Also, tape splices tend to jam in the projector and burn the film if they are not skillfully made. The alternative to this is to edit the material in the camera, that is, to shoot the film in the exact sequence carried by the outline or storyboard, including titles. This means that all decisions as to the length of each shot and the use of titles must be made in advance. The outline indicates that the subject can be covered in about four minutes. However, examination of the film cartridge reveals that it contains 50 feet of film with 72 frames/ft.[3] The camera shoots the film at a rate of 18 frames/sec. This means a total shooting time of 200 seconds or three minutes and

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[2] See the example in Appendix C.

[3] Regular 8mm film has 80 frames/ft; 16mm film has 40 frames/ft.

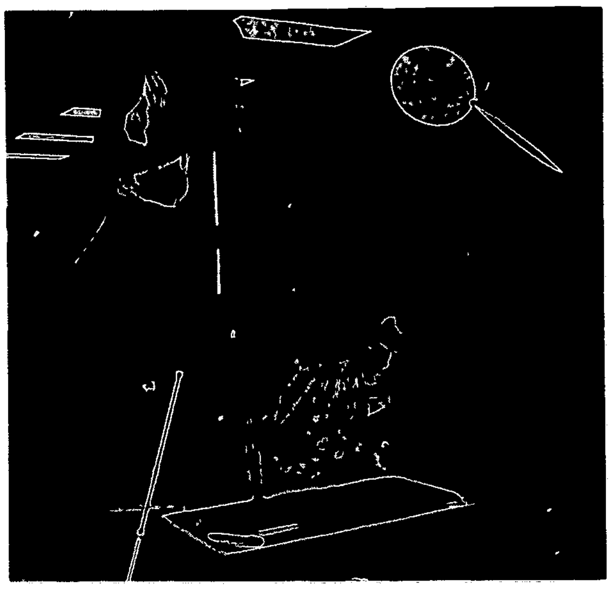
20 seconds. With this time the limiting factor for the length of the film, the physicist-film maker has to make a series of psychological, perceptual, and artistic decisions. For instance, how long should a title run? The title of this particular example is *Two Fluids in a Box;* reading this title out loud twice takes about four seconds. We allow four seconds more to settle down. The decision is that the title should run for eight seconds. Decisions of this sort are made for each title and scene in the entire storyboard; when totaled the running time turns out to be four minutes and 40 seconds; 80 seconds must be deleted. If to secure these 80 seconds equal cuts were made from each scene, probably certain shots would become ridiculously short, causing the entire piece to seem rushed. Instead, careful reexamination of the storyboard will inevitably reveal unnecessary scenes; these could be deleted bringing the piece within the required length and in the process adding to its clarity.

Equipment

Having designed the film, the physicist will have to consider what equipment he will need and what it will cost. His budget for this venture is on the order of $500. To begin with, $320 of it is spent as follows: camera and accessories, $200; used tripod, $20; photoflood bulbs, $15; four lamp sockets and extension cords, $25; two aluminum telescoping stands for lights, $15; and about $40 worth of film. Couple this equipment with some ingenious use of equipment already in the department and a laboratory stop watch and production can start.

The camera purchased measures approximately 8″ x 3″ x 4″, including the film cartridge. It is battery driven and is equipped with a motorized zoom lens which can also be used manually. It has varying shutter speeds from single frame to thirty-two frames per second and automatic exposure control. It also has a through-the-lens viewfinder with an adjustable eyepiece. (This last feature is very useful to aging cameramen.) The major disadvantage of this particular camera is that it does not allow manual exposure control. The only additional accessory which would have been useful would have been a series of three close-up adapter lenses, which are slipped on the front of the camera lens to provide a series of focal ranges. The camera lens itself will not focus when the camera is less than four feet from the subject.

The physicist is now ready to prepare title cards for his film and these require special attention.[4] Black letters on a lightly colored background prove to be very effective. The side of the card itself should be large enough to be easily handled and lettering should be done in simple block form with a broad point pen, a brush or with the popular felt wick pens. Illegible titles are epidemic in educational films.



A typical, inexpensive set up for making titles. For animation effect, titles can be changed below while cameraman photographs each card in succession. (Courtesy of John Vergis)

Lighting a motion picture scene need not be nearly as difficult as some professionals claim. The human eye is still a much more sensitive instrument than the camera, and in general what looks good to the eye will also look good on film, if the illumination is within the exposure range of the stock used. Color film requires less specialized lighting than black and white because the variation in color takes the place, in part, of the black and white contrast range. The biggest pitfall for the amateur cameraman, particularly when using a camera with automatic exposure adjustment, is the uneven lighting of a set. If an exposure meter is used to examine all parts of each frame to make sure they fall within the exposure range of the stock, mistakes of this nature will be avoided.

Shooting the Film

Another area of concentration for the beginning cameraman should be on the shot itself. The basic

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[4] See Appendix C for more detailed information.

problem in this case is how to relate a series of relatively disconnected views so that they reveal a continuing operation or idea which follows in some sort of logical progression. This flow can be broken in a number of ways, either intentionally or by accident. A cut from a relatively long shot into an extreme close-up may disorient the viewer or may be quite appropriate, depending on the circumstance. Shots, all of five-second duration cut one after the other, might be monotonous. Sequences of shots in which the camera moves more than 90° around the subject from shot to shot will almost always be disturbing. There are many more examples of maladroit editing. A helpful assumption here is that a population such as that in the United States, most of whom have spent hundreds and even thousands of hours viewing motion pictures and television, must have developed a subliminal sense for editing.

The actual shooting of a film requires a series of physical moves for both the camera and lighting equipment. Each new set up must be examined in detail. Has any item in the previous scene been shifted during the camera move? Is any polished surface reflecting a light or the cameraman's face onto the film? Is any necessary component missing? Constant vigilance is necessary.

If a film is being shot for subsequent editing, then the cameraman may try more than one alternative for each scene and may repeat a shot to correct previous errors. If, however, he is editing within the camera, he must use extraordinary care.

When the film is "in the can," that is, when the shooting is complete, the local camera store will forward it for processing at about $2.00 per 50-foot roll. Additional prints may be made from the "original" but they will be of somewhat lesser quality, although quite usable. The camera store provides this service as well. If prints are desired, then the original should be handled with great care and projected only once in order to avoid damage and the picking up of dirt.

The use of 8mm film as "original" material for more than a few prints is mechanically difficult. The ability to make multiple prints does make possible the exchange of films between interested individuals and institutions.

In summary, these outline instructions for producing a film by in-camera editing will not lead to instant creation of festival material. They will, however, lead to usable film and if the spirit is adhered to, the physicist will have put his major effort into planning the physics and the pedagogy and will produce a film whose strength is in these areas rather than in technique. Having produced one such film, however, the hook may be set and the next film will require an editing table, several cameras, a folding chair . . . and a trip to Cannes.

FILMING IN A PROFESSIONAL STUDIO

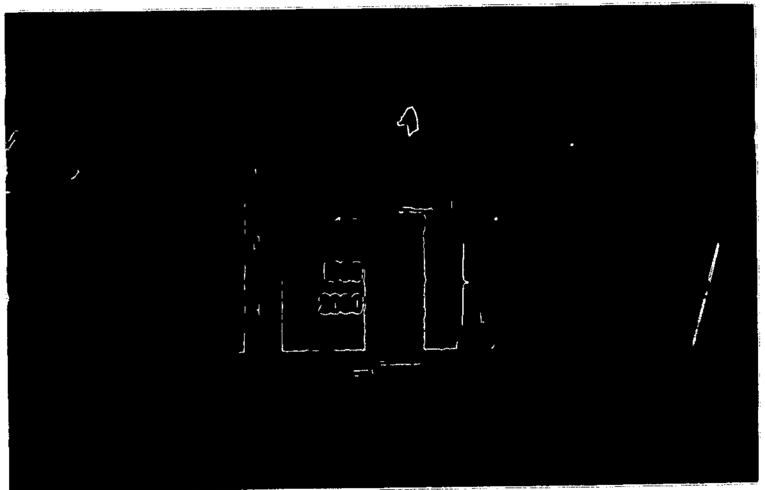
There are many types of films and subjects for filming which pose technical problems too difficult for solution in the kind of local production described in the previous article. Filmed experiments, for instance, will in most cases demand a precision and a technical versatility beyond the range of equipment and know-how of the physicist-film maker. In the following article, Jacques Parent, Program Producer at the National Film Board of Canada, describes the requirements for precision filming which lead physicists to seek the collaboration of a professional and the facilities of his studios.

Jacques Parent and the National Film Board of Canada have a distinguished record in the production of excellent science films. They have been engaged in the past few years, in collaboration with Project Physics, in the production of a large number of single concept films for use with the material being developed for high school and junior college courses. This collaboration is producing a rich reservoir of short films which will also find application in college physics and will add significantly to the reservoir of film making expertise in physics.

A professional film maker is a man who has at his disposal means of making films and technical skills which are not readily available to the amateur. What follows below is a discussion (not necessarily in the order of their importance) of these "tools of the trade."

Shooting Space

The amateur physicist who sets about filming his own table-top demonstration will most likely set up his demonstration in an ordinary physics laboratory or classroom and, having made his storyboard, will set up lights and camera, and begin to shoot. If a professional group were to consider shooting the same demonstration, beginning in the same room, by the time the cameraman had selected a suitable lens and the proper type of lighting, he would want to have the walls pushed out twenty feet in both directions and the ceiling raised some ten to fifteen feet. The exacting requirements of professional equipment have led many new professional or semi-professional film making groups to snatch up warehouses, old theaters, movie houses, or abandoned churches as sites for their activities. Good films can be made in small areas; this is not, however, the quickest, or the most economical, way to make films. Height, for example, is often a major requirement in the filming of physics demonstrations: suspending pendula from a good height makes it easier to light a scene with a minimum of shadows.



Crew at the National Film Board of Canada prepares to shoot a falling body sequence for *Acceleration Due to Gravity—Method 1.* (Courtesy of the National Film Board of Canada)

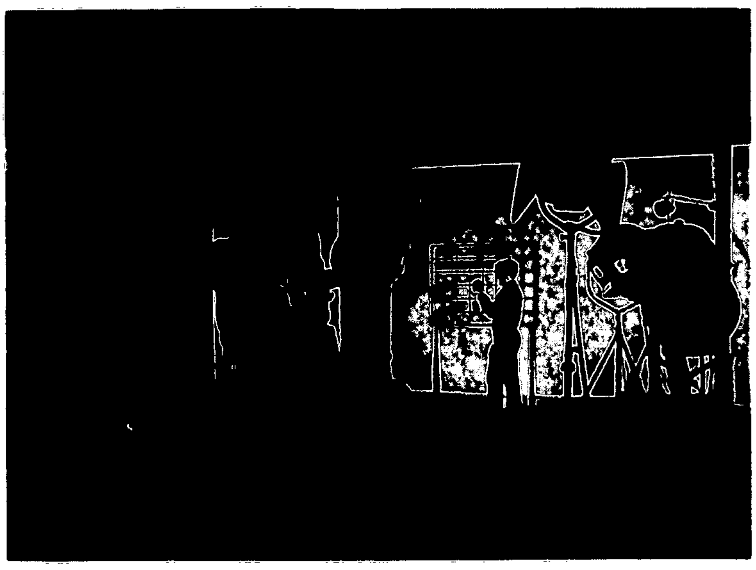
Filming Equipment

1. *Power*

   Unless they are already especially equipped for television work, most spaces available to the amateur are unsatisfactory for professional work because they cannot provide the power requirements which enable a film maker to shoot types of film. Power requirements of 300 to 600 amps are not uncommon in the work of the professional. Physics films in particular are very demanding in this respect: at the National Film Board, we have at times used 600 amps to light an area one meter wide by one meter high for a sequence shot on color stock at 8000 frames/sec (exposure time: 1/25,000th of a second).

2. *Lights*

   Lights used in film studios are expensive and bulky: a bulb alone for a 10 kilowatt light costs more than $100; the average rental rate for such lamps in the industry is $10 per day per lamp. The National Film Board often uses fifteen such lamps for sequences in the Project Physics loops. The cost of electricity for these lights is staggering. The cables needed to supply the lamps would fill an average-sized truck. And furthermore, such equipment can only be safely handled by qualified electricians.



Professional photographers require expensive lighting arrangements for high speed sequences. This is the set up for *Collisions with an Unknown Object* (Chadwick experiment) in which a model first ball ("neutron") hits "nuclei" of two different sizes. (Courtesy of National Film Board of Canada)

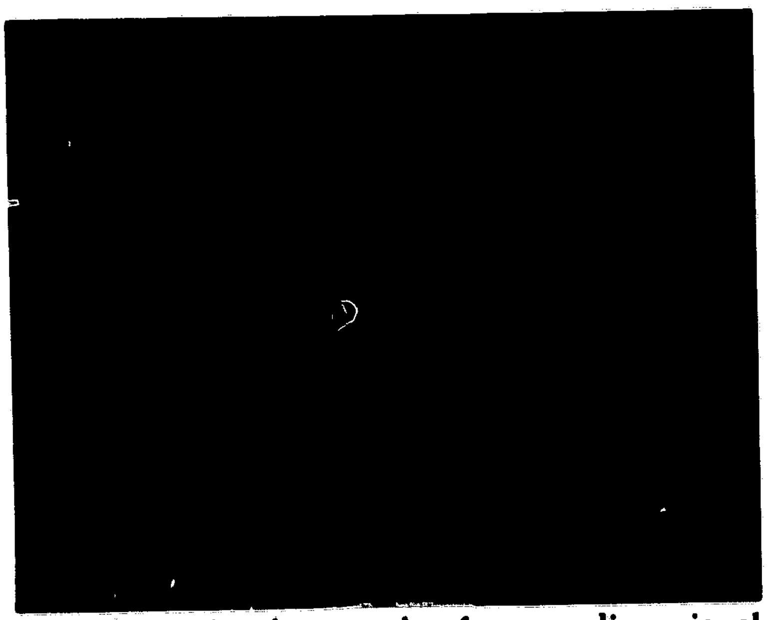
Why are so many lights needed? Good films have been made using four-light quartz lamps. But these are the exceptions. Let us look at the typical requirements which affect the amount of lighting needed. A table-top demonstration is filmed using 16mm equipment. The cameraman selects the lens which will give him the least amount of distortion. Then he places his lights in such a way as to minimize disturbing shadows in the background; the background must therefore be a certain distance behind the table. He draws lines from the camera which show the lens coverage and adds to that area 20% for 8mm projector cut off. The amount of background area which has to be lighted is now obviously far greater than the actual demonstration area being filmed. All of this assumes, of course, that the sequence is being shot at the conventional 18 frames/sec and not at some higher camera speed, as is often the case when making physics films.

3. *Conventional filming equipment*

   A professional film maker can normally select the camera he uses for any particular job from a wide variety of camera types. Each camera comes equipped with a wide variety of accessories. In the course of one day's shooting, it is quite common for a professional film maker to use two or three cameras, ten different lenses, some of which (like the 300mm or the 1000mm) are not found in everyone's kitchen. And even if the right lens is available, the socket for it often is not. In one day of shooting at the National Film Board not long ago, we used four different types of dolly equipment for what we thought was a simple travelling shot. In addition, the professional will need auxiliary equipment such as gear heads for the camera, light meters, filters, tripods, batteries, synch motors, magazines, gobo stands, hydraulic lifts for 10 kilowatt lights, diffusers, fork lifts for conventional shooting.

4. *Specialized cinematography techniques*

   It is becoming evident as we at the National Film Board study more closely the most efficient use of the moving image in a teaching situation (e.g., in physics) that some of the desirable sequences will be increasingly more difficult to produce. The "physics" aspects of the film are difficult enough to design. After this is done, the filming problems — low luminosity, the scale problem, the need for fast and slow action — may be still more difficult to surmount. Finally, the equipment one needs for these jobs is expensive. In the specialized fields of high-speed cinematography, time lapse, computer animation, macro-photography, micro-cinematography, strobing, etc., there are no short cuts to quality. Existing equipment was in most cases originally de-

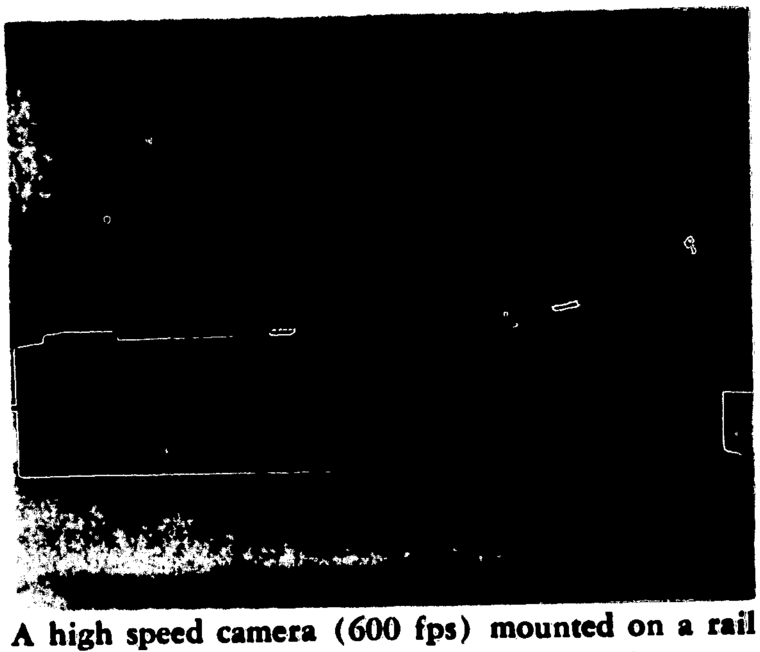


A stroboscopic photograph of a two-dimensional collision capable of producing data for student analysis. (Courtesy of the National Film Board of Canada)

signed to satisfy special research needs and not to meet professional film making standards. Most of this equipment has to be modified and maintained and must be operated by specially trained personnel. In some cases it has to be entirely redesigned for the film maker's purposes. This is a frustrating and costly way to make films — but rewarding at times.

In the last two years, the National Film Board has tested, in the field of high speed cinematography alone, six different types of cameras. We have calculated with great precision — frame by frame in the case of rotary prism mechanisms of the continuous drive cameras — the amount of lateral and vertical excursion at different operating speeds. This becomes important when one is filming to provide data for analysis. It is a problem that, while it cannot be licked, can be minimized. However, better equipment is being developed and as more knowledge comes to bear in this field, it will become easier for the uninitiated to step in.

Yet the camera is only one part of the story. As the frame rate goes up, so does the amount of illumination needed. There is at present no adequate high luminosity source available for this purpose; we have even tried DC-8 aircraft landing lights, but so far with no success. (I am not talking here about strobing, which is a different problem altogether.) We are presently investigating the use of high reflectance front screen projection to overcome the luminosity problem, but so far it seems that this will help only in the lower high-speed range.



A high speed camera (600 fps) mounted on a rail (foreground) follows a simple cart as it moves toward collision with a second cart at rest. From the film *A Matter of Relative Motion,* which shows the collision viewed by a camera at rest, at the same speed at the initial car, at half that speed, to illustrate Galilean inertial frames of reference. (Courtesy of the National Film Board of Canada)

5. ***Film stock and special effects***

   High-speed film stocks are now available, but must be used with great care. While they do allow scenes to be shot with lower illumination, the quality of release prints obtained is far from adequate as yet because of excessive contrast and grain. In addition, there is no intermediate laboratory stock to match the high-speed original for use in preparing high quality release prints.

Personnel

1. *Film director*

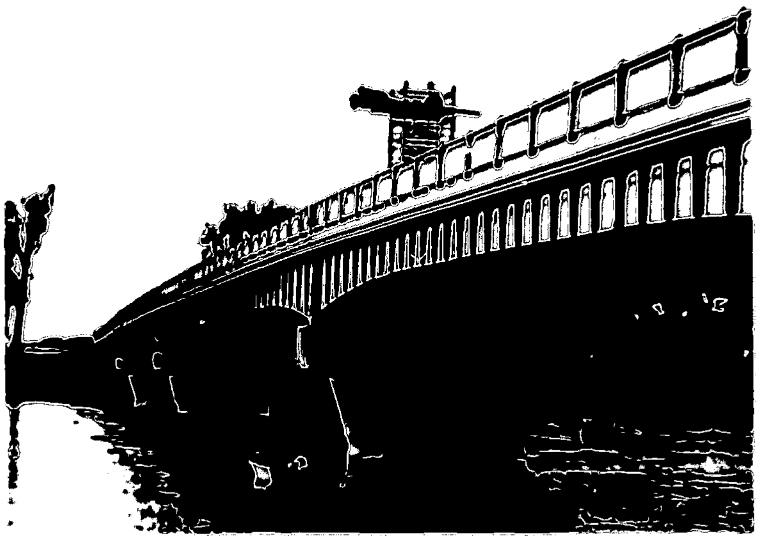
   It is difficult to evaluate the potential contribution of professional film makers to the making of educational films. In the industry, the film director is the man who gets things done while continuously planning ahead for other things which have to be done. This talent is often missing in the local production operation.

What can an experienced film director bring to the educational film? In the past, the role of physicists and teachers in the production of physics films has been negligible and the films produced have been correspondingly poor both scientifically and pedagogically. Experienced film makers have underestimated the importance of the choice and organization of the content. Recently teachers have decided to produce films on their own: as a result, both the physics content and the pedagogy have improved, but the films have occasionally been "cinematographically" poor. Even the most experienced teacher often lacks a "visual sense" (an eye for image composition, color schemes). What is evident to every "billboard" artist is not always evident to a teacher. Obviously some of both skills is needed. More recently film makers have become matter specialists, and conversely, these specialists have become aware of the need for adequate film technique.

The small format 8 mm screen, or television screen, requires a greatly simplified image. Too many details may confuse the viewer. A crack in a cement wall or a spider crawling on a man's lapel may be more important to the young viewer than the highly sophisticated equipment on the table. Camera movements should continually aim to orient the viewer, not to disorient him. And there are many other things which a patient, skilled film maker learns over the years which he can bring to this type of project: editing skill, film pace, story development, and uncluttered flow of information.

2. *Cameraman*

We have found from experience that cameramen's skills differ just as the skills of any other professional. Some are most skilled at exterior shooting; some are best for interior shooting; one might choose one cameraman for shooting from helicopter or aircraft and another for fixed camera shooting, another for hand held cameras; some are not good for anything. A professional film maker has access to a wide variety of cameramen, whereas a small audio visual center relies usually on one or two persons who have to do all shooting.



In a precarious pose, cameraman hangs suspended from a bridge to shoot a sequence for *Vector Addition I*. (Courtesy of the National Film Board of Canada)

3. *Set designers and props*

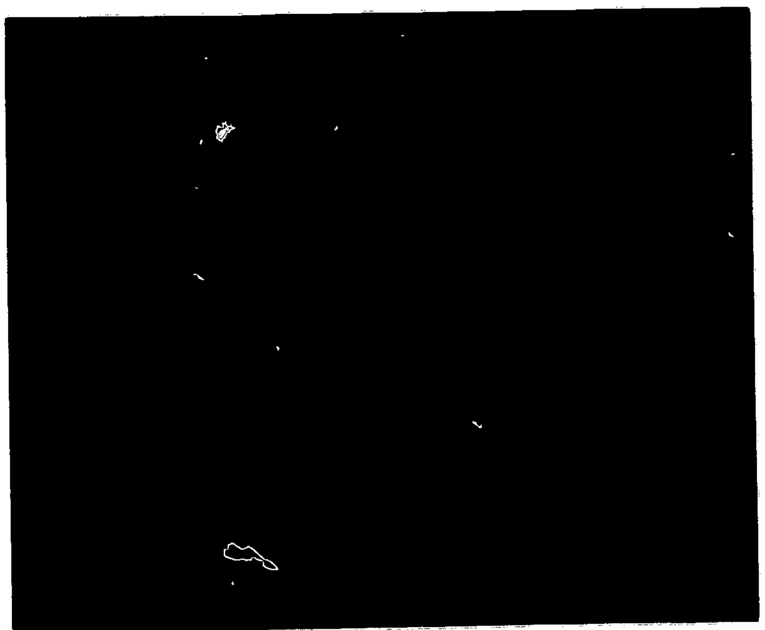
As one seeks to make better films, the need for film "props" becomes inevitable. Film is essentially a "visual" medium. What the viewer sees on the screen can be visually pleasant or unpleasant. A strong personality on the screen may overrule a slight nervous twitching of a physical handicap. A fat man on the screen does not move about as gracefully as a trim fellow (and he will fill more of the small screen!). A professional film director has access to experienced people who can provide various types of props. What can be trouble to teachers making films is simple routine around a film studio. Film directors also have access to good designers with training who can assist in set design, props, etc. The importance of these skills to a successful film should not be underestimated.

COMPUTER-ANIMATED FILM MAKING

> *". . . A good deal of instruction in the physical sciences is in terms of 'movies' of mathematical models of nature—except that the student does not normally see the movies, he only hears verbal descriptions of them."*[5]

As long as the physics instructor is content with simple one-parameter (and one-dimensional) descriptions of nature, a chalk and blackboard presentation of the variation of this parameter with time will be adequate (though not ideal). However, if the parameter is multi-dimensional or if it is important to consider simultaneously the time dependence of more than one parameter, then the blackboard begins to restrict the description and a film begins to offer advantages.

If this time dependence requires for its establishment difficult and/or tedious computation, then a computer becomes valuable. Instances come easily to mind in which both these conditions hold, and it is to improve the ability to present to our classes such complex and time-varying examples that physicists have turned to the technique of computer-animation, in which the dynamic display of film is combined with the computer's enormous computational resources.



Two bodies of unequal mass orbit about the center of mass under an attractive force. From Frank Sinden's *Fixed System of Orbiting Bodies.* (Courtesy of Education Development Center)

This film making technique is relatively new, but already there are examples which provide convincing evidence of the great potential it holds.[6] In one of these, *Scattering of Quantum Mechanical Wave Packets from Potential Well and Barrier,*[7] for instance, one sees in impressive detail the behavior of a one-dimensional Gaussian wave packet as it traverses square wells and rectangular barriers of different potential energies. The pedagogical superiority of the film to the presentation of the asymptotic solutions by a static drawing is easily seen. The MIT Education Research Center has underway the production of several additional computer-animated films in quantum mechanics which should be available by fall 1967.

The article by E. E. Zajac in Appendix B describes the step-by-step process of making a film by this technique; it may be useful to summarize these steps briefly here.

The first step should precede all film making, choosing a limited subject area and deciding in frame-by-frame fashion what will be displayed in the film sequence, i.e., the storyboard. A computer program is then constructed which contains the instructions necessary to produce the points and lines of the initial frame of the sequence and the instructions necessary to change what is displayed in the initial frame for each of the succeeding frames in accordance with the chosen mathematical model. This program is fed into a general-purpose computer and the output recorded on magnetic tape which is then used on a microfilm recorder to control the electron beam of a cathode ray tube. The result is the display of graphic representations of the mathematical model. An ordered sequence of such displays is recorded

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[5] E. E. Zajao "Film Animation by Computer." New Scientist, 39, (February 10, 1966) reprinted as Appendix B of this report.

[6] See Appendix III of *Short Films for Physics Teaching,* available from the CCP, for a list of these films.

[7] Produced at Lawrence Radiation Laboratory with the collaboration of Abraham Goldberg, Harry Shey, and Judah Schwartz; available from Palmer Laboratories.

frame by frame on motion picture film to produce a dynamic or "animated" representation of the programmed mathematical model.

Until recently, making a computer-animated film required that, in addition to being a subject-matter expert, one had also to be reasonably adept at computing, to have some understanding of film making, and to have access to the necessary computers. Improvement in equipment and the accumulation of experience has made the process easier. To produce the film in-house the physicist needs to have a computer-controlled camera and CRT display such as the Stromberg-Carlson 4020 Micro-Film Recorder, the Data Display Model 80 or the Control Data Corporation Digigraphics display. In addition one would need a general-purpose computer such as the IBM 7090 or 360, or the CDC 3600, either connected directly to the small computer or capable of producing tapes which could be transferred to the small computer. For a finished product the staff and equipment for titling, optical printing, and editing would have to be available.

Education Development Center, Inc., 55 Chapel Street, Newton, Massachusetts, where some computer-animated films on fluid mechanics are currently being produced, has such facilities. Commercially, the Joseph Kaye and Co., Inc., in Cambridge Massachusetts is also prepared to provide such services.

But even lacking this complete facility, it will be relatively easy for a physicist to produce a film by computer-animation, for most of us do have or will have within the next few years access to some general-purpose computer with tape-writing capability. It is the computer-controlled cathode ray tube display equipped with an animation camera which is not generally available. However, from the preceding discussions it is clear that the computer calculation of what should be displayed on each frame of the film can be separated from its display and filming. If simplified routines, usable as sub-routines of a Fortran main program on several of the more popular general-purpose computers, can be written and tapes produced, the tapes can be mailed to an installation which has the necessary display capability and the photographic equipment and which can use the tapes to produce a 16mm film. One would, of course, have to contend with the time delays in mailing the tape and the film back and forth. Nonetheless, the CCP feels that the end product can be such an effective teaching device that this method is worth developing, at least for the production of films for local use.

To produce the necessary Fortran sub-programs for a variety of currently used computers and to explore the feasibility of producing computer-animated films in this way, we sponsored a small working group during the summer of 1967, which attemped to write the sub-programs and to produce a few sample films by this technique.[8] A report of this working group should be available from the CCP by December 1967.

A service facility to assist physicists making computer-animated films has been set up in the past year at the Polytechnic Institute of Brooklyn, by Edward Zajac (on leave from Bell Telephone Laboratories). The cost of converting magnetic tape output into 16mm film at this installation depends, of course, on how much information is contained in each frame of the film, but typically the computer and film costs would be between $.05 and $.10 per frame.

The Commission will continue its strong interest in this technique. Interested physicists should correspond with John W. Robson, Staff Physicist, at the CCP office.

Part IV Equipment

Equipment for 8mm film making[1]

INTRODUCTION

Such a great variety of photographic equipment exists for shooting and projecting film that it was clearly necessary for this report to limit the description of equipment in some way. Because the Conference concentrated on the short or "single concept" film, this report is limited to equipment suitable for producing and showing 8mm film and emphasizes projectors designed for cartridged films. This choice, however, still leaves us with the task of describing far too many cameras. Since we are interested in convincing physicists that there are useful films that they themselves can make, we have taken our cue from Kevin Smith's article in the film making section (pp. 26-29) and have described the characteristics an 8mm camera should have (including important accessories) in order that a physicist-film maker can proceed with confidence along steps described in the article for producing a short film by in-camera editing. Appendix D contains a chart of Regular 8, Super 8, and Single 8 cameras, listing their specifications according to the discussion on pp. 39-41 below.

We have followed these same guidelines in our discussion of film stocks, concentrating on 8mm film of all formats and leaving the description of 16mm, which is clearly the proper choice for the professional and the experienced amateur, to other sources. Appendix D contains a listing of 8mm film stocks and their specifications.

CAMERAS AND ACCESSORIES FOR AMATEUR SCIENTIFIC FILM MAKERS[2]

A physicist using Super 8 film need not have a "professional" Super 8 camera, which would cost more than $1000. The best grade of "home movie" camera is recommended; such cameras fall into the $200 to $250 range. The following features, available in several makes of Super 8 cameras, would be useful to the physics teacher making short films for use in his own classes.

Camera specifications

1. *Lens*

   A good lens is the first attribute of a good camera and one which will account for a large fraction of the cost of a camera. A fast lens (f/2 or better) with crisp resolution and low aberrations is necessary. However, not all f/2 lenses are of equal quality, and it is difficult for a beginner to judge lens quality even on the basis of a specification sheet. The reputation of the manufacturer is probably as good a criterion as any, unless one is prepared to delve deeply into the technology of practical photography. Buying guides and consumer ratings referred to in the bibliography will be helpful in this selection.

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[1] Walter Eppenstein (Chairman). Stephen Blucher, Joseph Bower, Bruce A. Egan, Elwood Miller, Nat C. Myers Jr., William Riley, Richard F. Roth, Gordon H. Tubbs, Harold Zallen (members).

[2] This section was written at our request by Franklin Miller, on leave from Kenyon College at the National Film Board of Canada, a pioneer in the production of short silent physics demonstration films. It is intended as a companion piece to "Local Production of Physics Films" in the report of the Working Group on Film Making Techniques.

2. *Through-the-lens reflex viewing*

With this capability, the operator can see while he is shooting exactly the same image that appears on the film by means of a semi-reflecting mirror and prism. This allows the film maker to frame his subject more reliably and to determine the effect of changes on camera placement, zooms, pans, and other maneuvers. For critical focussing, an adjustable eyepiece is an essential aid.

3. *Automatic exposure with manual override*

A built-in light meter controls the lens opening to compensate for variations in illumination of the subject. This capability greatly reduces the possibility of grossly underexposed or overexposed footage and for many applications, including scientific ones, such a capability is both useful and convenient. However, for much scientific photography, it is essential that the user be able to override the automatic exposure control. For example, the region of interest is often well lighted, but occupies only a small portion of the frame, which otherwise remains dark. In this case, the automatic exposure control, which responds to the illumination averaged over the frame, will set too large a lens opening and the region of interest will be overexposed. Although the automated aperture setting is useful for a first approximation, the user should be able to manually control the lens opening as well. A conventional (external) light meter is valuable for checking the lighting of various parts of the frame.

4. *A range of camera speeds*

The standard speed for projection of Super 8 film is 18 frames/sec. It should be possible to shoot film at 36 frames/sec, so that when projected normally the action will be in slow motion, at half speed. There are occasions, however, when it would be desirable to compress the time scale by shooting at, for instance, 9 frames/sec. It is not necessary to have a continuously variable camera speed for such purposes, but some provision should be available for selecting one of a few fixed speeds ranging from perhaps 6-36 frames/sec.

5. *Single-frame exposure*

For time-lapse photography or for special effects, e.g., animation, it is desirable to be able to expose a single frame of film at will. Such single-frame exposure will probably require use of a conventional light meter to obtain correct exposure.

6. *Zoom*

The ability to zoom (i.e., to change the size of the image while keeping it in focus) is a desirable feature. Zoom ratios vary: wider ratios mean more versatility (3:1, 4:1, and even 5:1 ratios are becoming common; 8:1 is available on professional cameras). Properly used, a zoom can provide emphasis while maintaining continuity of action. An equally important advantage of a zoom lens, even if zoom action is not required, is that it can provide the film maker with an infinitely variable selection of focal lengths (within limits). Thus a single zoom lens can serve both as a wide angle lens (short focal length) and as a telephoto lens (long focal length). Make sure that the lens can be zoomed without advancing the film.

7. *Electric operation*

Look for a battery-driven motor and, if a zoom lens is used, for a motorized zoom action. Many cameras also incorporate pushbutton electric focussing, which is handy but not indispensable.

Camera Accessories

1. *Auxiliary lenses*

It would be well to find out whether a "close-up adapter" lens is available on the camera you select. This is a positive lens used to supplement the power of the camera lens. Such an auxiliary slip-on lens is essential if shots are to be made in extreme close-up. For example, the zoom lens of a typical camera focuses on objects between four feet and infinity. At four feet, an object eight inches wide will fill the frame horizontally. With suitable auxiliary lenses, this same camera can focus to a distance of about 0.6 feet, so that a one-half inch object will fill the frame. A set of three close-up adapter lenses of power +1, +2, and +3 diopters allows all combinations from

+1 to +6 diopters. Such a set can significantly extend the usefulness of a camera.

2. *Tripod*

   The importance of a sturdy, heavy-duty tripod cannot be overemphasized. A tripod should have a hand crank to permit reliable adjustment of height.

3. *Lighting*

   So far, Super 8 film comes in one emulsion stock—the so-called daylight emulsion of speed ASA 40.[3] Other emulsions will eventually be available. Usually a physics demonstration is filmed indoors, using tungsten lamps. While it is possible to shoot film with a lamp attached to the camera itself, this procedure produces flat, shadowless lighting. For better lighting effects, lamps should be mounted on tripod supports placed on each side of the subject, above or below. A useful camera feature is an interlock which drops a suitable filter into place when a lamp is plugged into the camera housing; it must be possible, of course, to use this built-in filter independently of plugging a lamp into the camera socket. With the fast lenses and emulsions now available, it is generally sufficient to use four or six 500-watt photoflood lamps with built-in reflectors, or with separate metal reflectors. More will be needed if a large area is to be illuminated. Several "clip-on" reflectors will also prove useful.

4. *Editing and splicing*

   It is not always possible to shoot a film in the exact sequence desired; if a predetermined length such as 50 feet of Super 8 must be adhered to, some cutting and splicing is usually needed to bring the completed film to within the desired length, and to place scenes shot at different times in proper sequence. Film is edited by splicing together bits and pieces from several rolls of film. Super 8 splices by amateurs are usually made with Mylar tape; be very careful to rub the splice with a fingernail to remove all traces of air bubbles between film and Mylar. Use a splicer that makes an S-shaped cut. This splice is necessary when preparing film for use in an automatic cartridge; the older butt splice will not stand up under the twisting and turning of an endless loop. Several viewer-editor devices are on the market. As film goes from reel to reel, it passes by a rotating prism which both serves as a shutter and a reflector, projecting the image onto a small screen. A design defect in some viewers gives rise to a disturbing motion of the image on the screen as the prism turns; other viewers are free from this defect. If possible, test the action of the viewer before purchasing one.

Limitations of inexpensive cameras

We have described the minimal equipment needed by a teacher starting to make films for his own use. The home movie cameras, at best, are engineered for a mass market and are not as rugged as more expensive professional cameras. They must be handled carefully, preferably by one person only (the teacher). Some of the limitations of the inexpensive ($250) camera would be important to a professional film maker. The Super 8 cartridge cannot be rewound in the camera, so "burn-in" of legends or numerals cannot be made by the usual techniques of double exposure.[4] The motorized zoom lens usually cannot be removed, so exposure directly on the film, without the use of any lens, is not practicable. The behind-the-lens light meter needs periodic calibration. An "inexpensive" camera is really more complicated than a more expensive, rugged camera costing $1000. But the average physics teacher should not consider himself a professional film maker; his use of the medium is a limited one which should be served well by a camera such as has been described here.

FILM

Formats

Much time was spent in the working group session on the subject of film sizes and the question of standardization. While the preference of film users would be for maximum interchangeability of film and cart-

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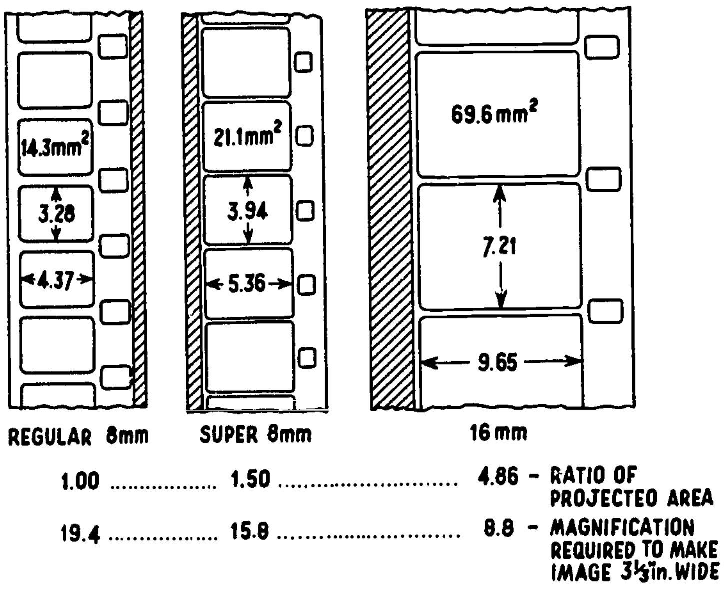
[3] Editor's note: There are others; see p. 42 for discussion of Super 8 emulsions.

[4] This can be accomplished with "Single 8" cartridges; see description page 43.

ridges, this clearly goes against the philosophy of competitive industry.

Until recently educational films came in two sizes, Regular 8mm and 16mm, with the latter dominating the field until the advent of the 8mm cartridge projector. There now are several more formats, Super 8 and Single 8, Viewlex, and the 9-½mm film introduced in Europe.

The place of 16mm film seems secure. Most professional filming will be done in 16mm because it offers a greater variety of film stocks and wider possibilities for laboratory work. It will probably remain the favorite for longer films designed for large audience viewing. In any case, 16mm can always be reduced to 8mm for cartridging.



The three major 8mm film formats—Regular 8, Super 8, Single 8 — compared.

The liveliest present controversy is between the Regular 8mm format and the Super 8 format (of which Single 8 is a variation). The essential difference between these two formats is shown above. By reducing the size of the sprocket holes and eliminating the space between frames, the image area on Super 8 and Single 8 has been increased 50% over that on Regular 8, which gives either a brighter projection image of the same size or a larger image for the same brightness. These three formats are described in greater detail and compared below:

1. ***Regular 8***

Regular 8mm film evolved from 16mm and carries the same size sprocket hole, but with half the separation (see above). The film is normally exposed in double width and then slit down the middle to give two strips of film with relatively large perforations on one edge and the image off-center, close to the other edge. A sound track can be added in the margin space between the perforations and the film edge. The evolution from 16mm has also created wasted space between frames, as is shown above. The major advantage of Regular 8 stems from its long domination of the market. A wide variety of cameras, projectors, accessories, and films is available in this format and adequate processing facilities have been established. Furthermore, in the present changeover period there will be many bargains in Regular 8 equipment. The film is somewhat less expensive than the Super 8 format (for comparison, see Table IV-1). There are projectors (not cartridge-loading ones at present) which will take both 8 and Super 8.

2. ***Super 8***

The most important advantage of this new format is clear from the drawing above; the image size of Super 8 is 21.1mm^2 compared to 14.3mm^2 in the Regular 8 format. The advantages in picture quality can be compared by use of the information on magnification (see Table IV-4), the number of times the picture must be enlarged before it reaches a width of three and one-half inches for viewing at a distance of ten inches (or for the projection set-up to be comparable when the viewer is sitting at a distance of three times the screen width from the screen). The magnification required for Regular 8 is almost 25% greater than that for Super 8 for the same image size. Other things being equal, the sharpness of the projected image is related to the magnification. Super 8 has other less important yet significant advantages: the change in spacing and shape of the sprocket holes makes Super 8 about 25% stronger under tension than Regular 8; locating the holes on the picture centerline enables splices to be stronger (they do not pass through a perforation); Super 8 has

Type of Film	Price (including processing)	Approximate price per minute	Approximate film cost for 15-min. movie
Single 8 Fujichrome	$4.40	$1.30	$20.00
Super 8 Kodachrome II	$4.90	$1.50	$22.00
Double 8 Kodachrome	$4.40	$1.20	$18.00

Table IV-1

The table above gives the manufacturer's list prices per 50-foot cartridge for Single 8 Fujichrome and Super 8 Kodachrome II, the only films available until recently in the new formats, and the price per roll for the unmagazined Kodachrome used in old-style double 8mm cameras. (Chart reprinted from *Consumer Reports*, June 1967)

more area on the unperforated side than Regular 8, allowing more precise guiding of the film and flatter presentation at the projector aperture.

There are disadvantages, some of which will disappear with more pressure from the market place. One which will not disappear is caused by the increase in separation between sprocket holes. The Super 8 film moves somewhat more rapidly through the projector and gives less projection time per foot of film. There are 72 frames/ft of Super 8 film as against 80 frames/ft of Regular 8; both are projected at 18 frames/sec. For added comparison, 16mm has 40 frames/ft, projected at 24 frames/sec. The other disadvantages are the present limited selection of equipment and film types.

Only two emulsions have been available in Super 8—Kodachrome II Type A, ASA 40 tungsten and ASA 25 daylight (with filter) and Dynachrome, ASA 40 daylight. In mid-1967 two new emulsions appeared: Agfachrome (in Super 8 cartridges), ASA 40 tungsten and ASA 25 daylight, and Moviechrome II (in Super 8 cartridges) also ASA 40 tungsten and ASA 25 daylight. Super 8 is marketed almost exclusively at present in preloaded cartridges[5], which allow no rewinding for special effects (lap dissolves, double exposures. etc.) and they cannot be reloaded.

The present narrowness of choice in Super 8 equipment will rapidly disappear. Thirty-nine new Super 8 cameras were introduced at the 1967 MPDFA show in Chicago with new and sophisticated features[6] including variable speed zoom, wider zoom ratios, instant diaphragm response to light variation, etc. It is clear that this format is here to stay.

3. *Single 8*

This interesting new format is being marketed in this country by the Fuji Photo Film Company, Ltd. of Japan. It has the same format as Super 8 but the emulsion (Fujichrome RT 50) is on a polyester film base which is stronger, and, more importantly, about one-third thinner. This allows the reels to be smaller and has enabled the Fuji Company to make a film cartridge in which the reels are placed edge to edge (in the same plane) rather than side by side (coaxially) as in the Super 8 cartridge. As a result, the Fujica Single 8 P1 and the more flexible Single 8 Reflex Zoom Z1 and Z2 are thinner than the Super 8 cameras and the cartridge design allows rewinding (for double exposure, etc.) and reloading. Even more important, the thinner film base allows more light to pass through and gives even brighter pictures in projection than Super 8.

Single 8 shares with Super 8 the disadvantage of limited selection of equipment and film types. It is somewhat harder to splice than Super 8 (it can take only dry, self-adhesive patches

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[5] There is a double Super 8 similar to the Regular (double) 8 which comes on larger reels. The reels must be switched at midpoint to expose the other side and it is then sliced down the middle in processing.

[6] See "Super 8: More Sophisticated," Photography, June 1967, pp. 106-7.

rather than "cement"). It is competitive in price with Super 8 and can be run in the same projector and even interspliced with Super 8. At the present time, few printing laboratories in this country are equipped to handle Single 8 stock.

It was generally agreed that eventually the Super 8 format will probably become the most popular film size, but no one, at this point, can predict how long it will take. An analogy was drawn with phonograph records. For a number of years four record speeds have been available—78, 45, 33-1/3 and 16-2/3 rpm. In the long run only two of these systems seem to have survived and one tends to be the largest seller. However, the 45 and 33-1/3 rpm records now tend to serve a different function in the music business with the 45 rpm being a popular music record and the 33-1/3 being for long playing records of adult concert music. For many years, practically no research has gone into the improvement of 78 rpm records, although they are still available.

Film Printing and Reproduction

At present the decision to use a particular film format is strongly influenced by what is to happen to it after it leaves the camera. If optical effects are to be a part of the finished film, or if many prints are anticipated, then a 16mm original is needed. Laboratory work on all types of 8mm at this time is very restricted. For some time to come, most professional filming and much ambitious amateur filming will continue to be done on 16mm.

Kodachrome II, the most popular stock for amateur movie-making, is designed for proper contrast in projection; in any duplication process, contrast will be increased and there will be some loss of definition. Duplicate prints can be made from this film but they will be somewhat inferior to the original. But in most cases it is possible to obtain a usable print, particularly if the suggestions below are kept in mind. The cost of duplication on this direct reversal color stock is relatively high.

In indoor shooting, some of the difficulties connected with duplicating Kodachrome II film can be overcome by deliberately lighting the set for "flat" scenes of low contrast. Emulsions (not yet available in Super 8) have been developed which minimize the contrast enhancement formerly thought to be inevitable when printing directly from Kodachrome II originals.

There is yet no entirely satisfactory way for using Super 8 original film to make high quality duplicate prints in quantity. However, it is likely that within a year or two Super 8 will become available in some wide variety as is now the case for 16mm. Therefore, a description of present 16mm practice can serve as a preview of what is yet to come for Super 8. Three matched emulsion types are used. Exposure is made on 16mm Ektachrome Commercial Type #7255, a low contrast original film designed for duplicating and not for screening. The next step is to have the printing laboratory prepare an internegative on 16mm Eastman Internegative Type #7270. Finally, the internegative is used to make release prints on 16mm Eastman Color Print Type #7385. The same 16mm internegative can be used to make 16mm prints or, by optical reduction, Super 8 prints. When, and if, Ektachrome Type #7255 becomes available in Super 8 cartridges, laboratories will be able to reproduce Super 8 original film in quantity, with high quality. Even now, it is possible for Kodak to use a Super 8 Kodachrome II original to make an Ektachrome internegative on Type #7270. This can, in turn, be used for quantity printing on Type #7385, but the final result will have high contrast introduced by the initial reproduction from a projection-contrast film such as Kodachrome II.

It is clear that Kodak at least is moving to make quantity printing of 8mm economical. They have recently announced the development of a mass production Super 8 print system to accomplish the efficient production of high quality Super 8 magnetic sound prints.

The new system uses 35mm prestriped film which after slitting produces four Super 8 prints. The heart of the system is a fast contact printer, the Bell and Howell Model 6600 MS Panel Printer, which has only recently been developed. This printer, working from a 35mm internegative, transfers both the image and the sound onto the prestriped raw stock at 200 ft/min, producing, therefore, sixteen, 50-foot Super 8 prints per minute.

Kodak has also developed a new fine grain color print film, Type #7380, which has a significant grain size reduction compared to Type #7385 used in the 16mm printing.

While this fast system will hold no great interest for the physicist-amateur making a few films for his own class use, it is clear that it opens the way to the mass production of Super 8 for educational as well as entertainment films and that it is the "printing press" which was needed to make Super 8 the "paper back" of films.

Film Cartridging

At present the only cartridges for 8mm film are the silent cartridge for Technicolor projector which holds up to 50 feet of 8mm or Super 8 film (4-5 minutes maximum), the optical sound cartridge for the new Technicolor 1000A model which holds either 200 feet of Super 8 film (4-10 minutes) or 600 feet (10-30 minutes), and the sound cartridge for the Fairchild projector which holds 400 feet of Regular 8mm with magnetic striping (30 minutes maximum).

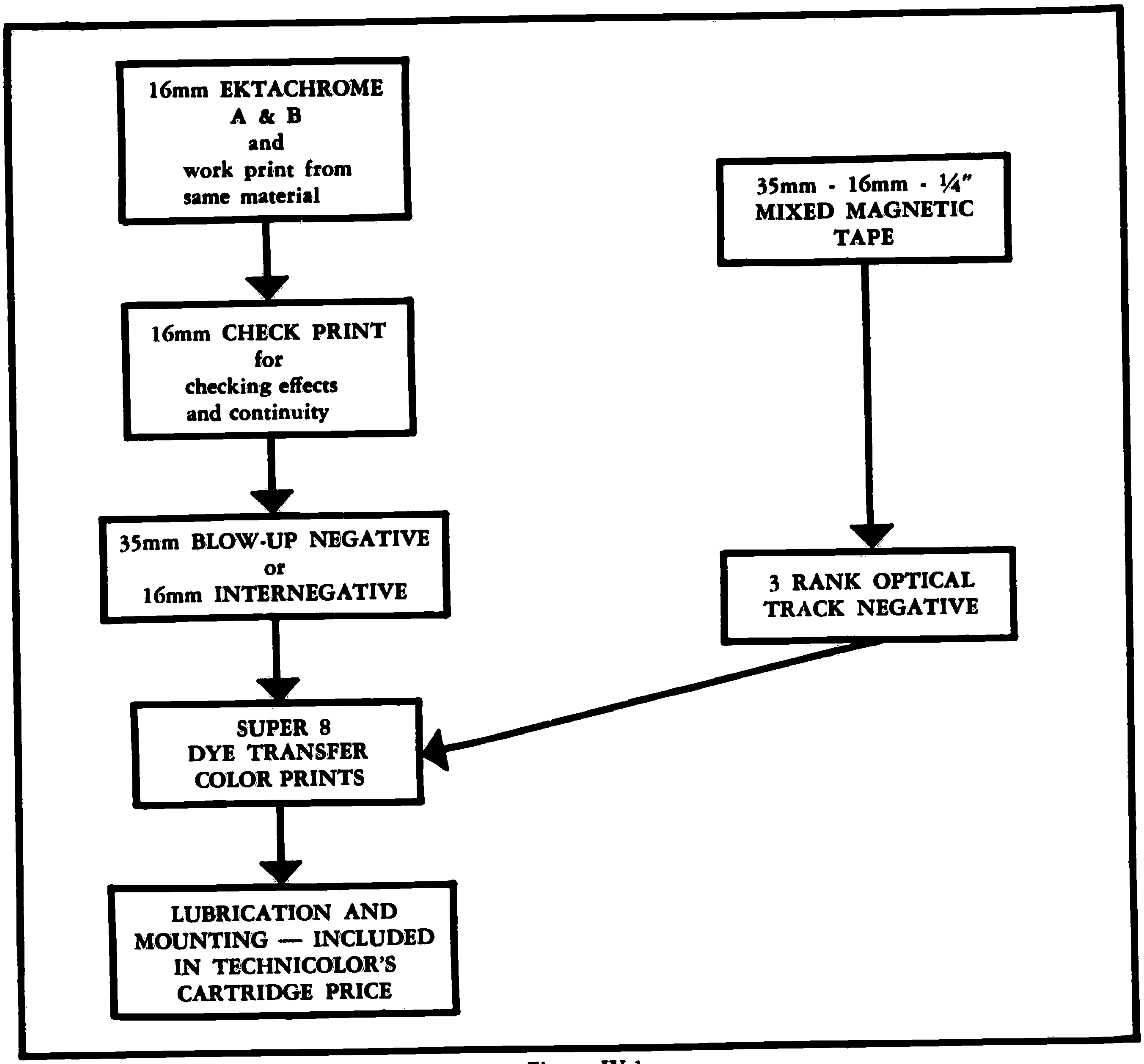

Figure IV-1

Sequence of operations for processing and loading film in cartridges at the Technicolor Corporation.

Technicolor Corporation will process and load film into their cartridges. The sequence of operations is given in the diagram in Figure IV-1. The sound track, if there is to be any, is provided on magnetic tape. The cartridges themselves cost $.75 for the short silent films and $3.97 for the 30-minute sound film, including loading and lubrication charges.

The larger cartridges for the Fairchild projectors cost from $6.60 to $9.95 per cartridge (based on quantity ordered); film treatment, costing between $.01 and $.015 per 8mm foot (minimum charge of $4.00), is mandatory for cartridge loads in excess of 200 feet. An additional charge of $1.50 to $3.00 per cartridge (depending on quantity) is made for cartridge loading.

It is possible to obtain cartridge-loading equipment[7] if the expected volume of film being produced warrants it. With the present systems, however, it will probably be best for the majority of physicists to leave the cartridging to the projector distributors.

There is hope that future cartridge projector systems will be developed in which the cartridge itself will cost a small fraction of what the film costs; Kodak is working on a quasi-cartridge system for which the cartridge cost is but a few cents a unit.[8] Such developments will certainly encourage wider use of 8mm film in education.

PROJECTORS

This section briefly summarizes some of the important things one should consider in choosing a movie projector. These first general remarks apply for the most part to projectors which will be used in classrooms in the conventional manner. Following these are somewhat more detailed descriptions of currently available cartridge projectors and several new systems which have features consistent with the more varied use of film which this Report foresees.

Lenses

Although a projector cannot add to the quality of a film it can detract from it. For best results, therefore, the projector lens should be as good as the camera lens. In deciding on the lens it is worth remembering that "zoom" lenses (see later discussion) are not as good, dollar for dollar, as fixed focus lenses. Detailed information on the relation between focal lengths and image size is provided by Table IV-4 in the section, "Utilization of Projected Materials," page 54.

Brightness

The brightness of the projected image is one of the most important comparison points for projectors. Lamp voltage and lens aperture do not provide a unique index for determining brightness; new high intensity lamps with built-in reflectors and the even newer quartz-iodine lamps focus light more efficiently and produce a brighter, color-constant light. To judge brightness take the following as a guide, using a light meter or a camera exposure meter (remember that "white" or bluish light will appear brighter to the eye than "warm" reddish light even though the meter reading may be the same):

> **with the projector running at normal speed, but without film, and the screen at the requisite distance, you should get an incident-light reading of 3 to 4½ footcandles at the center —equivalent to an exposure of 1/10 second at *f*/5.6 to 1/30 second at *f*/4 with a film-speed setting of 100. Fall-off at the corners shouldn't be more than 50 percent, or one *f*-stop.**[9]

Film Transport

At silent speed (18 fps) a 400-foot reel takes one half-hour of Regular 8 film. Super 8 film of the same footage will have a reduction in running time of 10% However, the same reel will hold 33% more Single 8 film because of its thinner base. Projectors should be checked for image steadiness and quiet performance. It is also important to determine the ease with

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[7] Technicolor Magi-Cartridge Loading Station which can be bought for $100.00 from Technicolor. Gross of parts for the loader costs $114.00.

[8] See description of the Kodak Ektagraphic 8 System, page 48.

[9] *1967 Photography Directory and Buying Guide* (New York: Ziff-Davis), p. 24A.

which a projector can be stopped in mid-run and the reels removed — a useful feature for the instructor who wishes only to show part of a film. Most of the present projectors are self-threading, a highly desirable feature. Fast rewind is also a must.

Controls

1. *Zoom*
   The projector zoom lens does not function in the same way as a camera zoom lens, that is, it does not allow isolation and expansion of a small section of the image frame. Zoom capability is useful, however, because it enables the projectionist to adjust the image to a screen to fill from a range of projector distances and to compensate for the frame sizes of different 8mm formats without moving the projector.

2. *Variable speed and reverse*
   Variable speed projection allows special effects, slow motion, and skimming over unimportant sections. Reverse allows rerunning of a scene without rewinding. Projectors with special settings for slow motion should be checked at this speed to make certain that the picture is "flicker" free.

   Still-frame projection is also potentially useful in instructional films but in most cases, the filter which protects the film from burning reduces the image brightness considerably.

CARTRIDGE LOADING PROJECTORS

If large quantities of film are to be made accessible to students, then viewing convenience must be optimized. The student must be able to obtain a film as easily as he does a book and he must be able to look at it without the inconvenience of learning how to thread a projector and without danger of damaging the film. The cartridge-loading projector is one highly successful way of making film available to students.

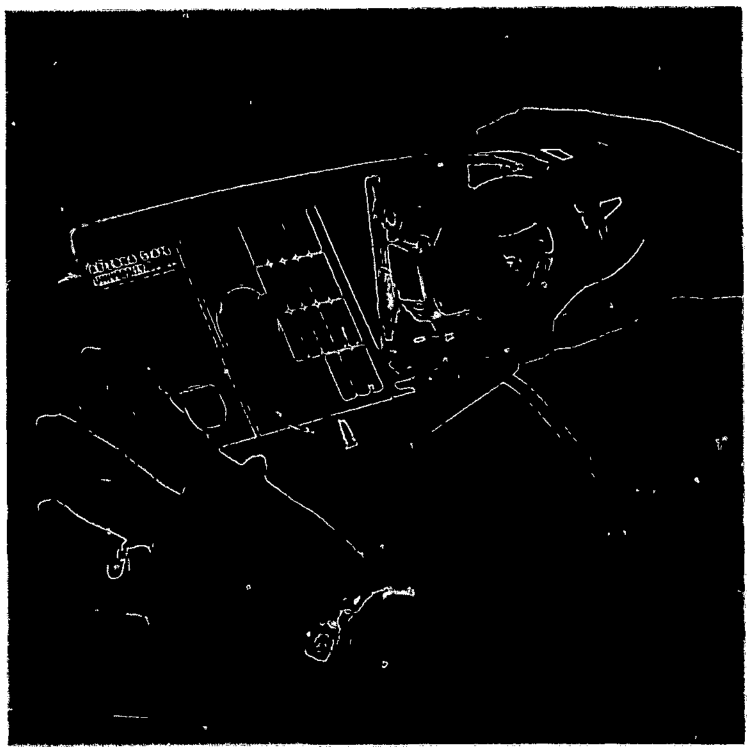
REEL-TO-REEL PROJECTORS

Appendix D describes briefly the important features of 8mm projectors. It should be mentioned, however, that the emergence of the new 8mm formats has been followed by the development of new convertible projectors designed to accommodate all 8mm formats, most of these have sprocketless drive; some can even take Regular 8 and Super 8 spliced into the same reel.

Technicolor Corporation

Technicolor Corporation has developed several series of cartridge-loading machines for both Regular and Super 8. Whether front or rear screen projection, each model accepts a plastic cartridge which, when pushed into the side back or front of the machine (depending on the model), automatically triggers the projector. The cartridge holds up to 50 feet of film in a loop and repeats automatically until removed from the projector. No threading or rewinding of film is necessary; and cartridges protect the film from fingerprints and damage from mishandling. Technicolor has also developed a cartridge-loading sound projector (Model 1000A below) with optical sound, which takes cartridges which hold either 200 feet of film and run from 4-10 minutes or 600 feet of film and run 10-30 minutes. The projector weighs only 18 lbs.

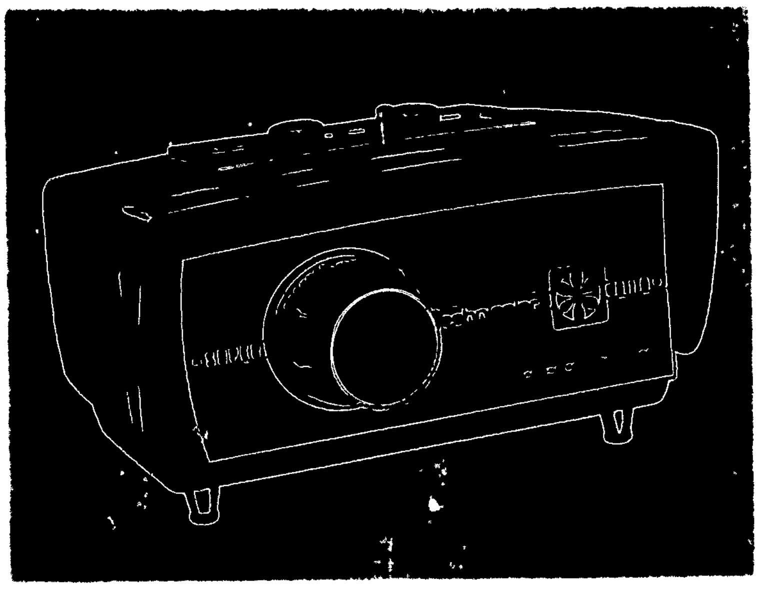
Table IV-2 includes brief descriptions of Technicolor models and their optional features.



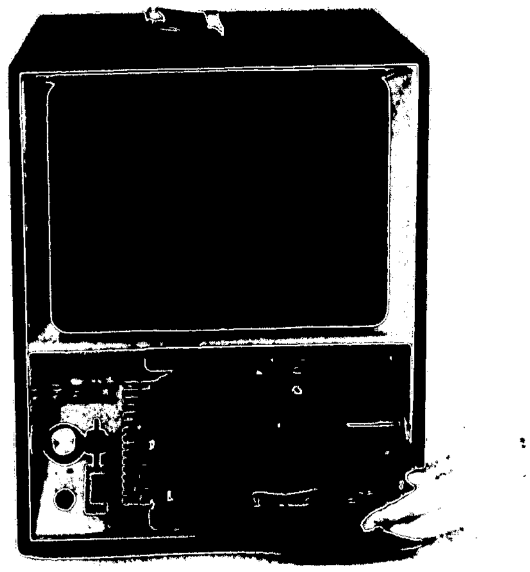
Technicolor Model 500 Regular 8 Projector being loaded from the rear.

BASIC MODEL #	LIST PRICE	LENS AND FOCAL LENGTH	LAMP	PROJECTOR SPEED (FPS)	AUXILIARY MODELS	EXTRAS
200A	$184.50	20, f/1.6	150 watt dichroic truflector DCL	16	200Z: Lens—15-25, f/1.5 zoom ($199.50) 200WA: Lens—9.5-15, f/1.5 zoom ($204.50) 200WS: Lens—10, f/1.1	Regular 8; remote control; single frame projection; tilt control.
500	$ 69.50	20, f/1.6	150 watt truflector DCH	16	500Z: Lens—15-25, f/1.5 zoom ($84.50) 500WA: Lens—9.5-15, f/1.5 zoom ($89.50) 500WS: Lens—10, f/1.1 ($94.50)	Regular 8; tilt control; optional: automatic shut-off; single frame projection; speed of 24 fps.
600A	$199.50	10, f/1.1	150 watt, 21.5 volt dichroic DCF	16	600E: voltage range, 220-250, 50 cycles 600AD: single frame projection, carrying handle, tilt control. ($249.50) 600ED: same as 600AD with voltage range of 220—250, 50 cycles	Regular 8; rear screen projection (15⅞ x 11¾″) optional: automatic shut-off; automatic shut-off with push-button restart; speed of 24 fps.
510A		20, f/1.5	150 watt truflector DJA	16	510Z: Lens—20-32, f/1.4 zoom 510WS: 10, f/1.1	Super 8; tilt control.
800	$ 99.50	15-25, f/1.5 zoom	150 watt truflector DCH	16	800WA: 9.5-15, f/1.5 zoom ($104.50) 800WS: Lens—10, f/1.1 ($109.50)	Regular 8; tilt control. Optional: automatic shut-off; automatic shut-off with push-button restart; single frame projection; speed of 24 fps.
810A		20, f/1.5	150 watt, 21.5 volt dichroic DCF	16	810Z: Lens—20-32, f/1.4 zoom 810WS: Lens—10, f/1.1	Super 8; single frame projection.
1000A	$299.95	20, f/1.1	Quartz-halogen 21.5 volt dichroic reflector, 150 watt	24		Super 8; optical sound; built-in 4 in. speaker; 7 watt amplifier; takes cartridges from 4-10 min. (200 ft., and 10-30 min. (600 ft.).
700A (Automatic Display Projection System)	$179.50	10, f/1.1	150 watt DCH	16		Regular 8; designed for unattended display; starts at push of a button; automatic shut-off at end of film; lighted panel, "To See Demonstration, Push Button." Built-in screen, 5¼ x 7″

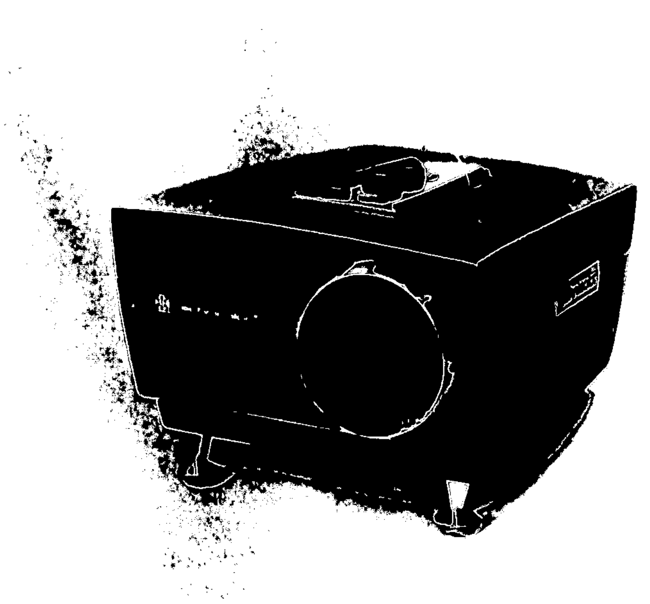
Table IV-2
Technicolor Cartridge-Loading Projectors



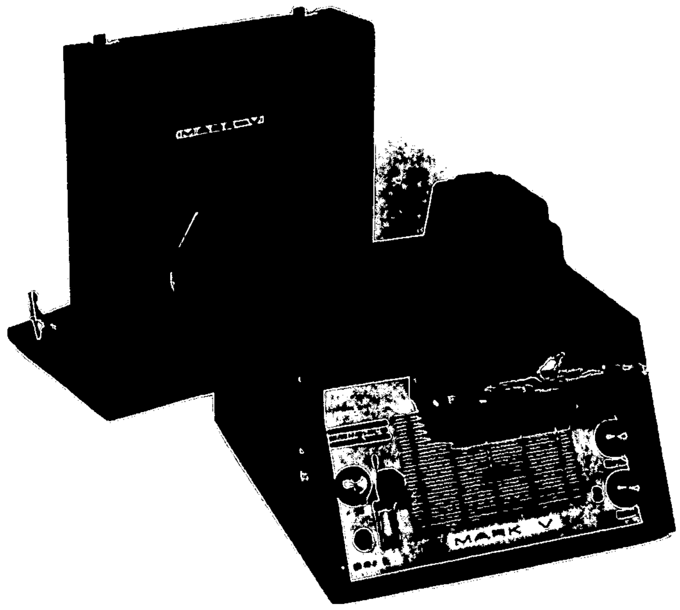
Technicolor Model 1000A Super 8 Projector



Fairchild Mark IV Projector



Technicolor Model 810 Super 8 Projector



Fairchild Mark V Projector

Fairchild Camera and Instrument Corporation

Fairchild cartridge-loading machines take up to 22 minutes of color and up to 30 minutes of black and white 8mm film with magnetic sound track. The Mark IV model is a rear screen projector; the cartridge is inserted in the front, a lever depressed, and the machine automatically runs, rewinding as it plays, and stopping automatically at the end of the loop. It has a built-in speaker, transistorized sound, and weighs 20 lbs. The Mark V is a front screen projector with a detachable built-in speaker. Cartridge loading is the same as for the Mark IV. Specifications for the Fairchild projectors appear in Table IV-3.

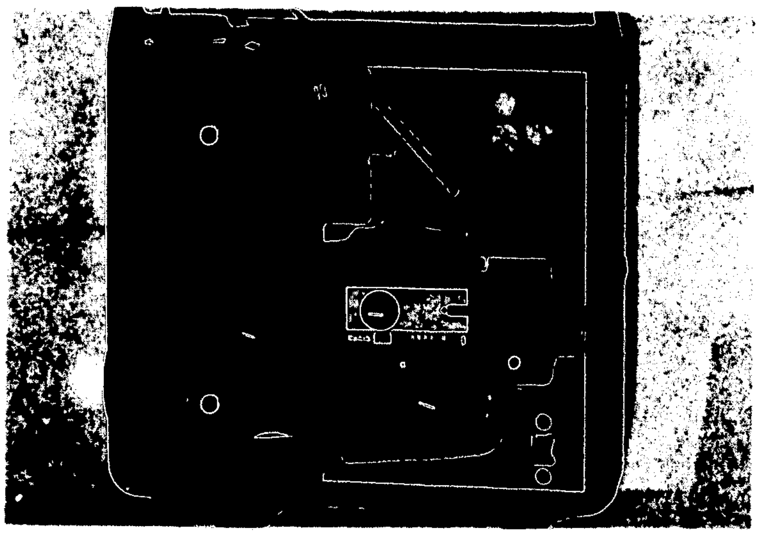
Kodak

Kodak has taken a new approach to cartridge-loading projectors. It is their belief that the continuous-loop feature adds little to the convenience of film viewing; that almost all films are looked at only once and not several times in a row. They have therefore preferred a reel-to-reel approach cartridged inexpensively for protection and ease of storage. In the new Ektagraphic 8 projector, Super 8 film is snapped onto an inexpensive plastic cartridge and then inserted into the gate. The film is threaded completely automatically and when it has run through, rewinds automatically at high speed. The film can be returned to its beginning at any point by depressing a rewind lever. The Kodak cartridge will take up to 50 feet of Super 8 film; the machine can also take up to 200

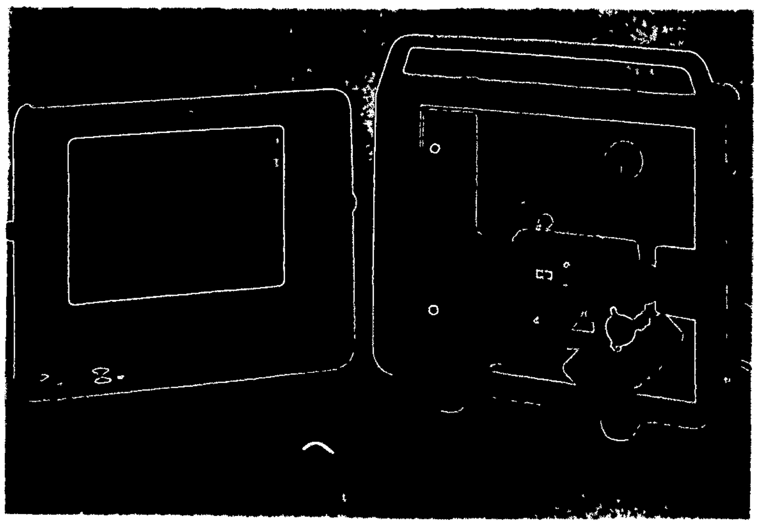
MODEL #	SPEED	LIST PRICE	AUXILIARY MODELS	LAMP	EXTRAS
400	24	$479.00		8 volt, 50 watt pre-focused	Regular 8; rear screen projection; screen size, 8½ x 11" built-in; 3-watt amplifier; 4 x 6" oval speaker, built-in.
Mark IV	24	$589.00	Record amplifier with microphone attachment $180.00	8 volt, 50 watt	Regular 8; rear-screen projection; screen size, 8½ x 11"; 3-watt transistorized amplifier; 5 x 7" oval built-in speaker. Outlets for headphones.
Mark V	24	$559.00		8 volt, 50 watt	Regular 8; front screen projection; speaker in detachable top. Otherwise similar to Mark IV.

Table IV-3
Fairchild Cartridge-Loading Projectors

feet of film on standard reels. The Ektagraphic 8 is scheduled for delivery in September 1967 at a cost of slightly over $100.



Kodak's Ektagraphic Silent Super 8 Projector



Kodak's Ektagraphic Sound 8 Projector

Hudson Photographic Industries, Inc.

Hudson's Sonomute 610 Single Concept Projector projects 8mm Technicolor cartridges on a rear screen. Its dimensions are 27"x13"x10" with a 5"x7" screen. The Sonomute 610 has a f/9.5 zoom lens and a 150 watt DCH lamp and sell for $300 list.

Audio-Sell

Audio-Sell has developed a cartridge tape recorder attachment for the Technicolor 800 projector which allows the synchronization of magnetic sound taped commentary and silent 8mm Technicolor loops. Model TMT-25 Tele-Sell has variable projection speed (14-25 fps), a 1½ watt amplifier, a 3"x5" speaker and sells for $1269.50 list.

Color Sonics, Inc.

Color Sonics Model 2600 is an audio-visual "juke box" unit in a case with push button control, designed for restaurants and bars, but potentially useful in education. It uses a small Fairchild cartridge which holds five minutes of film projected on a rear screen. The machine will hold 26 such cartridges at one time. Cartridges can be changed easily through a front door. Such a machine could be placed in dorms, laboratories, classrooms or libraries allowing students random access to a selection of films by push-button control. The Model 2600's screen is 300 square inches; Color Sonics claims the films can withstand 2,000 plays. The cartridges and the internal mechanism are manufactured by Fairchild.

MPO Productions, Inc.

The MPO Videotronic Super 8 cartridge-loading projector is a sound projector which takes loops holding about 14 minutes of film. It can be used as a rear-screen projector or it can be converted to project a picture on a wall or screen. The Videotronic projector sells for about $450.

UTILIZATION OF PROJECTED MATERIALS[10]

Regardless of the quality of a motion picture film or slide, or the advanced state of the art in hardware, successful projection techniques remain the key to transferring ideas and concepts from the projected image to the student's mind. By following good practices in setting up a classroom or laboratory for the showing of film, the instructor gains the ultimate flexibility for utilizing a slide or film clip in the lecture with the confidence that the class will receive the maximum benefit from the medium.

This section is intended to help clarify some of the steps necessary to insure that the message reaches the class without interference by the projection process.

For effective projection in the classroom, consideration should be given to the following:

1. selection of a screen location, size, and type;
2. selection of the optimum projector location;
3. providing required image brightness;
4. general considerations of student comfort in the lecture room including light control, adequate sound facilities, and seating.

For the optimum use of projection during a lecture there should be a minimum of equipment and facility adjustments. For all practical purposes, the screen should be in a fixed position away from direct light sources and from areas used more frequently, e.g., avoid if possible a screen location where a roll-down screen covers the chalkboard.

Under ideal conditions, the instructor should be able to push a button and insert into the lecture a film or slide for seconds or minutes as needed, with absolutely no mechanical distractions to the class.

Projection Screens*

The screen is most often the weakest link in using the projection systems. The efficiency with which the screen can transmit color brightness and contrast to the eye affects the ease with which the point being made can be understood by the student. Following are brief discussions of screen types and their suitability to classroom or laboratory applications:

1. ***Matte screens***

   Matte screens diffuse light evenly in all directions. Images on matte screens appear almost equally bright at any viewing angle. To avoid distortion because of viewing angle, however, viewers should be no more than about 30 degrees to the side of the projection axis, and not closer than two-image widths to the screen.

   Most matte screens are about 85% efficient. A metal finish matte screen will give valuable color correction to pictures where true rendition is important. A form of matte screen can be a smooth wall painted white, although it should be viewed critically before accepting it for classroom use.

2. ***Lenticular screens***

   These screens have a regular pattern of stripes, ribs, rectangles, or diamond shaped areas. The pattern is too small to see at viewing distances for which the screen is designed. The screen surface may appear to be enameled, pearlescent, granular metal, or smooth metal.

   By control of the shape of the reflection surfaces, the screen can reflect nearly all the light from the projector evenly over a fan shaped area 70 degrees wide and 20 degrees high. Many

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[10] This section is reprinted with permission from the publication *Modern Teaching Aids for College Chemistry* published by the Advisory Council on College Chemistry. The reader is referred to that publication for other useful discussion.

*Most of the information on screens was taken from Eastman Kodak publications.

lenticular screens provide an image three or four times as bright as a matte screen.

3. ***Beaded screens***

Beaded screens are useful in long narrow rooms or other locations where most viewers are near the projector beam. They are white surfaces with imbedded or attached small clear glass beads on silica chips. Most of the light reaching the beads is reflected back towards its source. Thus, a beaded screen provides a very bright image for viewers seated near the projector beam. As a viewer moves away from the beam, the image brightness decreases. At about 22 degrees from the projector beam, the image brightness on a beaded screen will be about the same as that on a matte screen. Beyond this angle it will be less bright than on the matte screen. Students should sit no closer than two and one half times the image width from a beaded screen.

4. ***Rear projection***

Rear-projection pictures have the same requirements for image brightness, size, and contrast as front-projected images. Rear projector screens are made of glass, plexiglass, or flexible plastics with one side of the screen a matte surface.

To reduce space requirements in rear projection, short focal length lenses sometimes are used. A single mirror between the projector and the rear screen is necessary; however large mirrors must be avoided. A special lens with a mirror encased and suitable for this purpose is available from Buhl Optics.

With most projectors, images as wide as 42 or 48 inches will be satisfactory on a dark rear projection screen in moderately lighted rooms. For larger images, a light screen in a darkened room is usually needed. In very brightly lighted rooms, images should usually be no more than 24 or 30 inches wide and the screen material dark.

5. ***Front vs. rear projection***

In considering which projection system is best for given conditions, two common arguments regarding both systems are discussed below.

Shortened projection distances are claimed as an advantage by proponents of each system. While this is true in both cases, a short projection distance often does not give the image sharpness and brightness desired. However, when space is at a premium, short projection distances may be necessary and the equipment can be made to perform adequately.

Visibility in lighted areas also is claimed as an advantage by proponents of both front and rear projection. Either system will do a good job, *depending upon conditions*. When a small image (up to 3 feet wide) is desired, a dark colored rear-projection screen may provide dramatically better image contrast and color saturation than a front-projection screen. Although a rear-projection screen reduces image brightness, the amount of room light reflected toward the audience is reduced by an even greater factor. The back of the screen must be shielded from stray light. Front-projection screens always must be shielded from direct light.

When a large image (wider than 3 feet) is desirable, front-projection systems using a lenticular screen usually give better results than rear-screen systems. Location and control of room lights are important factors to consider here. In any case, more care must be given to the orientation of the projector, screen, and audience than is necessary for a smaller rear-projected image.

6. ***Screen size***

This should be such that the back row of viewers is no more than six times the image width (W) from the screen, with the following exceptions:

a. Certain materials, including many teaching films, are designed with titles and important pictures bold enough to permit satisfactory viewing at distances of 8 to 10 times the image width. When this is true for the materials to be projected, the projector may be moved closer to the screen to give a smaller and brighter image. Moving the projector enough closer to change the back row from 6W to 8W will approximately double the image brightness and allow the front row to be moved a little nearer the screen.

b. In some situations, materials which limit maximum viewing distance to less than 6W are commonly used. Typewritten material projected with an overhead projector is an example. For showing the full area of an 8.5 by 11-inch page, pica type calls for a maximum viewing distance of 3W. The teacher should *critically* test this for his particular situation, perhaps by taking the poorest seat in the classroom.

A discussion of screen size with excellent solutions to common puzzles is available in Eastman Kodak publication *Effective Slides S-22,* and *Legibility Standards for Projected Material, S-4,* and in the ACS publication, *How to Make Slides.*

7. *Image brightness*

Required brightness (the amount of light the student sees) depends on viewing angle; screen type; projector design, wattage, life rating, and age of lamp; character of material being projected; image size; line of the optics. Lamp wattage alone gives little indication of image brightness,. Using wattage as a measure of image brightness is comparable to rating an engine by the fuel consumed rather than the work done.

The effectiveness of a projector, expressed as image brightness, is defined in terms of lumen output. Lumen output divided by image area (in square feet) gives the foot-candles falling on the screen from the projector. Foot-candles of illumination multiplied by the reflectance of the screen (about 0.85 for a good matte screen) gives in foot-lamberts, a measure of the brightness of the image seen by the viewer.

Thus, a projector with a 120-lumen output provides 10-foot-candles of illumination for a 3 by 4-foot (12 square foot) screen image; that is, 8.5 foot-lamberts of image brightness for the viewer of a good matte screen. With a projector light output of 80-100 lumens, and a matte screen in a well-darkened room, an image 3 or 4 feet wide can be viewed easily. As a rough estimate of the image brightness required, there should be as many foot-lamberts of light per square foot of screen as there are foot-candles of light in the room. For a more detailed discussion of image brightness see Eastman Kodak publication *S-14 What Can You Do With 100 Lumens?*

8. *Projector location*

Optimum projector locations depend upon a variety of factors including the lens and the screen size. Most manufacturers of projectors as well as lens suppliers (Buhl Optical Company) can provide a wide range of lenses for any type of projector. To decide on the lens needed for a given projector and situation, one should first determine the size of the screen to be used and then with the aid of a table such as Table IV-1, the correct focal length for the lens can be obtained.

Determining Projection Distance, Image Width, or Lens Focal Length*

To determine the projection distance for a desired image width (or the image width for a desired projection distance), find in the following table the factor that applies to the film format and lens you are using. Then position a straightedge on the nomograph so that the edge passes through the points for the two known figures; read the third figure at the point where the edge passes through the other scale. For greater accuracy, *add* the focal length of the lens to the projection distance determined for a desired image or *subtract* the focal length from the desired projection distance when determining the image width.

To determine the best lens focal length, position the straightedge so that it passes through the desired image width and projection distance. Now read the figure that is nearest to the point where the edge passes through the left-hand ("Factor") scale and then consult the table to find the lens with the factor nearest to this figure. If screen size is a limiting element in the projection situation, choose the lens with the next larger factor.

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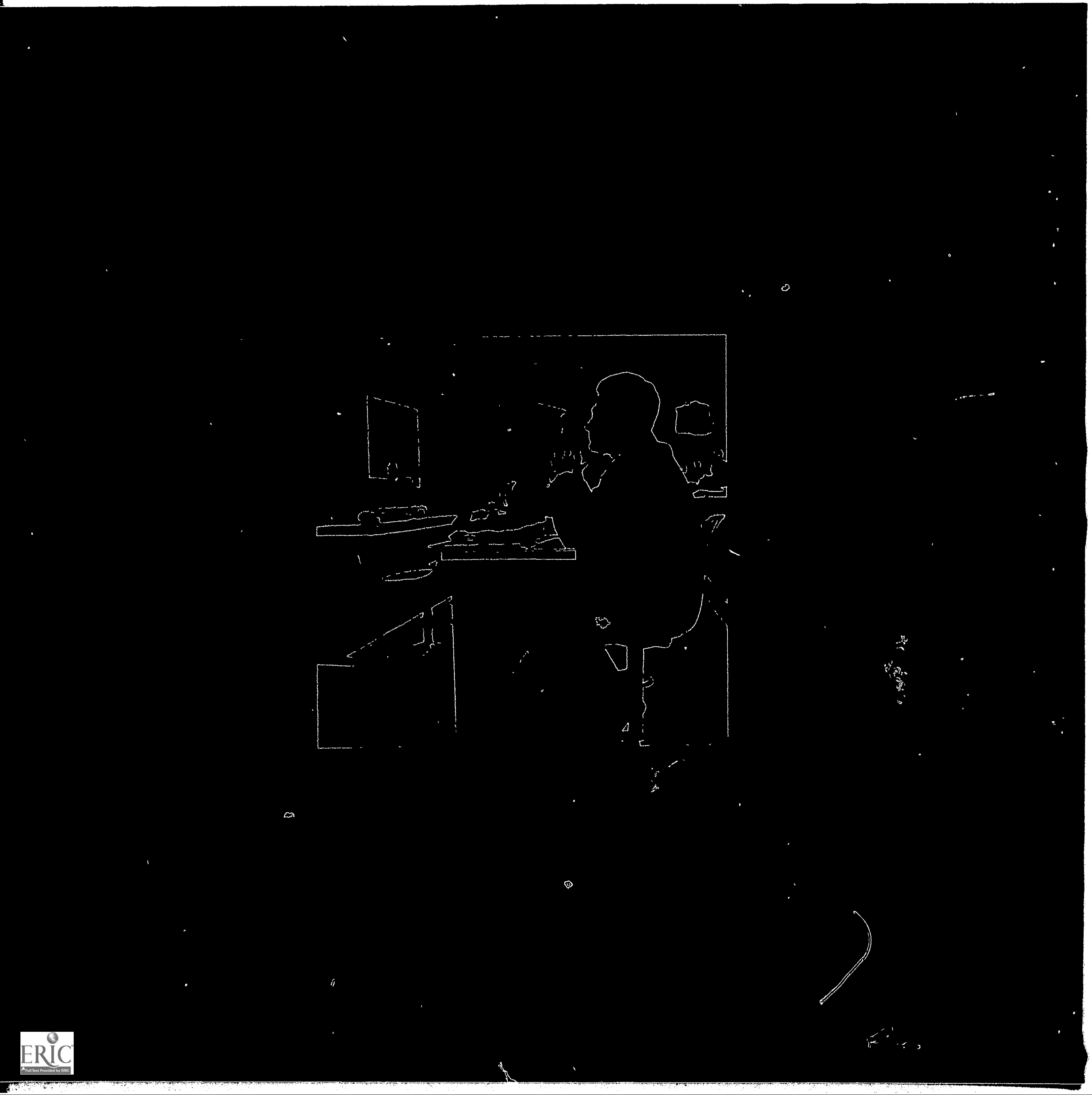
*Reproduced through permission of Eastman Kodak.

Type of Material	Lens Focal Length (Inches)	Factor
16mm Motion Pictures (0.284″ x 0.38″ projector mask)	1½	3.9
	1⅝	4.2
	2	5.3
	2½	6.6
	3	7.9
	4	10.5
Super 8 Motion Pictures (0.158″ x 0.211″ projector mask)	1.1 (28mm)	5.2
	Zoom (20-32mm)	3.7-6.0
8mm Motion Pictures (0.129″ x 0.172″ projector mask)	¾	4.4
	⅞ (22mm)	5.0
	Zoom (15-25mm)	3.4-5.7

Table IV-4

Part V Conclusions



Conclusions

The message we want this report to carry is twofold: (1) there is much for film to do in physics instruction; (2) the necessary technology is ready and waiting. Part II provides elaboration of the first of these themes and Parts III and IV support the second assertion.

The conferees suggested that, in addition to filmed demonstrations and films about physics and physicists, film be used to supplement the verbal presentation of definitions, to demonstrate models, and to present problems for solution. Looking beyond the classroom, they saw potential usefulness of film in laboratory, e.g., films which demonstrate the use of equipment and an occasional film which forms the experiment itself. But the widest use of film will come, we think, as instruction breaks away from the constraints of lecture and laboratory and becomes more flexible, as the emphasis shifts from teaching to learning. Then a full menu of visual physics from which students can choose or be served will have obvious importance.

In an effort to stir physicists to the production as well as the use of film, we have presented a summary of all the technical information which might conceivably be useful: a step-by-step description of the production of a short film by in-camera editing, insight into the assistance that can be given by a professional film studio, short articles on several of the special facets of film-making—titling, camera testing, etc.—and a brief but, we hope, helpful survey of equipment.

We hope, of course, that this Report, the ideas in it, the how-to-do-it sections, and the technical information will lead to an increased role for film in physics instruction. But neither the Conference participants nor the Commission on College Physics naively believes that a Report will by itself accomplish very much. Much more is needed and some of the next steps are already in sight.

The Visual Aids Committee of the AAPT, encouraged by a Conference resolution, has announced a Film Competition which will be held for the first time as a part of the 1968 Annual Joint Meeting of the AAPT-APS (Chicago, 29 January-1 February) and will, like the biennial apparatus competition, be a permanent part of these annual joint meetings. The description of this competition as it appeared in the CCP *Newsletter* #13 is as follows:

> **The competition will be open to any physics student or instructor who has not produced a film or films now in commercial distribution (a separate category may later be added for physicists who are experienced film makers). Prizes of $500, $300, and $100 will be awarded to first, second, and third place winners, respectively. Honorable mentions may be given for other films of merit.**
>
> **Films can be live or animated; the important considerations are that they be instructional in nature and "short." They should be single concept films in the sense that they are organized around a single phenomenon, idea, or theme in physics. The criteria for eligibility are that:**
>
> - **a. The film is not commercially available;**
> - **b. No commercial producers were involved in the production of the film;**
> - **c. The contestant regards the film as his own work;**
> - **d. The entry is submitted on 8mm film (any format) in reel or cartridge;**
> - **e. The film does not exceed five minutes;**
> - **f. Copies can be made available to interested physicists at a reasonable cost.**
>
> **Film notes will in general be helpful and will be considered as part of the entry. A maxi-**

mum of three entries per contestant will be permitted.

Entries will be judged primarily on content and pedagogy and secondarily on photographic technique. The films will be judged by a panel of three physicists, including one experienced film maker and at least one teaching physicist who has not made films.

The deadline for submission of films for the 1968 competition is January 10, 1968. Films may be submitted at any time and will be returned after the AAPT-APS meeting. Although the Committee will exercise due care in handling the entries, competitors are advised to keep at least one copy of any film submitted. Entries should be mailed to W. T. Joyner, Chairman of the AAPT Visual Aids Committee, Department of Physics, Hampden-Sydney College, Hampden-Sydney, Virginia.

The Commission on College Physics is particularly anxious to see pilot films made in some of the categories in which examples presently do not exist — laboratory instruction films, for example, or visual examination problems. We are willing to help with encouragement, advice, and even some support to see such films produced and look forward to hearing from those within the profession who would like to work with us on such projects.

We are also convinced that in the long run, no single filmed examples, no matter how good, will make significant in-roads against the inertia of established practice. We hope to work with some imaginative departments to develop pilot courses in which film plays a major role, for it will be only in such courses that the real usefulness of film can be assessed and from such courses that the necessary new film ideas will grow.

And, anticipating success, we must look even further ahead. If films for all the many purposes we have described in this Report suddenly become a part of physics instruction, we will need a much more flexible system of review, distribution and recognition than we now have. What incentive can we hold out to the physicist-film maker to make a good film which can be useful outside his own classes, and what help can we give to him if others ask for his film?

For the few excellent films of wide appeal, commercial film distributors will handle the problems and royalties will provide incentive and recognition. To be commercially attractive, however, a film must show promise of selling 250-300 prints per year.

At the other end of the scale will be the locally-produced film which is designed for a specific purpose and for which there may be five to ten requests per year. The physicist film maker himself can handle these requests if he follows the instruction on pages 26-29 and keeps a good print to have copies made from.

In between these extremes there is need for invention. What is needed is a "publication" system for films with all that the word "publication" implies: judgment of the film by one's peers, professional-level finishing of what may not be a completely finished film, and a means of making the film's existence known to prospective users and meeting their demands for it. If such a system can be established, then making a good film which is referred and accepted for publication can carry the same rewards and recognition as publishing a journal article. The CCP will work with the AAPT and other appropriate agencies to establish such a system.

Finally and importantly, the Commission recognizes the necessity (and the difficulties) of evaluation. There is urgent need for data on how films are being used at the present time in physics, for studies of the efficacy of learning through visual media as contrasted with more traditional means. We need to find out if there are within our prospective audiences students who are more easily reached and interested in this way. Because film making and, to a lesser extent, film viewing will for some time be considerably more expensive than writing and distributing books, any real surge forward into an age of accessible film must be built on the answers to these questions.

Appendix A Conference Agenda

Conference agenda

Wednesday, December 14		Holiday Inn
8:00 p.m.	Viewing of films	
Thursday, December 15		
Morning Session	Walter Eppenstein, RPI, Chairman	Experimental Classroom Library Building, RPI
9:00 a.m.	Welcome	Clayton Dohrenwald, Provost, RPI
9:10 a.m.	Introduction: The Uses of Single Concept Films in Education	John P. Vergis, Arizona State University
10:00 a.m.	Film-Centered Tutorial Instruction: The Purdue Botany Course	Joseph D. Novak, Purdue University
10:30 a.m.	Present and Potential Uses of Single Concept Films in Physics Instruction	*Panel:* Walter Eppenstein, RPI; Anthony P. French, MIT; Richard Hartzell, SUNY-Stony Brook; Fletcher Watson, Harvard University. Moderator: John M. Fowler, CCP
11:30 a.m.	Coffee Break	
11:45 a.m.	Film Making Equipment	Elwood Miller, Michigan State University
12:15 p.m.	The Making of Film Loops	
	1. Shoestring Operation	Wendell Slabaugh, Oregon State University
	2. Studio Production	Jacques Parent, National Film Board of Canada
1:30 p.m.	Lunch	Blue Room, Russell Sage Dining Hall
Afternoon Session	E. Leonard Jossem, Ohio State University, Chairman	Experimental Classroom
2:45 p.m.	New Techniques in Film Making	Shirley Clarke Wheaton Galentine
4:30 p.m.	Some Uses of Video Tape	Walter Eppenstein, RPI
5:00 p.m.	Computer-Animated Films	Edward E. Zajac, Polytechnic Institute of Brooklyn

5:30 p.m.	Discussion of Working Groups	John M. Fowler, CCP
6:00 p.m.	ADJOURN	
6:30 p.m.	Dinner	Blue Room, Russell Sage Dining Hall
8:00 p.m.	Film Viewing and Demonstration of Equipment	Rowland Laboratory, Room 2C25

Friday, December 16

9:00 a.m.	Working Sessions Meet	Rooms to be announced

Working Groups

1. Uses of Single Concept Films in Physics
   a. In-Class Use
   b. Laboratory
   c. Self-Instructional Uses
2. Film Making Techniques
3. Equipment

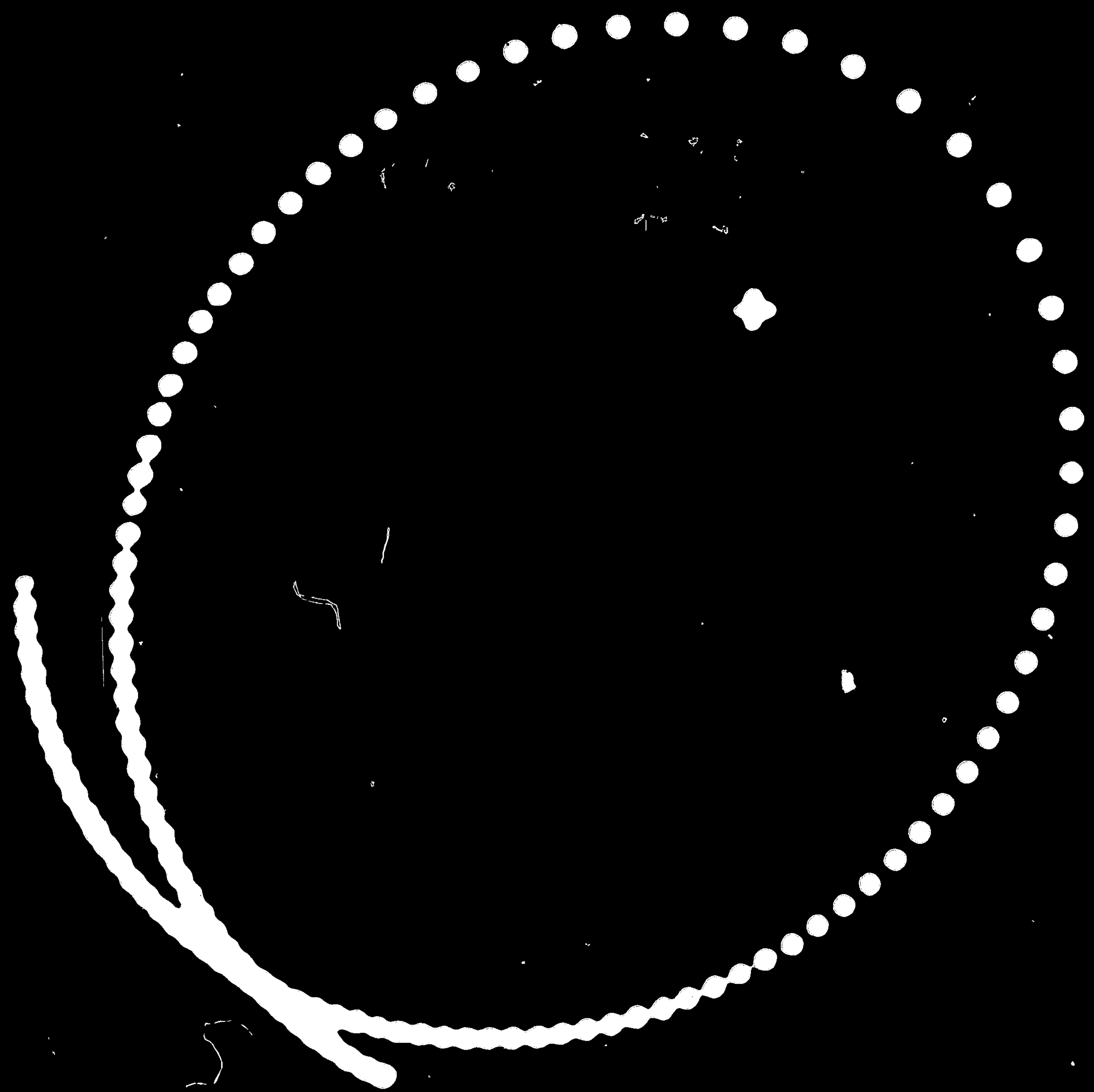
Distribution will be included in the Final Report, but will not be a full working session.

1:30 p.m.	Lunch	Blue Room, Russell Sage Dining Hall
5:00 p.m.	ADJOURN	
6:30 p.m.	Banquet	Holiday Inn
	After dinner remarks	Louis Forsdale, Columbia University
9:00 p.m.	Open House	Home of Dr. Robert Resnick 13 Oxford Road, Troy

Saturday, December 17

9:00 a.m.	Reports of Working Groups	
11:30 a.m.	Consideration of Final Report	
12:30 p.m.	ADJOURNMENT	

Appendix B Film Animation by Computer



Film Animation by Computer[1]

By feeding a cathode ray tube with data from a computer it becomes very easy to make animated motion pictures illustrating a mathematically complex sequence of events. The technique has great potential, in enabling research workers to visualize the results of computation and in preparing educational films.

Suppose you are teaching a course in celestial mechanics. You want to show the satellite orbits that would result if Newton's universal law of gravitation were other than an inverse square law. On a piece of paper you write:

```
DELT = 1.0
TFIN = 1000
EXP  = —3
CALL ORBIT (DELT, TFIN, EXP).
```

Then you take the paper to the computation centre. After a few hours, you return to pick up a movie, which you then show to the class.

In the movie the positions of the satellite and parent bodies are drawn on a frame of film every minute of their orbits (DELT = 1.0) for the first 1000 minutes (TFIN) = 1000). The satellite and parent body, obeying an inverse cube gravitational law (EXP = —3), start out in circular orbits. However, as you have shown in class mathematically, circular orbits for an inverse third power gravitational law are unstable. The 1000-frame (42-second) movie drives home the point; the students see the initial, almost perfectly circular orbits disintegrate, with the satellite making ever-closer swings about the parent body until the two bodies collide (Figure 1).

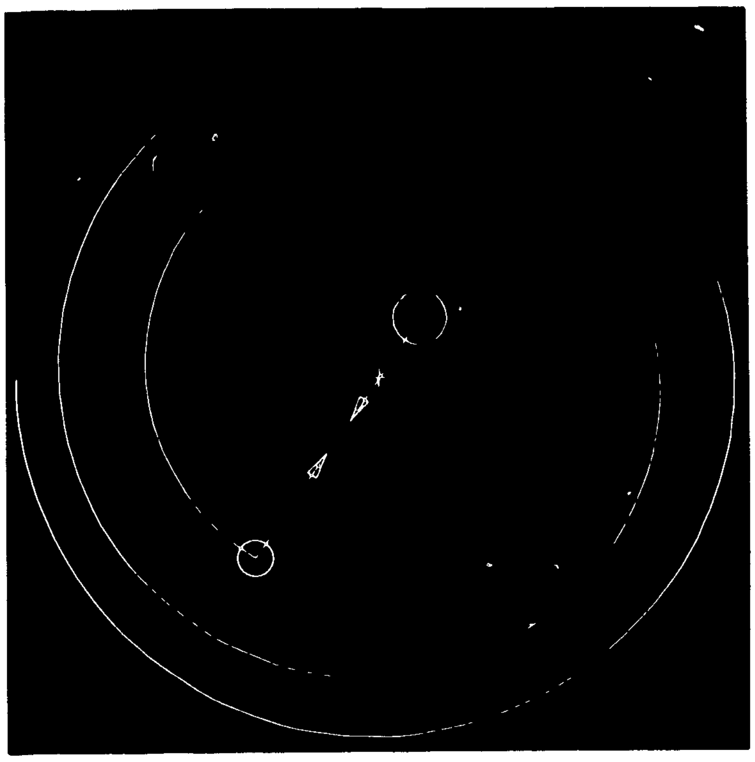


Figure 1

Two massive bodies interact according to an inverse cube law of force. The bodies either spiral in and collide, as shown, or spiral ever outward. From *Force, Mass and Motion.*

To those who have tried to make an animated scientific film by conventional means, this account may sound Utopian. Hand animation for a movie of this sort first requires the computation of the coordinates of the satellite for each frame of film. Then comes the tedious task of drawing and properly positioning the satellite 1000 times on celluloid "cels." Finally, the cels have to be individually photographed.

Yet, at the Bell Telephone Laboratories, I can today write the programme I have shown and obtain 16mm film, ready for viewing, within three or four hours. At present, there is only a handful of installations in the world where this procedure is possible. But within a few years, I suspect it will be available at most major universities and industrial laboratories in the United States and Western Europe.

---

[1] By E. E. Zajac, Bell Telephone Laboratories, Murray Hill, New Jersey. Reprinted from New Scientist, 29, 346-349, (February 10, 1966) with permission of the author and the publisher.

The cost of making the film, including computer time and processing, but not including my labour, would be about $30. However, this cost and the above description are deceiving, for they do not take into account the work of my colleague, F. W. Sinden, who constructed the "subprogramme" called ORBIT which computes the orbit and produces the film. To have a more balanced view, we have to consider how computer pictures are drawn and how subprogrammes such as ORBIT work.

The computer-driven cathode ray tube

Figures 2 and 3 are themselves computer drawn, to illustrate the picture-making process. The instructions or programme for the picture are fed into the computer, usually on punched cards (Figure 2). The computer then calculates numbers that specify the picture and the commands for film advances. These are read on to magnetic tape, shown in the bottom right of Figure 2. Next, the tape is rewound; it is then connected to a cathode ray tube and the film-advance mechanism of a camera (upper right, Figure 3). As the tape is run from its beginning, the numbers on the tape are translated into electron beam commands for the cathode ray tube; the picture appears on the face of the tube and is recorded on the camera film (the shutter is always open). When a frame is completed, a command from the tape to the camera causes the film to advance to the next frame. All this happens at electronic speeds, so that a film such as the celestial mechanics film described earlier might be made at the rate of 5 to 10 frames per second, or about one quarter of the rate of standard movie projection.

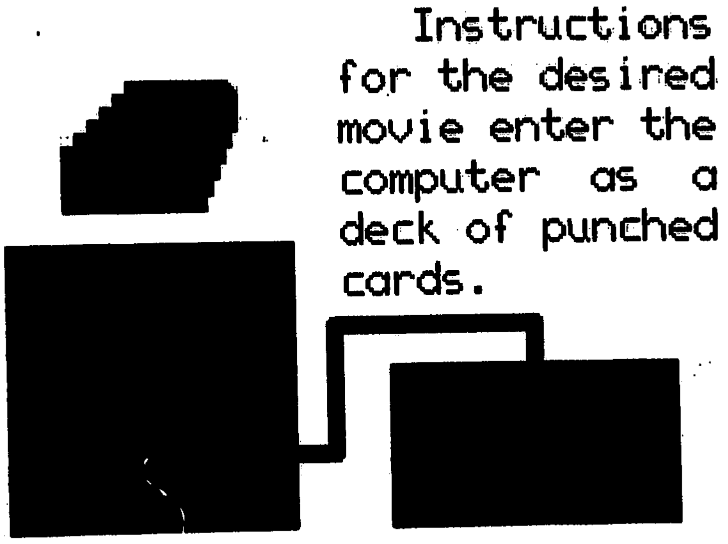


Figure 2

A programme on punched cards for a picture is fed into the computer. The computer writes the numbers representing the computed picture on to magnetic tape. From *A Computer Technique for the Production of Animated Movies*.

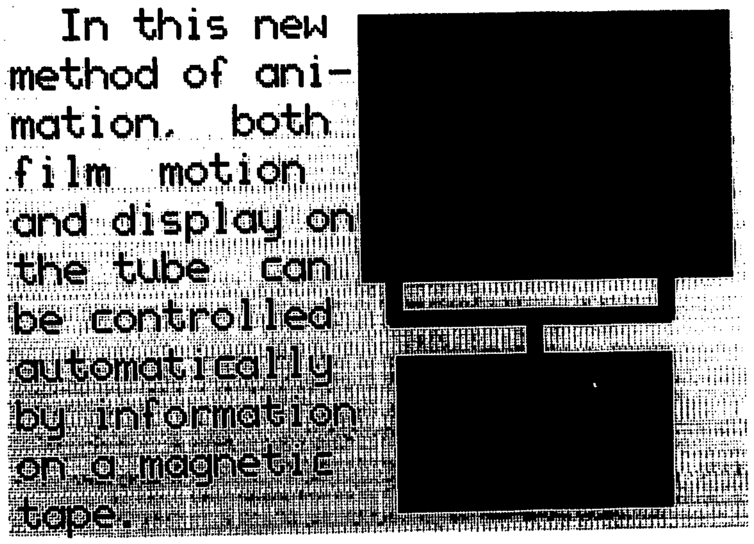


Figure 3

The computer picture is read from magnetic tape to drive a cathode ray tube and camera film advance mechanism. From *A Computer Technique for the Production of Animated Movies*.

Programming of computer animation

The cathode ray tube performs only two basic tasks: (1) it "types" a small font of standard-sized letters and (2) it sweeps a straight line segment between two specified points. (The description here pertains specifically to the SC-4020, a computer-driven cathode ray tube manufactured by the General Dynamics Corporation. However, other computer-driven cathode ray tubes work in a similar manner.)

Although these tasks are performed with high precision and reliability, they are in principle extremely simple. The advantages of computer animation do not lie with an elaborately versatile cathode ray tube. Rather, they lie with the power of a high-speed digital computer. Indeed, the special virtue of computer animation is that it brings the power of computing to the film medium.

To illustrate this power, let us consider how one builds a programme for an animated film, starting with the line-drawing ability of the cathode ray tube.

An example of the basic line drawing command is:

```
CALL LINE (-5, 3, 15, 22)
```

This command causes the electron beam to connect the point with horizontal coordinate X = -5 and vertical coordinate Y = 3 to the point with coordinates X = 15, Y = 22. The plotting area of the cathode ray tube is a square with X and Y ranging between -512 and + 512, giving more than one million reference points.

The above instruction is written in a standard scientific programming language called Fortran, although Fortran users will note that, in the interest of clarity, I have taken certain liberties with standard Fortran. A Fortran programme is actually executed in two passes through the computer. On the first pass, the symbolic Fortran instructions are translated into the basic numerical code of the computer; the output is a set of punched cards or a magnetic tape. In the second pass, this numerical code is read from the cards or tape and executed; the result is the final numerical output of the computer.

Fortran was written to allow symbol manipulation, akin to ordinary algebra (Fortran stands for "FORmula TRANslator"). For example, the two commands

```
Y = 5
CALL LINE (-15, Y, 30, Y)
```

will cause a horizontal line to be drawn from the point X = -15, Y = 5 to X = 30, Y = 5. Symbolic specification is convenient in the writing of "loops," for example

```
DO THRU*, I = 1, 100
Y = I
 *CALL LINE (-15, Y, 30, Y)
```

The first instruction signals the formation of the loop. It commands the computer to execute 100 times the instructions following, up to and including the instruction marked by the asterisk. Each time through the loop, the Y coordinate of the line is given the value of the counter, I. So on the 29th pass through the loop Y = 29, on the 30th pass Y = 30, and so on. In this example, 100 horizontal lines, spaced vertically one unit apart and lying between Y = 1 and Y = 100 would be drawn on a single frame of film.

Computer loops are tailor-made for animation. To illustrate, first introduce the instruction CALL FRAME. Fortran translates this into a command to the camera to advance the film by one frame. Insertion of CALL FRAME into the loop gives:

```
DO THRU* I = 1, 100
Y = I
CALL LINE (-15, Y, 30, Y)
*CALL FRAME
```

The result is animation. We get 100 frames of a movie showing the steady upward motion of a single horizontal line.

Even this simple four-instruction programme illustrates several points. First of all, note that a computer loop is not the same as a film loop. A film loop repeats the same sequence of events over and over. A computer loop repeats the same sequence of commands over and over. A command, such as Y = I, may call for a change from the previous passage through the loop. Thus, the event produced in each passage through the loop generally differs in a systematic way from the event produced in the previous passage.

Secondly, note the ease with which we can change the programme to produce a new animated sequence. Suppose we want the action to go only one-half as fast. We simply replace the command Y = I by Y = I/2, and the command DO THRU* I = 1,100 by DO THRU* I = 1,200. Or, we might decide that the line should extend from X = -5 to X = 50. This requires only that we change the LINE call to CALL LINE (-5, Y, 50, Y).

In fact we could allow for all of these changes at once by using symbols. The addition of an instruction, READ, allows us to specify particular values at the time of running. The complete programme then looks like this:

```
READ, SPEED, X1, X2
DO THRU* I = 1,100 X SPEED
Y = I/SPEED
CALL LINE (X1, Y, X2, Y)
*CALL FRAME
STOP
3, 10, 72
```

The READ instruction says to the computer, "When the card containing STOP has been reached, all instructions in this programme will have been loaded in. Look for numbers on the next card. Set SPEED equal to the first number, X1 to the second number, and X2 to the third number. Then execute the programme."

For each particular set of values of SPEED, X1, X2, we get a different film. This illustrates another point of great importance; a successful programme generates more than a single film; it makes possible a whole family of films. The family is a function of several variables just as in mathematics a family of curves can be a function of several variables. For each particular choice of values, a new film results. Different choices may give films that do not even resemble each other. Thus, in the celestial mechanics example, a single programme using the Newtonian law of gravitational force yields movies of circular, elliptical, parabolic and hyperbolic orbits, depending on the initial conditions.

Modern computing allows still another freedom. We can make our programme into subprogramme. First, we decide on a name. In Fortran, we are limited to names of six symbols. We pick HRZLIN (standing for horizontal line). Then we modify the previous programme as follows:

```
SUBROUTINE HRZLIN (SPEED, X1, X2)
DO THRU*I = 1,100 X SPEED
Y = I/SPEED
CALL LINE (X1, Y, XW2, Y)
*CALL FRAME
```

This programme is stored in the computer or on cards once and for all. If in some film in the future, we decide we want to show an ascending horizontal line, we would write:

```
READ, SPEED, X1, X2
CALL HRZLIN (SPEED, X1, X2)
STOP
2, 5, 50
```

If we did not want to experiment with several different SPEEDs, X1s and X2s, but rather knew that these variables should have the values 2, 5, and 50, the programme would be shorter still:

```
CALL HRZLIN (2, 5, 50)
```

This illustrates the powerful "naming" or subroutine capability of programming. By this means we can build up a library of programmes as we go along. This library differs markedly from the usual film library. Each entry represents a family of films rather than a single film. Each entry probably embodies loops. But these are computer loops, not film loops.

The reader can now perhaps understand the celestial mechanics example given at the outset. Having F. W. Sinden's general programme, ORBIT, for producing a family of orbit films as a function of the relevant variables, it is simply a matter of writing the instruction CALL ORBIT and specifying values to obtain the particular orbit film desired.

Applications of computer animation

Computer results usually emerge in the form of numbers printed on paper, sometimes hundreds of thousands of numbers per sheet on hundreds of thousands of sheets of paper. With computer animation one can translate the numbers into a series of pictures which can be scanned in succession as a movie. Figure 4 is a frame from such a movie. In this case, I was studying, by digital computer simula-

Figure 4

Box representing a satellite changes attitude according to a mathematical model of the Earth's gravity. Clock counts off orbits. From *Simulation of a Two-Gyro, Gravity-Gradient Attitude Control System.*

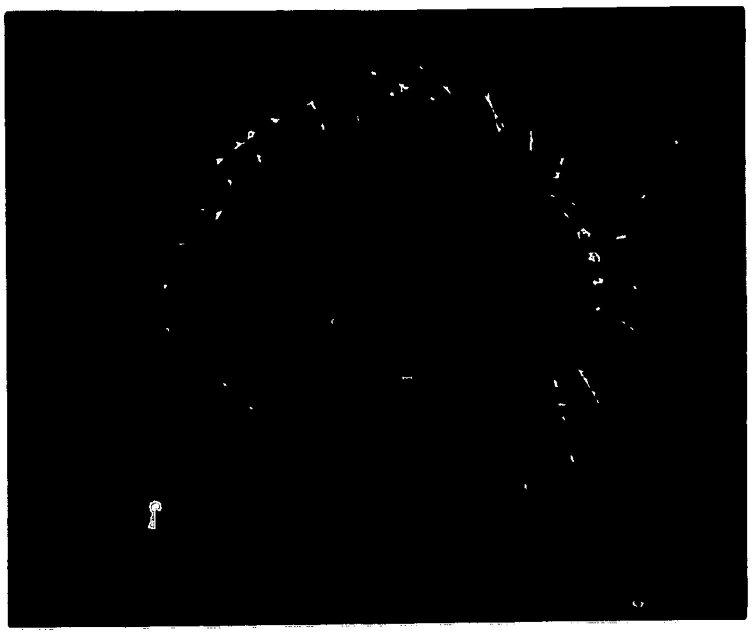


Figure 5

Superposition of every fifth frame during one orbit from Simulation of a *Two-Gyro, Gravity-Gradient Attitude Control System.*

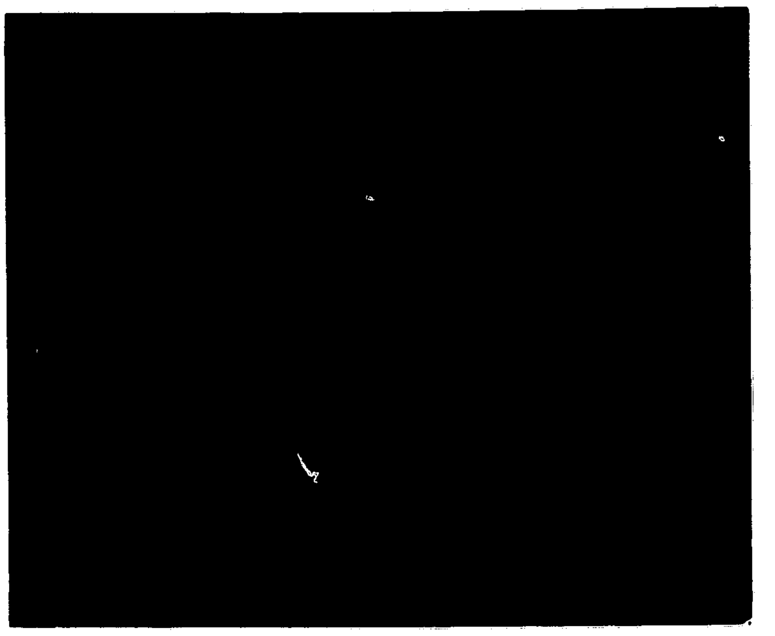


Figure 6

Satellite as seen in an orbiting reference frame. From *Simulation of a Two-Gyro, Gravity-Gradient Attitude Control System.*

tion, the orientation control of a satellite. At first, I had the computer print out numbers giving the satellite orientation at successive instants of time. The problem of visualizing the satellite motions from the printed numbers was formidable. So I wrote a subprogramme which took the numbers that would normally be printed out and used them to compute a perspective drawing of a box representing a satellite. Figure 5 shows the superposition of every fifth frame of the movie for the first satellite orbit (in the movie itself the Earth turns). An orbital clock in the upper right-hand corner counts off orbits.

In the programme it is easy to change the point of view of the perspective. In Figure 6, also taken from the movie, the viewer is travelling in orbit with the satellite.

Most of the applications of computer animation so far have been of this sort—usually short sequences visually displaying the results of a scientific computation. Examples are:

A movie of successive iterates of an iteration procedure for solving an optimization problem (Bell Telephone Laboratories; Sandia Corporation).

Flow of a viscous fluid, including the formation of a von Karman vortex street (Los Alamos).

Propagation of shock waves in a solid (Los Alamos; Lawrence Radiation Laboratory, Livermore, California).

Lines of constant pressure, temperature, precipitation, etc. in a dynamic meteorological model of the Earth's weather (Lawrence Radiation Laboratory)

Vibration of an aircraft (Boeing Aircraft)

Simulation of an aircraft carrier landing (Boeing Aircraft)

Most of the animation has been in black and white; however, the movies at the Lawrence Radiation Laboratory have been in colour.

The possibilities of the use of computer animation in this way as an output means for standard computing are limitless. Indeed, one can argue that graphical output is "natural," and the usual numerical computer output is woefully inefficient. The human eye has great pattern recognition ability; for this very reason the usual first step in handling scientific data is to plot it. The human eye also quickly picks out a moving object from a static background. Movies allow one to take advantage of this ability by adding the dimension of time to the familiar spatial dimensions in studying computer output.

Moreover, many of the calculations done on a computer are of essentially dynamic phenomena. One wants to see the unfolding or evolution of a process either as a function of time or of some other variable. Motion pictures are the obvious way of accomplishing this.

Finally, as the sample frames of Figures 4-6 show, it is easy to make perspective views of solid objects. It is likewise easy to make two perspectives side by side, that is, to make stereographic movies. This line of research has been pursued by A. M. Noll of the Bell Telephone Laboratories. Among other things, he has made a movie of a four-dimensional cube rotating about one of its axes, as seen when projected into three dimensions.

Educational use of computer animation

The use of computer animation for the display of the results of scientific computations is a form of education—one scientist passing information to another. It suggests the use of computer animation for the classroom.

One immediately thinks of a whole host of phenomena and concepts that uniquely lend themselves to illustration by computer movies. The idea of a "limit" in the calculus, for example, is essentially a dynamic one, as the standard terminology suggests —"f(X) approaches f(Xa) as X-Xa approaches zero." Other examples are Newton's laws of motion, kinetic theory in physics and chemistry, fluid flow in engineering—in fact, one can argue that a good deal of the instruction in the physical sciences is in terms of "movies" of mathematical models of nature—except that the student does not normally see the movies; he only hears verbal descriptions of them.

Perhaps more important is the opportunity computer animation gives to the scientist and engineer to make his own movies. As our examples have shown, the user programmes computer animation in the language of mathematics, a language in which the physical scientist or engineer is proficient. Moreover, the scientist can make films with a minimum of dependence on directors, producers, and animators. Much as in writing a book, where one submits a manuscript and receives back a proof in print ready for reading, so can one now submit a programme and receive back a proof film, ready for viewing. The scientist can be master of his own house; if he wishes, he can maintain complete creative control over the film he makes.

One might expect the professional science film-maker to feel threatened by this development. Paradoxically, the opposite has been the case with the few film-makers who have had a chance to try computer animation and to appreciate its flexibility and power. One professional animator told me that he has always been envious of composers. All a composer needed was a piano to try out his latest creation. The animator on the other hand could only with great labour try out his ideas. For example, if the action were too fast, cels would have to be redrawn and the scene laboriously rephotographed. In computer animation, such things as speed can be left as a variable. The film-maker has much more freedom to experiment. He is free to bring his full artistic abilities to bear in his partnership with scientists in film-making.

One of the few purely educational computer animated films is *Force, Mass and Motion,* by F. W. Sinden of the Bell Telephone Laboratories. The film illustrates Newton's laws in two dimensions. Orbits are shown of two massive bodies under central force action for various laws, such as inverse cube, direct cube, etc., as well as for the familiar inverse square law. Figure 1 and Figures 7 and 8 are frames from Sinden's movie.

Another educational movie by Roger N. Shepard and the author is entitled *A Pair of Paradoxes.* It combines two psychological phenomena discovered recently. One, due to L. S. and R. Penrose of the University of London, is a winding stair case that seems to go ever upward while at the same time closing upon itself after each circuit. The other, due to Shepard, is a tone that seems to go ever upward while at the same time remaining near the middle of the scale. Figure 9 is a frame from this movie.

The future

It is now several years since films were first animated by computer (some computer films are known to have been made on the Whirlwind computer at MIT in 1951). However, they have made relatively little impact, especially in science education where their prospects are perhaps brightest. Probably the reason is the lack of a suitable champion. As I have indicated above, most of the development has been in industrial laboratories, where the interest has been

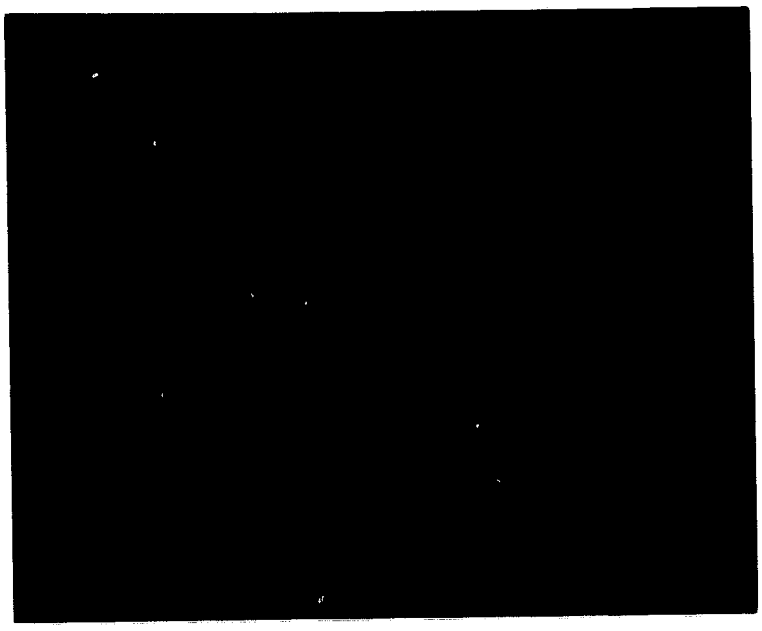


Figure 7

Orbits of bodies with inverse square law interaction. The plus sign is the moving centre of mass. From *Force, Mass and Motion*

Figure 8

Orbits of two bodies with a direct cube force law of interaction. From *Force, Mass and Motion.*

in straightforward technical applications as a computer output device. Very little work has been done at universities, and that which has been done has also been aimed at scientific rather than educational research.

To exploit the full educational potential of computer animation will require the partnership of three specialties: computing, film-making, and the subject-matter science or technology about which a film is to be made. A central facility where these skills could comes together would give the educational uses of computers a great push forward. So far no such facility exists.

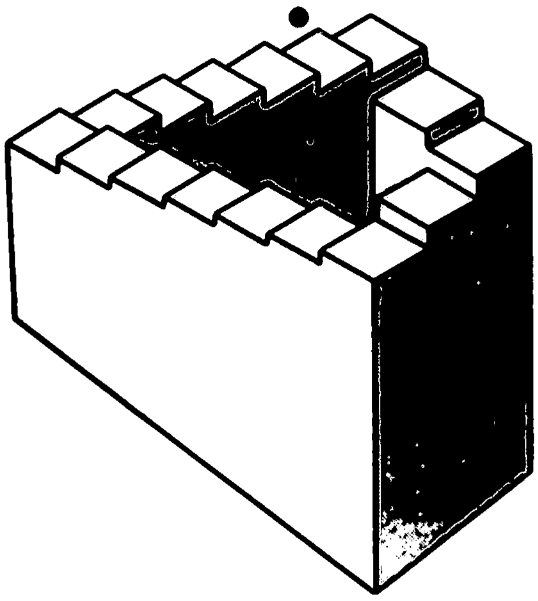


Figure 9

Ball bouncing along an impossible staircase. From *A Pair of Paradoxes,* which combines the Penrose and Penrose visual illusion with the auditory illusion of R. N. Shepard.

Another need is for higher-level computer languages. We have already seen an example of a computer language in Fortran, which allowed us to write formulas to programme in terms of symbols rather than numbers, and to name sequences of instructions as subprogrammes.

Recently, a great deal of activity has gone into improving on Fortran, especially in the mechanism for naming. In particular, computer languages in certain specialties have been written. These contain, built into the language, names for the concepts and operations peculiar to that specialty. Such a language for movie-making would be very useful. It would contain convenient ways of specifying and moving objects mathematically and ways of projecting the object into a picture plane; it would allow the programmer to imagine himself as a cameraman with commands for panning, zooming in or out, dissolving, fading, etc.

A big first step in the direction of a universal movie language has already been made. K. C. Knowlton of the Bell Telephone Laboratories has written a language for movie making called BEFLIX which allows one to do many of the things mentioned. Figures 2 and 3 illustrating computer animation are taken from a 17-minute movie made in BEFLIX entitled *A Computer Technique for the Production of*

Animated Movies. The instructions BEFLIX look quite different from those in Fortran. An example is:

PAINT, A, B, WRITE, 2

which says: "Paint the rectangular area specified by the opposite diagonal points A and B. First erase what is now in this area and then write in 2s." By filling rectangular areas of the screen with various alphabetical and numerical characters, Knowlton generates the different textures of grey shown in Figures 2 and 3. Unlike the satellite and orbit examples of Figure 1 and Figures 4-6, each frame of which was a line drawing, a frame of a film in BEFLIX is completely filled with varying shades of grey. Thus, BEFLIX is more akin to the scanning technique of television. BEFLIX can be easily learned in a few weeks by persons with no knowledge of mathematics or computing.

Special-purpose computer languages are attempts to make easier the specifications of image inputs to the computer. Another recent development in this direction is the light pen, the stylus-like device that allows one to draw computer-recognizable pictures on the face of a cathode ray tube. The combination of the light pen and special-purpose languages is perhaps the ultimate in a graphical man-machine communication system—one which is still in its infancy. The future for computer animation is, in my opinion, very bright. It is, however, too early to tell exactly what its impact will be, especially in science education. Here, the computer does best the animation that is couched in mathematics—precisely the animation that is hardest to do by hand. So hard, in fact, that only a few examples of it have been tried in the classroom. We therefore have little experience with which to predict the future.

But all those who have tried computer animation so far are excited by its possibilities, I think their expectations will be more than fulfilled.

Author's note

Some of the films mentioned are available on loan from the Technical Information Library, Bell Telephone Laboratories, Murray Hill, New Jersey, USA. These are all 16mm films:

Simulation of a Two-Gyro, Gravity-Gradient Attitude Control System (4 min., sound)

Force, Mass and Motion (10 min., sound)

A Pair of Paradoxes (2 min., sound)

A Computer Technique for the Production of Animated Movies (17 min., silent)

Appendix C Producing a Film

THE STORYBOARD

"Storyboard" is the general term used to designate a sequenced collection of annotated sketches, each representing a scene in a proposed film. The sketches may be treated in a variety of ways. Some may be roughly done, several on a sheet of paper, while others may be more carefully drawn, each scene on a specially designed card or page.

Although the pages or cards may be loosely assembled in book or pack form, they are best arranged in sequenced rows in a specially designed board (see Figure 1). In this way, they more nearly approach the visual continuity they will assume on a screen.

Below is the storyboard for the film *Two Fluids in a Box* made under simulated local conditions by Kevin Smith, Executive Producer of Education Development Center's Film Studio. The equipment used is described in his article on pages 26-29. The drawings are Mr. Smith's; the text, which was originally hand printed, has been typed for clarity. The drawings represent positions of the objects in the demonstration at relatively specific moments and provide a guide to the demonstrator as he runs through his demonstration during filming. Note that both descriptions and time limits for each scene are specific.

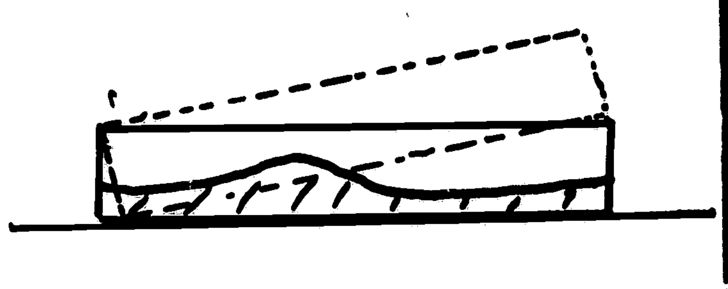
1

TWO FLUIDS IN A BOX
Density differ by 3%

Opening title: Black on white

Time: 8 seconds

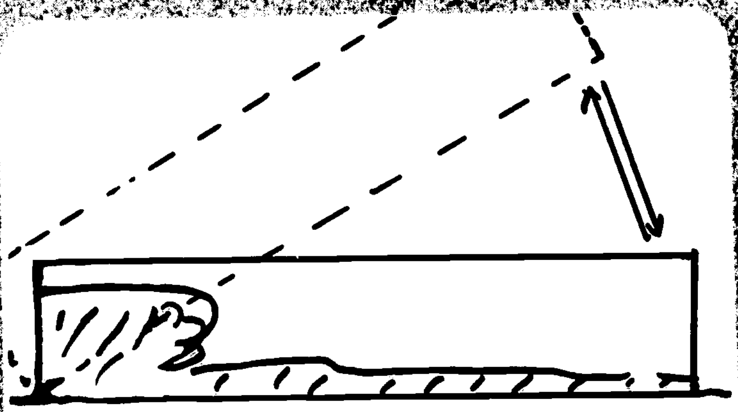
2



Description: Hand enters R. Lifts one end of tank creating gentle wave--lowers tank. Hold for observation.

Time: 22 seconds

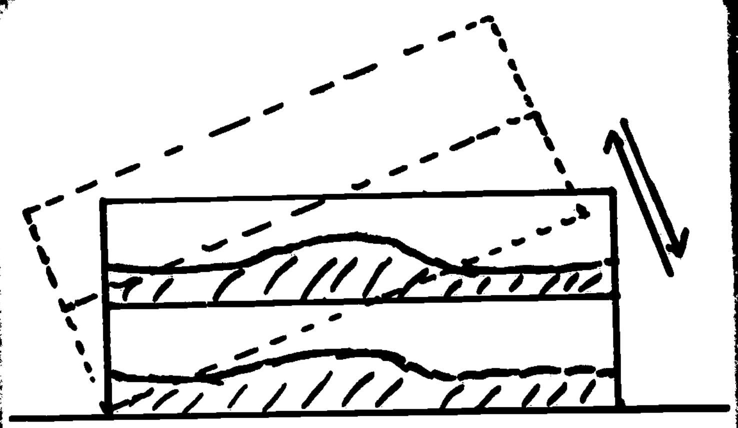
3



Description: Hold full screen. Action same as #2 except larger to create turbulence.

Time: 20 seconds

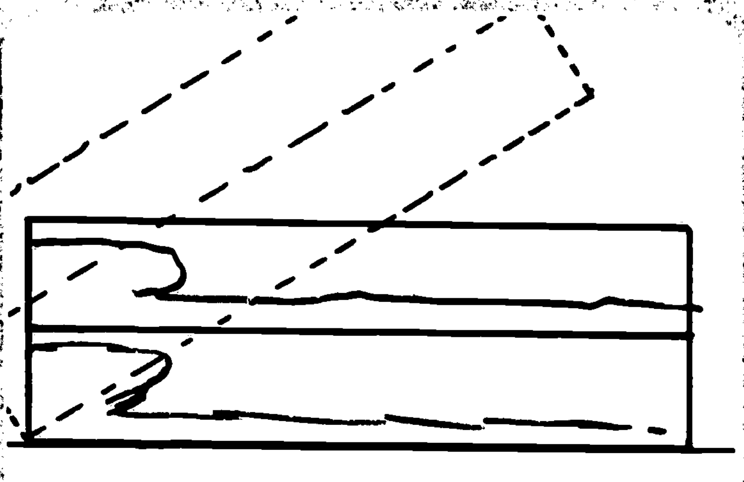
4



Description: Action same as #2. (non-turbulent). Note: fasten tanks together with double-face tape.

Time: 25 seconds

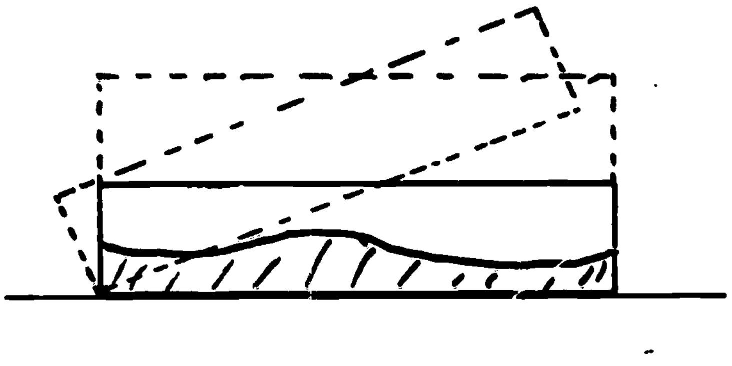
5



Description: same as shot #3.

Time: 23 seconds

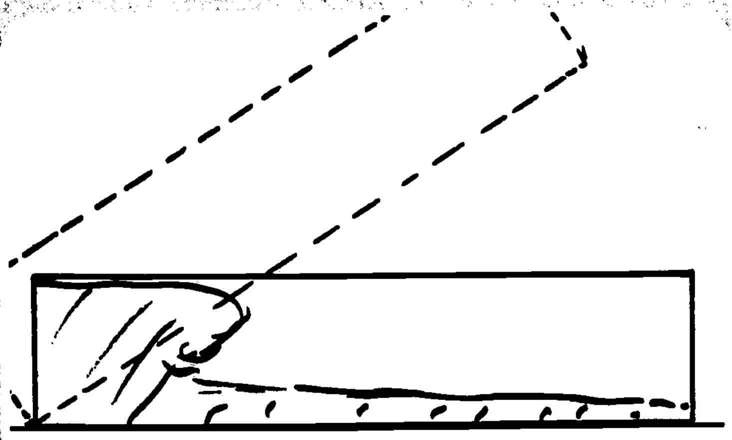
6



Description: Hand from R. lifts top tank, places it behind bottom tank--

Lift and lower to make non-turbulent wave. Zoom to fill frame (hold tanks firmly with both hands. Time: 30 seconds.

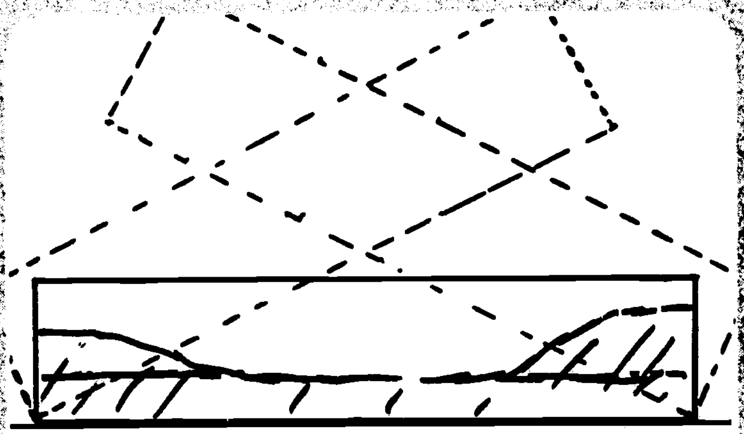
7



Description: Hold full frame--lift and lower for turbulent wave; tanks side by side as in shot #6.

Time: 20 seconds

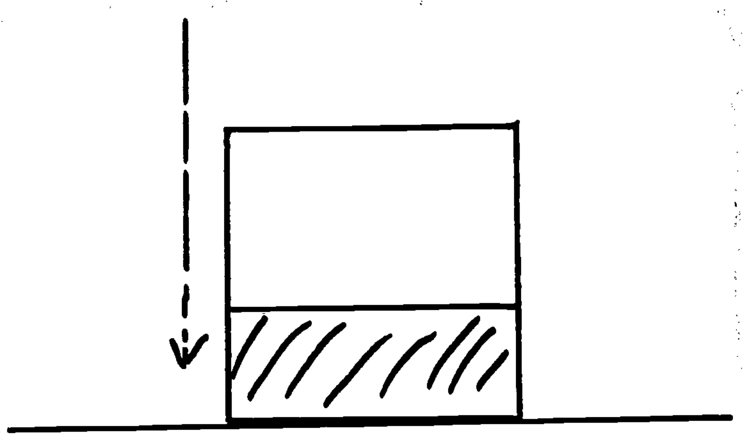
8



Description: Lift opposite ends equal distances and lower--semi-turbulent. Note: This requires two people. Rehearse.

Time: 22 seconds

9



Description: Start camera after tank is lowered from a very high tilt. (Remove hands before camera starts). Use +2 lens adapter for close up.

Time: 25 seconds

10

THE END

Run out film.

Total run: 200 seconds

PROCEDURE FOR TESTING CAMERA

1. Slate film: Name of camera, etc. (2 sec.)
2. Place tripod about 25 feet from a brick wall. Be sure camera is level. With zoom in full telephoto position, focus on bricks. (Shoot 5 sec.)
3. Set zoom at midway point (13mm). (Shoot 5 sec.)
4. Set zoom at full wide angle position. (Shoot 5 sec.)
5. Hang up sheet of newspaper in shaded area. Move camera to closest focussing distance. Be sure camera is level. Check footage scale. With zoom in full telephoto position, mark corners of viewfinder area on newspaper. (5 sec.)
6. Set zoom at midway point (13mm). Mark corners. (5 sec.)
7. Set zoom at full wide angle. Mark corners. (5 sec.)
8. From #7, position zoom to telephoto position keeping center of newspaper centered.
9. Find a scene that progresses from deep shade to full sunlight. Set zoom on 13mm. Very slowly pan from shade to sunlight and back again. (15 sec.)

   In this test, if possible, find shade that is dark enough to move viewfinder needle to the underexposure reminder and sunlight bright enough to move it to the overexposure reminder.

10. Perform same operations in 5 sec.
11. If camera's exposure meter as viewed in viewfinder indicates iris f stops, check these against a hand meter.
12. With sun at your back find a spot from which you get a well-lighted view of a building, for example. Set zoom at wide angle. Slowly pan from left to right. This should take at least 15 seconds.
13. From the same shooting position frame an interesting part of the building with zoom set at full telephoto. Do not pan. (Shoot 5 sec.)
14. Move camera toward building and shoot series of 5 close-up details. (Average time: 5 seconds)
15. With camera close to building, set zoom at full wide angle position. Aim upward and slowly pan down to level position. Allow at least 10 seconds.
16. Pan upward and at the same time slowly zoom to full telephoto position.
17. Move indoors. Tape or pin sheet of colored construction paper to a vertical surface. Light it evenly with two photofloods. Place camera at closest focussing distance. Set zoom so viewfinder and paper edge coincide. (Shoot 3 sec.) Do not move camera.
18. Pin a small contrasting geometric figure to paper. (Shoot 3 sec.) Repeat this with four other figures of varying colors.
19. Repeat the above using the single frame setting. Vary the number of frames for each interval.
20. With rest of film practice pan, following moving figures.

SHOOTING NOTES

1. ***Focussing eyepieces:***

   If camera has adjustable eye lens, be sure it is producing a sharp image at infinity.

2. ***Close-up shooting:***

   Do close-up work (about 5 feet or less) only with those cameras that frame reasonably well and remain sharply in focus.

3. ***Panning and tilting:***

   Do not pan or tilt unless absolutely necessary to follow action or to move a relatively short distance.

4. ***Size of image:***

   Due to the inherent physical weakness of 8mm film (a low definition medium), fine detail is often lost. Therefore, films will be more successful if the material is large and relatively free from fine printing, small detail in infinity shots, etc.

5. ***Lettering:***
   a. Style: In general all lettering should be bold gothic (Lower case letters, due to the patterns caused by the heights, are more legible than all upper case letters).
   b. Height: They should be about vertical image height.
   c. Spacing: Distance between letters should be optically measured. This means that spacing will vary from letter to letter. Think of the spaces as representing total special areas that must be equated. Spaces between words should be about one letter wide. Spaces between lines should be no more than the height of a line of letters.
   d. Contrast: Black letters on pastel colored backgrounds give good results. Paper color should not be too dark or white or almost white. The latter may work with manual control cameras but may turn gray when filmed by some of the automatic exposure types. Black on yellow generally produces acceptable results.

Verbal material should appear on the screen twice as long as it takes an average reader to read it. This can be reduced in loop films to the actual reading time.

The motion picture camera's ability to make things magically appear and disappear works to advantage in calling attention to important items. Letters and words can be made to appear serially, to "flash" on and off, to change color, or to move over the image surface via animation. Effects can be precisely timed by counting the number of single frame shots per projection second.

Conventional shooting technique establishes the environment of any specific action through the use of a long, medium, and close-up shot. The zoom lens can tie these three into a smooth, unbroken sequence, thereby permitting the viewer to maintain a continuous orientation with the action. This often is necessary in instructional skill films. For example, conventional filming may show a medium shot of a projector and then cut to a close-up of its sound drum. Only knowledgeable viewers may be able to relate the two.

If the camera has no zoom, a high degree of orientation can still be maintained by matching action directed toward a point of interest. For example, returning to the medium shot of the projector, it is desirable to cut to the sound drum but before that is done, point to the sound drum, and then cut to the close-up of the fingers indicating the drum. If the action is matched reasonably well, most viewers will make the transition without difficulty.

6. ***Exposure:***

   If there is difficulty in measuring reflected light from a variety of light and dark objects, learn to use a gray card. Place it over the material to [illegible] photographed and take your readings from it.

TITLING AND ANIMATION[1]

Titling

Well-planned, informative titles are essential to a good educational film. Because they differ so distinctly from the frame-by-frame progression of the action, titles can serve to emphasize segments of a film. They can reduce filming time by explaining preliminaries or providing specifications not shown directly and they can help avoid misinterpretation of the action. More obviously, titles are used for credits on a finished film and for presenting the subject of the film.

The film maker must choose the wording for his titles and their positions in the film carefully. This is particularly true in a short film of the 8mm cartridged variety, where action is relatively compact and filming time scarce. After having decided how many titles he wishes to incorporate into his film and where they should appear, the film maker can begin to write. The title should be concise, clear, and should convey information to the viewer which enhances his understanding of the action. Titles can convey, for instance, a mathematical or physical relationship, identify equipment or phenomena, provide background information, or alert the viewer to an aspect or aspects of the action in scenes past or to come. Before decid-

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[1] Much of the information for this section was provided by the booklet, *Basic Titling and Animation,* published by Eastman Kodak. The entire booklet, which provides much more detailed information on both aspects of filming, is available from photographic supply stores or from Eastman Kodak for $1.00.

ing on a title, the film maker should read it aloud or flash it before a colleague. Words and phrases often have different connotations to different people.

Titles must be carefully lettered. The eye responds much more favorably to artistic presentation than to makeshift, haphazard work. Hand-lettered titles can be effective, but they require extreme skill and patience and are therefore best left to the experts, which makes them an expensive undertaking. The physicist interested in doing his own titling work would do best to use one of a number of lettering systems described below:

1. Hand-set type, such as Fototype, is available in most art supply stores. It can be placed against a suitable background and photographed with fine grain positive film from which either a positive or negative intermediate can then be made. The intermediate can be enlarged as desired.
2. Hand-lettering systems are available which work by a number of methods—stencil tracing, either directly through a stencil,[2] or using a template with tracing arm,[3] gummed letters,[4] or three-dimensional letters in several styles and sizes.[5] The plastic letters sold at bookstores for name plates can also be used. They come as a strip of injection moldings; the letters are easily separable and can be cemented with acetone to any smooth surface. Any of these hand-set titles can be mounted on glass and superimposed on a scene to reduce the time required to present scene and title. Finally, ordinary typewriter type blackened with a bold pen will provide sufficient, although less professional-looking, titles.

Some thought should go into the color of both letters and background. Generally dark letters on light backing photograph best, although there are obviously exceptions. To avoid visual monotony, the background can be varied by using textured paper, material, or simple borders or ornaments. If three-dimensional letters are used, titles can be filmed from a slight angle or colored lights may be used to achieve decorative effects.

When laying the title out for photographing, the film maker should use title cards large enough to work on conveniently, yet small enough too for easy storage —10″ x 12″ is a satisfactory size for most purposes. Care should be taken to allow for the dimensions of the 8mm frame when projected.[6] Letters themselves should be proportional in size to the height of the screen: as a rule, the smallest letters on the title card should measure 1/25th of the total projected height.

The filming of titles follows most rules for close-up photography. The surface must be evenly illuminated and lighting must be of a proper color temperature if the filming is done in color. The title can be shot either horizontally by positioning the card between the legs of the tripod (see page 28) or vertically by photographing cards positioned on a wall.

In either case, lights should be carefully positioned; exposure can be determined with an incident-light meter held at the plane of the title and facing the camera. The most troublesome part of filming the title is proper centering and framing. The title must be centered accurately to avoid causing the title to appear off-center.[7] For this a focusing alignment gauge, or "rackover," is available for cameras without reflex viewing. The gauge shifts the camera so that the viewfinder is in the lens position while setting up and framing the shot. The setting of the camera should be tested before final title shots are made.

Animation

Animation is a means of creating an illusion of motion by photographing a series of still pictures in succession. Like the frames of a motion picture, each sequence is a slight variation of the one preceding; when projected in rapid succession, the film seemingly recreates the motion of the object filmed. This is the result of persistence of vision which causes the eye to retain for a brief instant each image presented to it, and to fuse each image with the one preceding, creating the illusion of motion.

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[2] Wrico Lettering Systems

[3] LeRoy Lettering System or the Varigraph System

[4] Art Type

[5] Mitten's Title Letters

[6] Templates marked with projection areas for slides, T.V. and film are available for $1.00 from Eastman Kodak.

[7] Often the fact that projectors and cameras do not have identical edge guiding makes a title appear off-center when projected. Film also tends to shrink with age which causes the title to move off-center.

The advantages of animation over live action in instructional films may be briefly summarized as follows:[8]

1. Animated sequences can treat specific points that require special analysis or clarification;
2. A moving diagram can be superimposed on an actual image allowing the film maker to simplify and analyze working principles not at all clear in the filmed presentation;
3. Animation allows sectionalizing of a complex moving process; layer after layer of the total image can be stripped down so that the whole can clearly be seen to be the sum of the parts;
4. Aesthetically, animated sequences can introduce a variety of graphic styles and presentations to illuminate physical principles;
5. Animation can more flexibly and conveniently reduce or increase the speed of a process being demonstrated—important elements can be presented emphatically in slow motion while unimportant events can be speeded up or merely flashed by.
6. Animation allows the film maker to rotate a three-dimensional object.

The most compelling type of animation for the physicist-film maker will undoubtedly be animation of graphs, charts, etc. It is through this technique that processes can be simplified graphically or that arrows can be superimposed on live action to focus the viewer's attention or to lead him through a process. Much more complex and tedious is "cell" animation, a process which involves photographing a series of drawings on acetate sheets, one frame at a time, changing cells between frames. This is the technique perfected by Walt Disney. It allows the film maker the possibility of showing complex actions in slow, simplified form, as well as of stripping a machine or a process layer by layer to its very core. Because of the skill and patience required for cell animation, little use will probably be made of it by the physicist.

Moving lines that seem to draw themselves on a graph can be animated by placing a sheet of acetate over the graph and inking the line in, one segment at a time, shooting the scene frame by frame between segments. If the line is complex in shape or direction, the motion can be reversed by placing the film so that it is upside down with reference to the camera. The line is then drawn in completely on the top sheet of acetate with water-soluble ink or paint. To animate the line, portions are wiped away with a damp cloth and the scene recorded, again frame by frame. Turning the film right side up for projection reverses the action and causes the line to draw itself as desired.

This technique is useful also for creating moving arrows. Arrows need not be drawn individually. One arrow can be photographed and reproduced in enough copies for all frames. These are then cut out and pasted with rubber cement to regular blank animation cells. Starting with the position for the beginning of the scene, the initial cell is then used as a guide for affixing the arrows for subsequent frames in their proper order. Cells should be numbered with a wax pencil so that they can be kept in order.

Equipment for Animation

1. ***Camera***

   Any camera used for animation should be equipped for single-frame exposures (special motors can be attached to some cameras to allow this capability but the cost of such an installation is often greater than the cost of the camera itself). Ideally, the single-frame release should give uniform exposures from frame to frame. Most spring-wound cameras do not meet this requirement exactly; differences in spring tension at various stages of winding, plus varying amounts of friction within the mechanism, preclude absolute accuracy. Also, the manner in which the release lever or button is depressed seems to affect the shutter timing in single-frame work. Employing a solenoid to trip the release lever yields better results than hand releasing.

   Reflex viewing is of prime importance for critical focusing and framing at the short distances involved in most animation work. A backwind that enables the film to be rewound in the camera for multiple exposure work is particularly useful. A variable shutter that enables in-camera fades will give still greater scope and variety. When used in conjunction with the backwind, it permits camera dissolves as scene transitions.

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[8] We are indebted here to John Halas of Halas & Batchelor Cartoon Films, and Roger Manvell whose article, "The New Instructional Film" (The Science Teacher, 5, 1962) provided some of the information which follows.

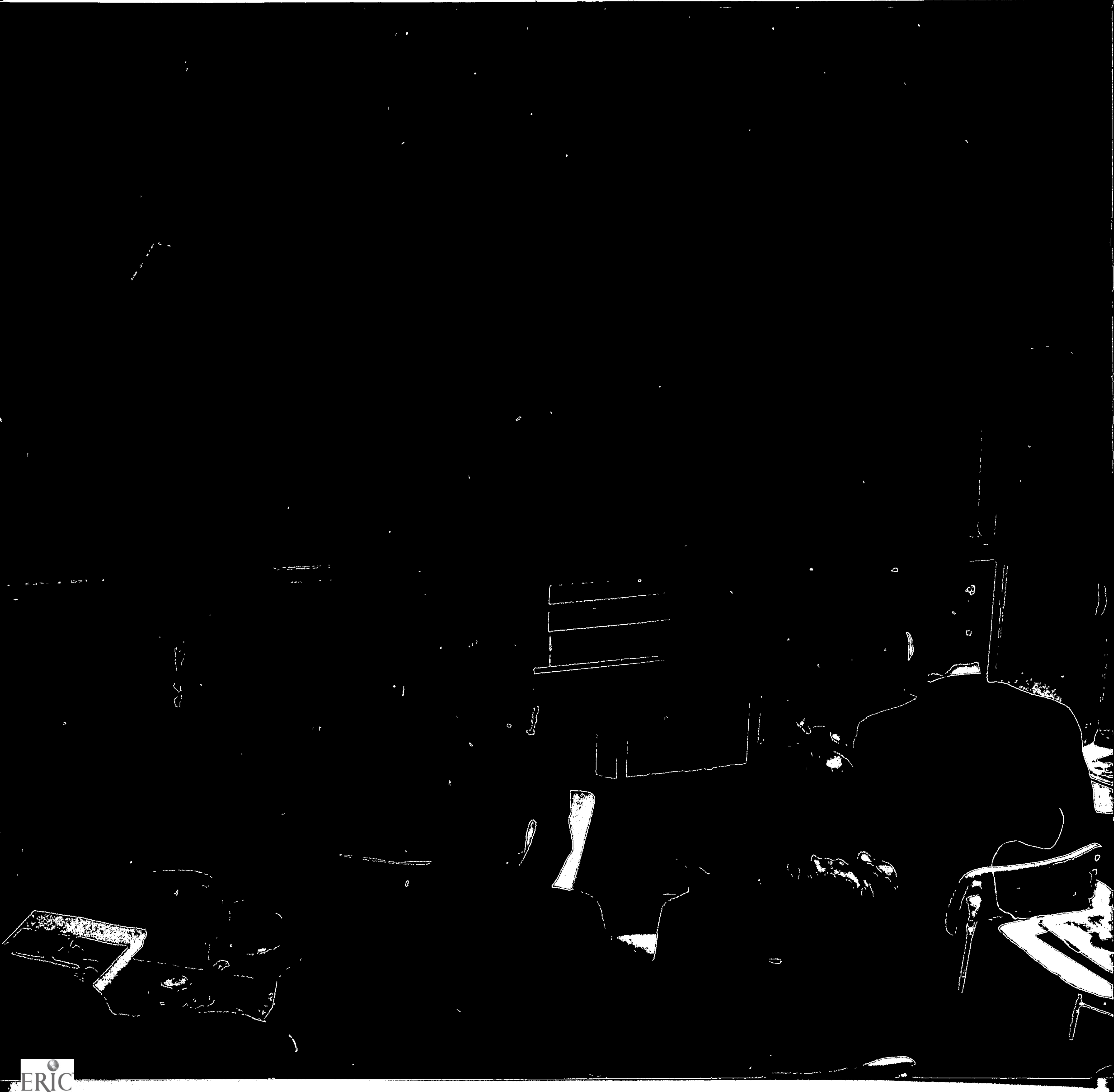
2. *Animation stand*

Professional animation stands are extremely costly. Filming of animated sequences can be accomplished either between the legs of the tripod or by positioning the sequence on the wall. Generally the instructions for shooting animated sequences and titles are similar (see p. 81).

3. *Lighting*

Because of the relatively limited areas filmed, lighting problems are minimal. Even when filming in color, No. 2 photoflood lights in clamp-on reflectors are ample, although care must be taken to use lamps compatible with the film stock being used.

Appendix D Equipment



8MM CAMERAS

The charts which follow list all 8mm camera models—Regular 8, Super 8, and Single 8—for which information was available as of summer 1967. They are listed alphabetically by manufacturer and then by model name and/or number. The specifications on camera features correspond in category to those designated as important by Franklin Miller in his article "Cameras and Accessories for Amateur Scientific Film Makers," pages 39-41.

Further information is available from manufacturers or from the buying guides mentioned on page 125.

Regular 8 Camera Models

CAMERA		LIST PRICE	LENS (mm) AND FOCAL LENGTH	REFLEX FINDER	EXPOSURE CONTROL	CAMERA SPEEDS (fps)	SINGLE FRAME EXPOSURE	ZOOM	ELECTRIC FILM DRIVE	ASA	OTHER FEATURES
BEAULIEU	*MAR 8 G*	$445.00	6.5-52, f/1.8 zoom	yes	automatic	18	yes	electric	yes		Roll-loading, 25 ft. capacity; variable shutter; frame counter; rewind.
	MCR 8 G	$409.00	6.5-52, f/1.8 zoom	yes	through-the-lens meter for semi-automatic	18	yes	electric	yes		Same as MAR 8 G.
BELL & HOWELL	*Autoload 305*	$89.95	13, f/1.8	yes	fully automatic	16	yes	no zoom	no	10-40	Cartridge-loading; 9 ft. run.
	Autoload 315	$119.95	9-29, f/1.8 zoom	yes	fully automatic	16	yes	manual	no	10-40	Cartridge-loading; 9 ft. run.
	Autoload 315 PZ	$149.95	9-29, f/1.8 zoom	yes	fully automatic	16	yes	manual	no	10-40	Cartridge-loading; 15 ft. run.
	Autoload 418	$249.95	9-27, f/1.8 zoom	yes	fully automatic	16, 48	yes	electric	no	3-250	Roll-loading; accepts cartridges; exposure beacon in viewfinder.
	Sunometer 319	$ 49.95	10, f/1.9	no	manual	16	yes	no zoom	no		Roll-loading; 25 ft. capacity, double-width; rotating shutter, 166° angle.
BOLEX	*Zoom Reflex Automatic K-2*	$490.00	8-36; stops down to f/16	yes	fully automatic, through the lens, with manual override	12, 18, 24, 40	yes	manual or electric	no		Roll-loading, 25 ft. capacity; variable shutter; film rewind; audible frame counter.
	Zoom Reflex Automatic P-4	$275.00	9-36, f/1.9; stops down to f/16	yes	fully automatic with manual override	12, 18, 40	yes	manual	no	10-400	Roll-loading, 25 ft. capacity; exposure warning; rotating eyepiece adjustable from −5 to +5 diopters; variable shutter, film rewind; audible frame counter.
	H 8 Rex	$480.00	12.5, f/1.3	yes	through the lens,	12-24	yes	no zoom	no		Roll-loading, 100 ft. capacity; tri-lens turret; adjustable eyepiece; automatic frame counter; film rewind; one-frame shaft; variable shutter; automatic fade-timer; audible scene length indicator.
	H 8 Rex Automatic	$740.00	8-36, 36 EE zoom; stops down to f/16	yes	automatic electric eye with manual override	12-24	yes	electric	no	10-400	Same as H 8 Rex.

BOLSEY	*Uniset*	$ 49.50	10, f/1.8	no	manual	16	no	no zoom	no		25 ft. cartridge.
CAMEX	*CRM*	$259.00	12.5, f/1.9	yes	manual	8-32	yes	no zoom	no		Roll-loading, 25 ft. capacity; double-width; reverse wind; audible sound after every 20 inches of film; adjustable eyepiece.
CARENA	*Zoomex S*	$429.50	6.5-52, f/1.8 zoom; stops down to f/16	yes	fully automatic with manual override	8-32	yes	manual	no	10-100	Roll-loading, 25 ft. capacity; automatic threading; f/stop, exposure warning in viewfinder.
CINEMAX	*8 H*	$150.00	9-30, f/1.8 zoom; stops down to f/22	yes	fully automatic	12, 16, 24	yes	manual	yes	10-400	Roll-loading.
GAF	*Ansco Titan*	$ 69.95	13, f/1.8	yes	fully automatic	16	no	no zoom	yes	10-64	Roll-loading, 25 ft. capacity; warning signal in viewfinder.
	Ansco Titan II	$ 89.95	13, f/1.8 zoom	yes	fully automatic	16	no	manual	yes	10-64	Same as above.
	Ansco Titan IV	$129.95	10-30, f/1.8 zoom	yes	fully automatic with manual override	16	no	manual	yes	10-400	Same as above plus provision for remote control.
GM	*Model ZE*	$ 69.95	9.5-20, f/1.8 zoom	no	fully automatic	16	no	manual	yes	10-40	Roll-loading, 25 ft., double 8 capacity.
HONEYWELL FILMATIC	*84-A*	$299.50	7.5-35, f/1.8 zoom; stops down to f/16	yes	fully automatic with manual override; behind the lens meter	12, 16, 24, 32	yes	manual	yes	10-320	Roll-loading, 25 ft. capacity (100 ft. with accessory magazine); self-threading; rangefinder focusing; provision for remote control; full power rewind; frame counter.
	84-B	$349.50	9-36, f/1.4 zoom; stops down to f/16	yes	fully automatic with manual override; behind the lens meter	12, 16, 24, 32	yes	manual	yes	10-320	Same as above.
	84-C	$399.50	7.5-45, f/1.8 zoom; stops down to f/16	yes	fully automatic with manual override; behind the lens meter	12, 16, 24, 32	yes	manual	yes	10-320	Same as above.
KODAK	*Brownie Fun Saver*	$ 18.95	f/2.7	no	manual	16	no	no zoom	no	40	Roll-loading, 25 ft. capacity; 7 ft. run.
	Escort 8 Zoom	$ 91.95	19-27, f/1.6 zoom	no	fully automatic	16	no	manual	no	10-40	Roll-loading, 25 ft. capacity; low-light indicator; 35 second run per winding.
KOPIL-CASPECO	*Reflex Zoom*	$ 69.95	9-30, f/1.8 zoom; stops down to f/22	yes	fully automatic, through the lens	16	no	manual	yes	5-400	Roll-loading, 25 ft. capacity; provision for remote control; exposure scale in viewfinder; frame counter.
NEOPTA	*Admira 8 G*	$ 59.95	12.5, f/2.8; stops down to f/16	no	semi-automatic	16	yes	no zoom	no	12-200	Roll-loading, 25 ft. capacity; 8 ft. run.

CAMERA		LIST PRICE	LENS (mm) AND FOCAL LENGTH	REFLEX FINDER	EXPOSURE CONTROL	CAMERA SPEEDS (fps)	SINGLE FRAME EXPOSURE	ZOOM	ELECTRIC FILM DRIVE	ASA	OTHER FEATURES
PATHE	*Imperial 8*	$299.95	8-40, f/1.9 zoom	yes	fully automatic with manual override; through the lens	8-64	yes	electric	no	10-400	Roll-loading, 25 ft. capacity; 8½ ft. run; film rewind; frame counter; adjustable eyepiece; fading and dissolving device; rubber eyecup; filter-holding lens shade.
	Royal 8	$199.95	9-36, f/1.8 zoom	yes	fully automatic with manual override; through the lens	8-64	yes	electric	no	10-400	Same as above.
SAIMIC-8	*ZE-25*	$ 49.95	12-30, f/1.8 zoom	yes	fully automatic with manual override	12, 16, 24, 32	yes	manual	no	10-320	Roll-loading, 25 ft. capacity; 5 ft. run.
SEDIC 8	*Reflex Zoom*	$ 65.85	f/1.8 zoom	yes	fully automatic, through the lens	16	no	manual	yes	10-320	Roll-loading, 25 ft. capacity; adjustable eyepiece; frame counter.

Super 8 Camera Models

CAMERA		LIST PRICE	LENS (mm) AND FOCAL LENGTH	REFLEX FINDER	EXPOSURE CONTROL	CAMERA SPEEDS (fps)	SINGLE FRAME EXPOSURE	ZOOM	ELECTRIC FILM DRIVE	ASA	OTHER FEATURES
ARGUS	*810 Super Eight*	$ 70.00	13, f/1.8; stops down to f/22	no	fully automatic	18	no	no zoom	yes	25-40	
	812 Super Eight	$130.00	10-30, f/1.8 zoom	yes	dully automatic	18	yes	manual	yes	25-400	
	814 Super Eight	$165.00	8-35, f/1.8 zoom	yes	fully automatic with manual override	18, 32	yes	electric and manual	yes	25-400	
	Showmaster 820	$160.00	8.5-35, f/1.8 zoom	yes	fully automatic with manual override	18	yes	manual	yes	25-250	Remote control up to 15 ft.
	Showmaster 822	$200.00	8.5-35, f/1.8 zoom	yes	fully automatic with manual override	18, 32	yes	electric	yes	25-250	Remote control up to 15 ft.
BAUER	*C-1*	$195.95	9-36, f/1.8 zoom	yes	fully automatic with manual override	12, 18, 24	yes	electric	yes	6-125	
	C-2	$259.95	8-40, zoom	yes	fully automatic with manual override	12, 18, 24	yes	electric	yes	6-125	Built-in fader, independent of shutter and diaphragm.

BEAULIEU	*2008*	$695.00	8-64, f/1.9; zoom stops down to F-22	yes	automatic, semi-automatic, through the lens, with manual override	2-50	yes	manual and electric	yes	10-400	Remote control; radio control up to 2 miles.
BELL & HOWELL	*430*	$160.00	11-35, f/1.9 zoom; stops down to f/22	yes	fully automatic	18	yes	manual	yes	10-400	Underexposure indicator; illumination sensed at film plane.
	431	$220.00	11-35, f/1.9 zoom	yes	fully automatic	18, 36	yes	electric	yes	10-400	Same as 430.
	432	$270.00	9-45, f/1.9 zoom; stops down to f/64	yes	fully automatic; manual override	18, 36	yes	electric	yes	10-400	Provisions for remote control; focussing eyepiece; exposure warning; power focussing.
CANON	*84C*	$169.95	10-30, f/1.8; stops down to f/16	yes	fully automatic, through the lens	18	yes	manual	yes	25-160	Remote control up to 25 ft.; adjustable eyepiece.
	85C	$199.95	9.5-47.5, f/1.8	yes	fully automatic, through the lens	18	yes	manual	yes	25-160	Same as 84C.
CRESTLINE	*CRS-I*	$ 54.95	15, f/1.8	no	fully automatic	18	no	no zoom	yes	25-40	
	CRS-II	$ 74.95	10-25, f/1.8	no	fully automatic	18	no	manual	yes	25-40	
DEJUR	*Electra V*	$170.00	10-30, f/1.8; stops down to f/22	yes	fully automatic with manual override	16, 32	no	electric		25-300	Adjustable eyepiece; automatic exposure compensation in slow motion; remote control to 15 ft.
	Electra VI	$199.95	10-30, f/1.8; stops down to f/22	yes	fully automatic with manual override	16, 32	no	electric	yes	25-300	Same as Electra V, only zoom focuses from 4 ft.
	Electra VII	$219.95	8.5-35, f/1.8 zoom	yes	fully automatic with manual override	16, 32	no	electric	yes	25-300	Same as Electra V.
EUMIG	*Super 8 Viennette*	$179.95	9-27, f/1.9 zoom	yes	fully automatic with manual override	18, 24	yes	electric	yes	25-100	Remote control.
GAF	*Anscomatic S/84*	$ 95.00	f/1.7 zoom; stops down to f/22	yes	fully automatic with manual override	18	no	manual	yes	25-100	Remote control up to 9 ft.
	Anscomatic S/85	$130.00	8.5-35, f/1.7 zoom; stops down to f/22	yes	fully automatic with manual override	18	yes	manual	yes	25-100	Same as S/84.
	Anscomatic S/86	$175.00	8.5-42, f/1.7 zoom stops down to f/22	yes	fully automatic with manual override	18, 32	yes	manual	yes	25-100	Same as S/84.
HONEYWELL	*Dual-Filmatic*	$209.50	9-36, f/1.9 zoom; stops down to f/22	yes	fully automatic, through the lens, with manual override	18, 24	yes	electric and manual	yes	10-100	Accepts Super and Single 8; split-image focusing; remote control to 15 ft.; Single 8 can be reversed.

CAMERA		LIST PRICE	LENS (mm) AND FOCAL LENGTH	REFLEX FINDER	EXPOSURE CONTROL	CAMERA SPEEDS (fps)	SINGLE FRAME EXPOSURE	ZOOM	ELECTRIC FILM DRIVE	ASA	OTHER FEATURES
	Tri-Filmatic	$279.50									Same as Dual-Filmatic but accepts Regular 8 as well.
KALIMAR		$100.00	f/1.8	yes	fully automatic, through the lens, with manual override	18	no	no zoom	yes	25-100	Remote control.
KEYSTONE	*K-610H*	$ 69.95	15, f/1.8	no	fully automatic	18	no	no zoom	yes	25-40	Exposure warning signals.
	K-615H	$129.95	9.5-30, f/1.8 zoom	yes	fully automatic, through the lens	16	no	manual	yes	25-64	
	K-620H	$165.00	11-33, f/1.8 zoom; stops down to f/16	no	fully automatic	18	yes	manual	yes	10-40	Remote control.
	K-625H	$205.00	8.5-35, f/1.8 zoom	yes	fully automatic	18	yes	manual	yes	10-40	Remote control.
	K-622H	$139.95	10-30, f/1.8 zoom	yes	fully automatic, through the lens	18	no	electric	yes	25-40	Focusing eyepiece; exposure warning.
	K-623H	$199.95	9-36, f/1.8 zoom	yes	fully automatic, through the lens, with manual override	18	no	electric	yes	25-100	Focusing eyepiece.
KOBENA	*121*	$ 59.95	13, f/1.8; stops down to f/22	no	fully automatic	18	no	no zoom	yes	25-40	Remote control to 15 ft.; built-in frame counter.
	221	$ 89.95	10.5-21, f/1.8; zoom stops down f/22	yes	fully automatic	18	no	manual	yes	25-400	Diopter visual correction to reflex finder; remote control to 15 ft.; built-in frame counter.
	321	$119.50	10-30, f/1.8 zoom	yes	fully automatic with manual override	18	no	manual	yes	25-400	Same as 221.
	421	$159.50	8.5-35, f/1.8 zoom	yes	fully automatic with manual override	12, 18, 24	no	electric	yes	25-400	Same as 221.
KODAK	*Instamatic M2*	$ 39.95	f/1.8; stops down to f/23	no	manual	18	no	no zoom	no		
	Instamatic M4	$ 69.95	f/1.8, stops	no	fully automatic	18	no	no zoom	no	16, 25, 64 (daylight); 25, 40, 100 (photoflood)	

	Instamatic M5	$119.95	13-28, f/1.9 zoom	yes	fully automatic	18	no	manual	yes	16-100	Adjustable eyepiece.
	Instamatic M6	$159.95	12-36, f/1.8 zoom; stops down to f/27	yes	fully automatic	18	yes	manual	yes	same as M-4	Adjustable eyepiece.
MINOLTA	*Autopack-K3*	$149.50	12-28, f/1.8 zoom	yes	fully automatic, through the lens	18	yes	manual	yes	16-100	Aperture scale, exposure warning, film remaining shown in viewfinder.
	Autopack-K5	$189.50	9.5-30, f/1.8 zoom	yes	fully automatic through the lens	12, 18, 24	yes	manual	yes	10-250	Remote control to 10 ft. Same as K3.
NIKON	*Zoom Super 8*	$269.50	8.8-45, f/1.8 zoom	yes	fully automatic, through the lens, with manual override	12, 18, 24	yes	manual or electric	yes	10-160	Split image focusing; remote control; meter needle, aperture scale, exposure warning shown in viewfinder; adjustable eyepiece.
NIZO	*S8*	$269.50	8-40, f/1.8 zoom, stops down to f/22	yes	full automatic with manual override	18, 24	yes	electric	yes	16-800	Remote control to 75 ft., ±2 diopter adjustable eyepiece.
	S8-T	$359.50	7-56, f/1.8 zoom	yes	fully automatic with manual override	18, 24	yes	electric	yes	16-800	Same as S8 except red light flashes at film end.
PETRI	*Super 8*		8.5-34, f/1.7 zoom	yes	fully automatic with manual override	18, 24	yes	manual	yes		Remote control; low-light exposure indicator.
RAINBOW	*JP-1*	$ 99.50	12-30, f/1.8 zoom	yes	fully automatic, through the lens, with manual override	18	no	manual	yes	16-250	Remote control: film rewind; built-in frame counter.
REVERE	*Automatic S1*	$ 29.95	16, f/2.5	no	manual	16	no	no zoom	yes		
RICHMOND	*Super 100*	$ 59.95	f/1.8	no	fully automatic	18	no	no zoom	yes	40	
	Super 200	$ 79.95	f/1.8 zoom	no	fully automatic	18	no	manual	yes	40	
SANKYO	*Super CM*	$139.95	10-30, f/1.7 zoom	yes	fully automatic with manual override	18	yes	manual	yes	25-250	Low-light signal in viewfinder.
SEARS	*Easi-Load C115*	$ 49.95	f/1.8, stops down to f/22	no	fully automatic	18	no	no zoom	yes	25-40	
	Easi-Load C116	$ 69.95	10-20, f/1.8 zoom	no	fully automatic with manual override	18	no	manual	yes	25-64	
	Easi-Load C160	$129.95	11-35, f/1.95, zoom stops down to f/64	yes	fully automatic	18, 36	yes	manual	yes	6-400	Adjustable eyepiece; underexposure meter in viewfinder.
	Easi-Load C161	$169.95	11-35, f/1.95 zoom stops down to f/64	yes	fully automatic	18, 36	yes	electric and manual	yes	6-400	Remote control socket.

CAMERA		LIST PRICE	LENS (mm) AND FOCAL LENGTH	REFLEX FINDER	EXPOSURE CONTROL	CAMERA SPEEDS (fps)	SINGLE FRAME EXPOSURE	ZOOM	ELECTRIC FILM DRIVE	ASA	OTHER FEATURES
SEARS (cont.)	*9150*	$ 99.95	11-35, f/1.95 zoom, stops down to f/64	no	fully automatic, through the lens	18	no	manual	no	6-400	
	9162	$219.95	9-45, f/1.8 zoom	yes	fully automatic, through the lens	18, 36	yes	electric	yes	10-400	Adjustable eyepiece; split-image range finder; remote control.
	9166	$189.95	8.5-42.5, f/1.8 zoom	yes	fully automatic with manual override	18	yes	electric and manual	yes	25-250	Focusing eyepiece; low-light signal and f/stop shown in viewfinder.
VERNON	*4XR*	$119.95	8.5-35, f/1.8 zoom; stops down to f/22	yes	fully automatic	18	no	manual	yes	25-400	
	Super 707	$ 54.95	3.5", f/1.8; stops down to f/22	no	fully automatic	18	no	no zoom	yes	16-100	
	Super 708	$ 79.95	10-25, f/1.8 zoom	no	fully automatic	18	no	manual	yes	16-100	
VICEROY	*CRS III-Zoom Reflex*	$119.95	9-25, f/1.8 zoom; stops down to f/22	yes	fully automatic with manual override	18, 24	no	manual	yes	10-400	Remote control; built-in frame counter.
	CRS-IV Power Zoom Reflex	$159.95	9-36, f/1.8 zoom	yes	fully automatic, through the lens, with manual override	12, 18, 24	yes	electric	yes	10-400	Variable shutter.
	CRS VI-Zoom CDS	$ 74.95	9-25, f/1.8 zoom; stops down to f/22	no	fully automatic	18	no	manual	yes	10-200	
WARDS	*703*	$ 43.95	13; f/1.8; stops down to f/16	no	fully automatic	18	no	no zoom	yes	25-40	
	704	$ 64.95	12.5-25, f/1.8 zoom	no	fully automatic	18	no	manual	yes	25-40	
	705	$ 88.95	11-27.5, f/1.8 zoom	yes	fully automatic	18, 24	no	manual	yes	10-400	
YASHICA	*Super-8 25*	$110.00	12-30, f/1.8 zoom	yes	fully automatic with manual override	18	yes	manual	yes	25-40	Aperture scale, exposure warning shown on viewfinder
	Super-10	$ 69.95	15, f/1.7; stops down to f/16	no	fully automatic	18	yes	no zoom	yes	25-50	F/stop exposure warning on viewfinder.
	Super-25	$114.95	12-30, f/1.8 zoom	yes	fully automatic	18	yes	manual	yes	25-50	Same as Super-10.

	Super-30	$129.95	10-30, f/1.7 zoom; stops down to f/22	yes	fully automatic, through the lens	18	yes	manual	yes	25-100	F/stop, exposure warning in viewfinder; aerial image, scale focusing.
	Super-50	$159.95	8.5-42.5, f/1.8	yes	fully automatic, through the lens	18	yes	electric	yes	25-100	Same as Super 30, but remote control to 15 ft.

Single 8 Camera Models

CAMERA		LIST PRICE	LENS (mm) AND FOCAL LENGTH	REFLEX FINDER	EXPOSURE CONTROL	CAMERA SPEEDS (fps)	SINGLE FRAME EXPOSURE	ZOOM	ELECTRIC FILM DRIVE	ASA	OTHER FEATURES
FUJICA	*Single 8 P-1*	$ 79.95	11.5, f/1.8; stops down to f/16	no	fully automatic	18	no	no zoom	yes	16-400	F/stop shown on viewfinder.
	Single 8Z-1	$159.50	9.5-29, f/1.6 zoom; stops down to f/16	yes	fully automatic with manual override	18, 24	yes	manual	yes	16-400	Remote control.
	Single 8 Z-2		8.5-34, f/1.8 zoom	yes	fully automatic with manual override	18, 24	yes	manual	yes	16-400	Provision for intentional double exposure, fades and dissolves.
HONEYWELL	*Dual-Filmatic*	$209.50	9-36, f/1.9; stops down to f/22	yes	fully automatic, through the lens with manual override	18, 24	yes	electric and manual	yes	10-100	Accepts Super and Single 8 split-image focusing; remote control to 15 ft.; Single 8 can be reversed.
	Tri-Filmatic	$279.50									Same as Dual-Filmatic but accepts Regular 8 as well.

8MM SOUND CAMERA

FAIRCHILD	*900*	$785.00	9-30, f/1.8 zoom	yes	fully automatic with manual override	16, 24			yes	10-400	8mm magnetic sound-on-film recording; automatic loading, 50 ft. double 8 rolls (prestriped), 200 ft. (standard silent); underexposure warning; provision for remote control; 56 frame picture/sound separation; automatic volume control with manual override.

8MM PROJECTORS

Below in chart form are specifications for 8mm projectors available on the market as of June 1967. The list includes Regular 8 and Super 8 models (which also accept Single 8 film), both sound and silent, and is ordered alphabetically by manufacturer and then by model name and/or number. Further information is available from the manufacturer or from the buying guides referred to on page 125.

Silent Projectors

1. *Regular 8 models*

PROJECTOR		LIST PRICE	PROJECTOR SPEEDS (fps)	LENS (mm) AND FOCAL LENGTH	REEL CAPACITY	TYPE OF LAMP	EXTRAS
ARGUS	*Showmaster 462*	$115.00	variable	14, 5-25, f/1.5 zoom	400 feet	150 watt, DFA; built-in reflector	Reverse and single frame projection; self-threading.
	Showmaster 500	$ 75.00	18	22, f/1.5	400 feet	150 watt, DFA; built-in reflector	Reverse and single frame projection.
BELL & HOWELL	*Autoload 245 Bay*	$ 99.95	18	17-27, f/1.6 zoom	400 feet	DFC, built-in reflector	Reverse and single frame projection; self-threading.
	Autoload 256	$ 79.95	18	1″, f/1.6	400 feet	DFC, built-in reflector	Same as Autoload 245 Bay
	Autoload 266	$144.95	variable	1″, f/1.6	400 feet	DEF	Same as Autoload 245 Bay but has 7-10 fps slow motion.
	Autoload 266Y	$164.95	variable	17-27, f/1.6 zoom	400 feet	DEF	Same as Autoload 245 Bay but has 7-10 fps slow motion.
BOLEX	*18-5 Automatic*	$169.95 $199.95	variable	15 or 20, f/1.3 12, 5-25, f/1.3 zoom	400 feet		Automatic or manual threading; 5 fps slow motion; framing control.
BRUMBERGER	*1503*	$ 39.95	18	¾″, f/1.6 with sliding focus	200 feet	300 watt, reflector	
	1500	$ 29.95	18		200 feet	150 watt	Similar to 1503 with different lens.
CAVALIER		$ 59.95	variable	15-25, f/1.5 zoom	400 feet	150 watt, DFA direct lighting	Reverse and single frame projection; self-threading.
DALIA	*Zoom Auto Deluxe*	$ 79.50	variable	15-25, f/1.6 zoom	400 feet	50 watt, 8 volt	Self-threading; reverse and single frame projection.
GAF	*Anscovision 180*	$ 74.95	18	¾″ f/1.5	400 feet	150 watt, direct lighting, DFA	Self-threading.
	Anscovision 280	$ 99.95	variable	15-25, f/1.5 zoom	400 feet	150 watt, direct lighting, DFA	Similar to Anscovision 180 but has reverse and single frame projection; slow motion to 8 fps.
KODAK	*Brownie 8 Model A15*	$ 54.95	18	¾″, f/1.6	200 feet	150 watt, Truflector DFN	Automatic threading.
	Chevron 8 Model 10	$204.50	variable	22, f/1	400 feet	dichroic DKR	Automatic threading; high speed rewind; still and reverse capability; air jet cooling.

OLYMPIC	*Model 500*	$ 39.95	18	¾", f/5	400 feet	150 watt, direct lighting	
LIESEGANG	*S1 Synchro*	$199.50 $219.00	variable	20 or 16, f/1.3 15-25, f/1.6	400 feet		Automatic threading; slow motion; reverse and still projection.
RICHMOND	*Aurora I*	$ 69.95	18	¾", f/1.5	400 feet	150 watt DFA Truflector	Accepts striped film; recorder/playback attachment; automatic threading.
	Aurora II	$ 89.95	18	¾", f/1.5	400 feet	150 watt, DFA Truflector	Similar to Aurora I, but has 1-9 fps slow motion; reverse and single frame projection.
	Model 600	$ 59.95	18	¾", f/1.5	400 feet	DCH Truflector, 150 watt; built-in reflector; direct lighting	Accepts striped film; recorder/playback attachment.
	Model 800	$ 79.95	18	15-25, f/1.5 zoom	400 feet	DCH Truflector, 150-watt; built-in reflector; direct lighting	7-9 fps slow motion.
SEARS	*Automatic 9270*	$ 89.95	variable	1", f/1.6	400 feet	150 line-voltage, DFC	Self-threading; slow motion; still and reverse projection.
	9288 Super Automatic	$114.95	variable	23, f/1.2	400 feet	150 watt, Super Truflector; T14; 21.5 volt; dichroic reflector	Automatic threading; slow motion; reverse and still projection.

2. Super 8 (Single 8) Models

PROJECTOR		LIST PRICE	PROJECTOR SPEEDS (fps)	LENS (mm) AND FOCAL LENGTH	REEL CAPACITY	TYPE OF LAMP	EXTRAS
ARGUS	*Showmaster 870*	$ 80.00	18	23, f/1.5	400 feet	150 watt, direct-lighting DFG	Reverse and single frame projection.
	Showmaster 871	$105.00	18	23, f/1.5	400 feet		Reverse and single frame projection; self-threading.
	Showmaster 872	$130.00	18	18, 5-32, f/1.5 zoom	400 feet		Self-threading; reverse and single frame projection.
AGFA-GEVAERT	*Movector BS*	$119.95	18	15-25, f/1.3 zoom	400 feet	8 volt, 50 watt	Automatic loading; reverse and single frame projection.
BAUER	*T1-S*	$179.95	18	18-30, f/1.3 zoom	400 feet	100 watt, 12 volt, quartz-iodine high intensity, (equivalent to 750 watts)	Self-threading; can be operated in synchronization with tape recorder and built-in synchronizer at 3¼ ips.
	T3	$ 79.95 $ 99.95	9, 18	20, f/1.3 or 18-30, f/1.4 zoom	200 feet	8 volt, 50 watt	Automatic loading.

PROJECTOR		LIST PRICE	PROJECTOR SPEEDS (fps)	LENS (mm) AND FOCAL LENGTH	REEL CAPACITY	TYPE OF LAMP	EXTRAS
BELL & HOWELL	*356*	$ 94.95	18	25, 1", f/1.6	400 feet	150 watt, direct-lighting DJL	Self-threading; reverse and single frame projection.
	3572	$114.95	18	17-27, f/1.6	400 feet	150 watt, direct-lighting DJL	Self-threading; reverse and single frame projection; dial focusing.
	482	$149.95	6-22	17-27, f/1.6	400 feet	250 watt, direct-lighting; DLH	Self-threading; reverse and single frame projection; dial focusing; slow motion.
	482Z	$169.95	6-22	17-27, f/1.6 zoom	400 feet		Self-threading; reverse and single frame projection; dial focusing; slow motion.
	483	$189.95	6-22	17-27, f/1.2	400 feet	200 watt, direct-lighting DSW low voltage	Self-threading; reverse and single frame projection; dial focusing; slow motion.
	483Z	$214.95	6-22	19-32, f/1.2 zoom	400 feet	200 watt, direct-lighting DSW low voltage	Self-threading; reverse and single frame projection; dial focusing; slow motion.
BELL & HOWELL	*466Z*	$189.95	6-22	19-23, f/1.2 zoom	400 feet	120 volt, 250 watt DLH	Self-threading; flickerless slow motion; single frame projection.
BOLEX	*18-5 Super*	$179.50	18	15, 20, or 25, f/1.3	400 feet		Reverse projection; slow motion.
	18-5 Super	$209.50	18	17-28, f/1.3 zoom	400 feet		Reverse projection; slow motion.
CASPECO	*P-200*	$119.95	variable	20-30, f/1.4 zoom	400 feet	8 volt, 50 watt	Automatic loading; reverse and single frame projection.
DEJUR	*Dual PT-90*	$219.95	6-22	15-25, f/1.4 zoom	400 feet	high intensity dichroic lamp	Both 8 and Super 8; automatic threading.
	Dual PT-90MV	$234.95	6-22	15-25, f/1.4 zoom	400 feet	high intensity dichroic lamp	Both 8 and Super 8; automatic threading; multiple voltage control.
	Dual PT-99	$244.95	6-22	15-25, f/1.4 zoom	400 feet	high intensity dichroic lamp	Both 8 and Super 8; automatic threading; built-in viewer.
	Dual PT-99MV	$259.95	6-22	15-25, f/1.4 zoom	400 feet	high intensity dichroic lamp	Both 8 and Super 8; automatic threading; multiple voltage control.
	Eldorado I PT-80	$159.95	6-22	15-25, f/1.5 zoom	400 feet		Reverse and single frame projection; slow motion; fast rewind.
	Eldorado I PT-80 MV	$174.95			400 feet		Reverse and single frame projection; slow motion; fast rewind.
	Eldorado II PT-88	$194.95			400 feet		Reverse and single frame projection; slow motion; fast rewind; built-in viewer.

	Eldorado II PT-88 MV	$209.95			400 feet		Reverse and single frame projection; slow motion; fast rewind; built in viewer; multiple voltage control.
	DP-77	$139.95	6-22	15-25, f/1.	400 feet		Self-threading; 8 and Super 8.
	DP-808	$149.95	6-22	15-25, f/1.4 zoom	400 feet	120 volt, 150 watt DFG	Self-threading; automatic switch turns on projector lamp as film enters; 8 and Super 8.
	DP-888	$179.95	6-22	15-25, f/1.4 zoom	400 feet	120 volt, 150 watt, DFG	Same as DP-808; built-in viewer; 8 and Super 8.
EUMIG	*Mark M*	$179.95	18, 24	15-25, f/1.3	400 feet	12 volt quartz-iodine (750 watts)	Reverse and single frame projection; self-threading.
	VII	$159.95	18, 24	20, f/1.3	400 feet	12 volt; quartz-iodine (750 watts)	Reverse and single frame projection; self-threading.
FUJICA	*M3*	$159.50	12-24	15-25, f/1.3 zoom	400 feet	8 volt; 50 watt	8, Super 8, Single 8; reverse and single frame projection; self-threading; slow motion; takes different formats on same reel.
	SM2	$149.50 $162.50	16-26	25, f/1.4 19-32, f/1.4 zoom	400 feet	150 watt, built-in reflector	Single frame projection; Super and single 8, automatic threading.
GAF	*Anscovision 380*	$ 84.95	18	¾", f/1.5, 25	400 feet	150 watt, direct-lighting, DFA	Self-threading.
	Anscovision 480	$114.95	variable	15-25, f/1.5 zoom	400 feet	150 watt, direct-lighting, DFA	Reverse and single frame projection.
	Anscovision 388	$ 74.95	18	f/1.4	400 feet	120 volt, 150 watt DFP	Self threading; 8 and Super 8.
	Anscovision 488	$ 89.95	variable	f/1.4	400 feet	120 volt, 150 watt DFP	Self-threading; 8 and Super 8; reverse and single frame projection.;
	Anscovision 588	$ 99.95	variable	f/1.5 zoom	400 feet	120 volt, 150 watt DFP	Self-threading; 8 and Super 8; reverse and single frame projection.
GOLDCREST	*88*	$ 74.95	variable	20-32, f/1.5 zoom	400 feet	8 volt, 50 watt reflector	Self-threading; reverse and single frame projection; 8 and Super 8.
HEURTIER	*P. 6-24*	$189.50 $209.50	18, 24	20 or 25, f/1.5 15-25, f/1.5 zoom	400 feet	low voltage, high intensity lamp	Both Super 8 and 8 mm; 6 or 8 fps slow motion; reverse and single frame projection; automatic threading; accepts striped film sound attachment.
		$410.00	18, 24				Sound base complete with microphone and speaker.
HONEYWELL	*FP8-C*	$169.50 $189.50	12-22	25, f/1.3 20-32, f/1.3 zoom	400 feet	21.5 volt, built-in reflector	8 and Super 8; automatic threading; reverse and single frame projection; high speed rewind.

PROJECTOR		LIST PRICE	PROJECTOR SPEEDS (fps)	LENS (mm) AND FOCAL LENGTH	REEL CAPACITY	TYPE OF LAMP	EXTRAS
HONEYWELL (cont.)	*Elmo FP8-C*	$209.50	12-22		400 feet	halogen lamp	Super 8 and 8; brighter version of FP8-C.
IMAC	*Super 8*	$109.95	variable	20-32, f/1.5 zoom	400 feet	8 volt, 50 watt	Automatic loading, reverse and single frame projection; rear pressure plate.
INTER-8 SUPER		$ 89.95	variable	20-30, f/1.4 zoom	400 feet	50 watt, 8 volt direct-lighting	Reverse and single frame projection; self-threading.
KEYSTONE	*K-519 M*	$ 70.00	18	15, f/1.3	200 feet	150 watt DJA Truflector	Sprocketless transport; self-threading.
	K-520	$ 85.00	18	20, f/1.3	200 feet	150 watt DJA reflected light lamp	Reverse and single frame projection; sprocketless transport; self-threading.
	K-525 M	$ 85.00	18	20, f/1.3	400 feet	150 watt DFG lamp	Reverse projection.
	K-530 M	$105.00	18	20, f/1.3	400 feet	150 watt DFG direct lighting	Reverse and single frame projection; self-threading.
	K-540 Z	$130.00	variable	18-30, f/1.4 zoom	400 feet	150 watt DFG direct lighting	Reverse and single frame projection; self-threading.
	K-550 Z	$149.95	5-26	18-30, f/1.4 zoom	400 feet	150 watt DFG direct lighting	Reverse and single frame projection; self-threading: slow-motion.
KODAK	*Instamatic M50*	$ 69.95	18	28, f/1.5	200 feet	150 watt DFN with reflected lighting	Self-threading; sprocketless transport.
	Instamatic M60	$ 84.95	18	28, f/1.5	200 feet	150 watt DFN with reflected lighting	Automatic speed rewind, built-in preview screen; otherwise same as M50;
	Instamatic M70	$149.50 $169.50	6, 18, 54	28, f/1.5 or 20-30, f/1.5 zoom	400 feet	150 watt DNE direct lighting	Self-threading; single frame projection; sprocketless transport; can be operated in conjunction with a tape recorder.
	Instamatic M80	$199.50 $219.50	9-26	20-32, f/1.5 or 20-32, f/1.5 zoom	400 feet	150 watt DNE direct lighting	8mm and Super 8; otherwise same as M70.
	Instamatic M90	$189.50 $195.00	6, 18, 54	28, f/1 20-32, f/1.5 zoom	400 feet	21 volt, 150 watt DNF direct lighting	Similar to M70.
	Instamatic M95	$224.95 $209.95 $229.95	6, 18, 54	28, f/1.0 or 22, f/1.5 or 20-30, f/.5 zoom	400 feet	21 volt, 150 watt Trubeam	8 and Super 8; reverse and single frame projection; automatic threading.
	Instamatic M65	$ 99.95	18	22, f/1.5	400 feet	150 watt DFN	8 and Super 8; automatic threading; preview screen.
LA GRANGE	*Dany 8 Deluxe*	$199.00	variable	15-25, f/1.4 zoom	400 feet	21.5 volt, 150 watt	Built-in screen with wall screen capability; automatic threading; reverse and single frame projection; provision for tape recorder synchronization.

MINOLTA	*AP-85*	$159.50	variable	17-30, f/1.4 zoom	400 feet	150-watt, built-in reflector	Reverse and single frame projection; self-threading.
NIZO	*FP 1S*	$219.50	18	15, f/1.4 or 15-25, f/1.5 zoom	400 feet	100-watt, 12 volt direct-lighting iodine	Reverse and single frame projection; self-threading; built-in signal generator enables addition of sound.
	FP 3	$169.50 $189.50	variable	20, f/1.3 or 18-36, f/1.4 zoom	400 feet	100 watt, 12 volt	Same as FP 1S, but no sound capability.
NORRIS	*Super 8 830*	$179.95 $199.95	variable	25, f/1.3 or 19-30, f/1.6 zoom	400 feet	halogen	Automatic loading; reverse and single frame projection; built-in tape coupler available ($209.95, $229.95).
RICHMOND	*Dual Eight*	$119.95		22, f/1.5	400 feet	120 volt, 150 watt DFG	Super 8 and 8; reverse and single frame projection.
	Aurora I-Super	$ 84.95	18	¾″ wide angle, f/1.5	400 feet	150-watt direct lighting DFG	Self-threading.
	Aurora II-Super	$ 97.95	9-20	¾″ wide angle f/1.5	400 feet	150-watt, direct lighting DFG	Reverse and single frame projection; self-threading.
	Aurora II-Z Super	$104.95	9-20	15-25, f/1.5 zoom	400 feet	150-watt, direct lighting DFG	Reverse and single frame projection; self-threading.
	600-Super	$ 69.95	18	¾″ wide angle f/1.5	400 feet	150-watt, direct lighting DFG	Same as Aurora I except no self-threading.
	800-WA-Super	$ 79.95	variable	¾″ wide angle, f/1.5	400 feet	150-watt, direct lighting DFG	Reverse projection; self-threading.
	800-Z-Super	$ 89.95	variable	15-25, f/1.5 zoom	400 feet	150-watt, direct-lighting DFG	Reverse projection.
RAINBOW	*JP-5*	$ 99.50	variable	15-25, f/1.4	400 feet	50-watt, 8 volt	Automatic loading.
SANKYO	*Dualex 8s*	$169.95	variable		400 feet		Super and regular 8. Self-threading; reverse and single frame projection.
	Super LM	$139.95	variable	20, f/1.3	400 feet	8 volt, 50-watt direct-lighting	Reverse and single frame projection.
SEARS	*Easi-Load 9200*	$109.95	18	25, f/1.6	400 feet	150 watt, direct-lihgting DJL	Slow motion; reverse and single frame projection; self-threading; can take sound.
	Easi-Load 9201	$122.95	18	15-25, f/1.6 zoom	400 feet	150 watt, direct-lighting DJL	Similar to 9200.
	Easi-Load 9202	$139.95	variable	25, f/1.2	400 feet	21 volt, 150 watt direct-lighting DHX	Similar to 9200 plus splicer.
	Easi-Load 9203	$159.95	variable	19-33, f/1.2 zoom	400 feet	21 volt, 150 watt direct-lighting DHX	Similar to 9200.
VERNON	*Raynox 5-500*	$ 99.95	variable	20-32, f/1.5 zoom	400 feet	50 watt, 8 volt direct-lighting	Reverse and single frame projection.

PROJECTOR		LIST PRICE	PROJECTOR SPEEDS (fps)	LENS (mm) AND FOCAL LENGTH	REEL CAPACITY	TYPE OF LAMP	EXTRAS
	ZRS Slimline	$119.95	variable	20-32, f/1.5 zoom	400 feet	8 volt, 50 watt reflector	Similar to Raynox 5-500, but is self-threading.
VICEROY	*801*	$ 64.95	18	20, f/1.4	400 feet	500 watt equivalent	Reverse projection; self-threading; . sprocketless transport; automatic rewind.
	802	$ 79.95	18	20, f/1.4	400 feet	500 watt equivalent	Forward, reverse, still, and fast forward controls. Similar to 801.
	803	$ 89.95	18	20, f/1.4	400 feet	500 watt equivalent	Forward, reverse, still, and fast forward controls, similar to 801.
WARDS	*866*	$ 62.95	18	20, f/1.5 zoom	300 feet	150 watt, direct-lighting DJA	Reverse and single frame projection; sprocketless transport; self-threading.
	886	$ 87.50	18	20, f/1.5 zoom	400 feet	500 watt, direct-lighting, DJA	Reverse projection; self-threading.
ZEISS-IKON	*MoviLux 58*	$199.95 $229.00	18, 24	18, f/1.2 or 15-25, f/1.4 zoom	400 feet	12 volt, 100 watt halogen	Reverse and single frame projection.

Sound projectors

1. Regular 8 models

PROJECTOR		LIST PRICE	PROJECTOR SPEEDS (fps)	LENS (mm) AND FOCAL LENGTH	TYPE OF LAMP	REEL CAPACITY	SOUND TRACK	EXTRAS
EUMIG	*Mark S*	$319.50	16, 18, 24	13-25, f/1.3	100 watt, 12 volt, quartz-iodine	400 feet	magnetic	Automatic threading; forward and reverse projection; 4-watt amplifier; built-in speaker; sound with sound, sound over sound recording.
HONEYWELL	*Elmo TP-8*	$495.00	16, 24		150 watt DCA	400 feet	magnetic	Record and playback; reverse projection; 10 watt amplifier; 5" speaker.
INTERNATIONAL AUDIO-VISUAL	*IAV-8*	$396.00	16, 24		150 watt	600 feet	magnetic & optical	Record and playback; reverse projection; 10 watt transistorized amplifier; 7" speaker.
	IAV Xenon 8	$1,496.	16, 24		Xenon, 150 watt	600 feet	magnetic & optical	Record and playback; reverse and single speed projection; slow motion; 10 watt transistorized amplifier; 7" speaker.

PATHE	*Norris 8-Zoom*	$199.95	8-26	15-25, f/1.6 zoom	12 volt, 100 watt	400 feet		Self-threading; reverse and single frame projection; operates with any tape recorder at 3¼ ips.
SEARS	*Soundstage 9258*	$199.95	18, 24	1″, f/1.2	150 watt DFP	400 feet	magnetic	Sound, record, playback; 2 watt amplifier; built-in speaker; reverse and single frame projection; automatic threading.
	Soundstage 9259	$214.95	18, 24	1″, f/1.2 zoom	150 watt DFP	400 feet	magnetic	Similar to Soundstage 9258.
TOEK	*Talkie 8*	on request		25, f/1.5	21 volt, 150 watt Truflector	600 feet	optical	5 x 8″ oval speaker.
	Talkie 8M	on request		25, f/1.5	21 volt, 150 watt Truflector	600 feet	optical & magnetic	Similar to Talkie 8.
VIEWLEX	*VOS-1*	$350.00	16, 24	20, f/1.4	150 watt, 21.5 volt DCA	600 feet	optical & magnetic	8mm and format M; 8 watt amplification; 5 x 7″ speaker; reverse projection; semi-automatic threading; record and playback.
VISCOUNT-CHUKOH	*Model 8T-1*	$249.50	16, 24	15-25, f/1.4 zoom	150 watt, 21.5 volt	400 feet	magnetic & optical	Record and playback; 5 x 7½″ speaker; reverse and single frame projection; automatic threading.

2. *Super 8 (Single 8) models*

PROJECTOR		LIST PRICE	PROJECTOR SPEEDS (fps)	LENS (mm) AND FOCAL LENGTH	TYPE OF LAMP	REEL CAPACITY	SOUND TRACK	EXTRAS
BOLEX	*18-5*	$360.00 $390.00	18, 24	15, f/1.2 or 14-25, f/1.3		800 feet	magnetic	Automatic threading; built-in frame counter; sound over sound.
CARENA	*858*	$559.50	18, 24	20, f/1.2	12 volt, 100 watt	400 feet	magnetic	For 8 and Super 8; record and playback; 3 watt amplifier; 2 inputs; 3 x 6″ detachable speaker; reverse and single frame projection; automatic threading; sound on sound recording and mixing; echo control; slow motion.
DUKANE	*28A8*	$550.00	18, 24	28, f/1.4	DNF halogen	600 feet	magnetic & optical	Self-threading; record and playback.
EUMIG	*Mark S Super 8*	$349.95	18, 24	15-25, f/1.3 zoom	quartz-iodine	400 feet	magnetic	Record and playback; automatic threading; reverse projection; 4 watt amplifier; built-in oval speaker, sound with sound; sound over sound recording.
HEURTIER	*P 6-24*	$599.50	6, 18, 8, 24	20 or 25, f/1.5	low-voltage, high intensity	400 feet	magnetic	Record and playback; 6 watt amplifier; 11 x 10″ speaker; reverse and single frame projection; automatic threading; slow motion at 6 fps.

PROJECTOR		LIST PRICE	PROJECTOR SPEEDS (fps)	LENS (mm) AND FOCAL LENGTH	TYPE OF LAMP	REEL CAPACITY	SOUND TRACK	EXTRAS
KODAK	*Ektagraphic Sound 8*	$199.50	18, 24			200 feet	magnetic	Automatic threading; limited availability in 1967.
	Instamatic M100	$575.95	18, 24	28, f/1.0	21 volt, 150 watt DKR	1200 feet	magnetic	Record and playback; transistorized, 4 watt amplifier; built-in 10 x 12" oval speaker, self-threading; reverse and single frame projection.
NIZO	*CSM-8*	$389.95	18, 24	18-30, f/1.3 zoom	21.5 volt, 150 watt	600 feet	magnetic	Self-threading; recording and playback; transistorized 5 watt amplifier; reverse projection.

Film

Below is a comprehensive listing of color and black and white film stocks commercially available for use in all three 8mm formats—Regular 8, Super 8, and Single 8. Double 8 refers to double width of Regular 8mm stock which is later sliced down the middle to give two strips of film. Film stocks on the chart are listed by manufacturers in alphabetical order. This chart is reprinted by permission of *Popular Photography* magazine from its 1967 Annual Buying Guide issue.

FILM WIDTH (mm)	FILM NAME	TYPE	EXPOSURE INDEX (ASA or equivalent) Day	Tung.	LENGTHS in FEET AND PACKING (D.L.=Daylight Loading; Mag.=Magazines B=Bulk; L.P.=Laboratory Packed)	SPECIAL CHARACTERISTICS FEATURES, AND USES
	Agfa-Gevaert, Inc.					
8	Agfachrome CT 13 S	Color	16	....	25 ft., 100 ft. D.L.	Fine-grain, very thin emulsion
8	Agfachrome CT 17S	Color	25(a)	40	25 ft., 100 ft. D.L.	Fine-grain, very thin emulsion
	Bolsey KII					
Sgl. 8	Daylight Type	Color	25	40	25 ft. D.L. magazine for Bolsey 8 camera	
Sgl. 8	Type A	Color	......	....	As above	
	Cinephonic					
Dbl. 8	Cinephonic, Type A	Color	10(a)	12	50 ft. D.L. rolls	Balanced for 3200 K photoflood
Dbl. 8	Cinephonic B & W	Pan	160	120	50 ft. D.L. rolls	
	Colorcade					
Dbl. 8	Colorcade	Color	10	10(a)	50 ft. D.L.	
Dbl. 8	Colorcade	Color	10(a)	16	50 ft. D.L.	
	Dynachrome					
Dbl. 8	Dynachrome 25	Color	25	12(a)	25 ft. D.L. rolls	Reversal, fine-grain
Dbl. 8	Dynachrome 40	Color	25(a)	40	25 ft. D.L. rolls	Reversal, fine-grain
Dbl. 8	Natural Color, Daylight Type	Color	10	5(a)	25 ft. D.L. rolls	Reversal
Dbl. 8	Natural Color, Type A	Color	10(a)	16	25 ft. D.L. rolls	Reversal
Super 8	Dynachrome Super 8	Color	40		50 ft. continuous cartridge	
	Eso-S					
Super 8	Durachrome	Color	25	40		
Dbl. 8	Durachrome	Color	10	16	25 ft. D.L., 200 ft. B	
Dbl.8	Miracle Color	Color	25(a)	40	25 ft. mag.; 25 ft. D.L.; 100 ft. H-8 Bolex	High-resolution, fine-grain
Super 8	Miracle Color	Color	25	40	25 ft. cassette	High-resolution, fine grain
Dbl. 8	Deluxe Sepia	Pan	40	25	25 ft. D.L.	High sensitivity
Dbl. 8	Miracle Hi-Speed	Pan	250	200	25 ft. D.L.; 25 ft. mag.	High sensitivity
Super 8	Miracle Hi-Speed	Pan	250	200		High sensitivity
Super 8	4-S High Speed	Pan	....	800		Recommended for very poor light conditions
Dbl. 8	4-S High Speed	Pan	....	800	25 ft. mag.	Recommended for very poor light conditions
Dbl. 8	Super Panchro	Pan	40	25	25 ft. mag.	All-purpose
Sgl. 8	Super Panchro	Pan	40	25	25 ft. mag.	All-purpose
8	Standard	Ortho	20	....	8mm: 25 ft. D.L.; 16mm: 100 ft. D.L.; 8 and 16 mm mag.	For outdoors
Dbl. 8	Hi-Speed Color	Color	....	125	8mm: 25 ft. D.L.; 16mm: 100 ft. D.L.; 50 ft. mag.	For available-light conditions
Dbl. 8	Triple Speed	Pan	....	1600	8mm: 25 ft. mag.; 16mm: 100 ft. D.L.; 50 ft. mag.	For low-light situations
Super 8	Triple Speed	Pan	....	1600	25 ft. mag.	
Dbl. 8	Economy Plus	Ortho	5	....	25 ft. D.L.	Fine-grain
Dbl. 8	F-G Positive	Ortho	5	2		Suitable for negative or reversal processing; no anti-halation backing

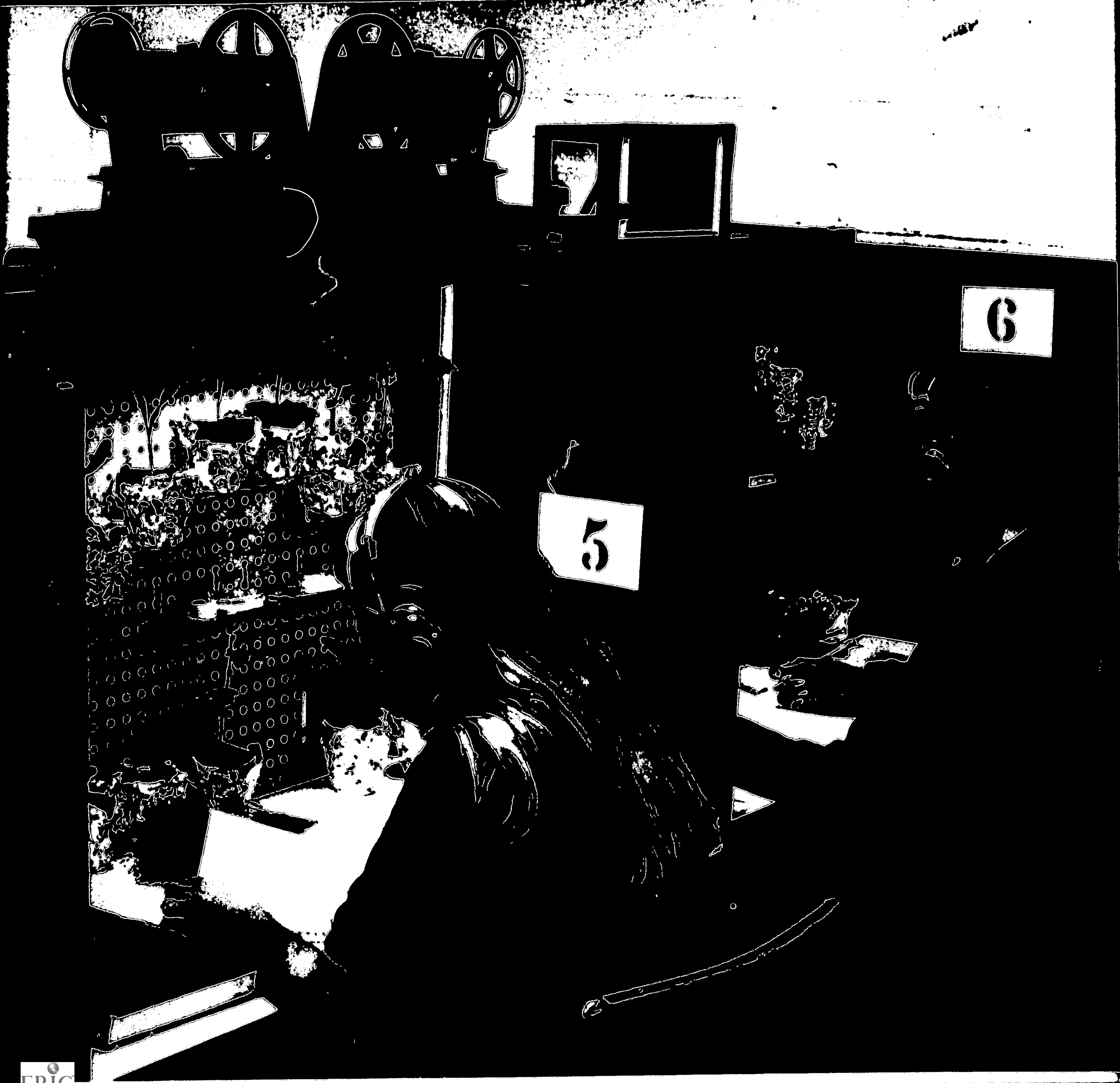
Dbl. 8	Hi-Speed Sepia		Pan	250	200	25 ft. mag.	Sepia color; for low-light situations
Super 8	Hi-Speed Sepia		Pan	250	200		Sepia color; for low-light situations
Dbl. 8	Pioneer Color		Color	40	100	200 ft. B.	
	Fotochrome						
Dbl. 8	Fotochrome		Color	16	24	25 ft. spool load	
	General Aniline & Film Corp.						
Dbl. 8	Moviechrome Daylight		Color	20	10(a)	25 ft. rolls	High-speed, fine grain
Dbl. 8	Moviechrome, Type A		Color	10(a)	16	25 ft. rolls	High-speed, fine grain
	Kin-O-Lux						
Dbl. 8	Kin-O-Lux T-V (Rev.)		Pan	64	50	25, 100 ft. D.L. Rolls	Medium speed; fine grain
Dbl. 8	New Gold Seal		Pan	200	160	25, 100 ft. D.L. Rolls	Use under poor light or tungsten
	Kodak						
Dbl. 8	Kodachrome II, Daylight Type		Color	25	12(a)	25, 100 ft. D.L. rolls; 25 ft. mag.	
Dbl. 8	Kodachrome II, Type A (Photoflood)		Color	25(a)	40	Same as above	
Super 8	Kodachrome II, Type A		Color	25(a)	40	50 ft. cartridge	
Dbl. 8	Fine Grain Positive		Bl. Sens.	....	2	100 ft. on core	For printing from negatives, title making
	Perfect Photo, Inc.						
Dbl. 8	Perfect 8 Hi-Speed		Color	25	40	25 ft. D.L. rolls	
	Perutz						
Dbl. 8	Perutz Perkine U15		Pan	25	16	25 ft. D.L.	Reversal
Dbl. 8	Perutz Perkine U21		Pan	100	80	25 ft. D.L.	Reversal
Dbl. 8	Perutz Perkine U27		Pan	400	320	25 ft. D.L.	Reversal
	Sears						
8	Sears Color 7270, Daylight		Color	25	....	25 ft. D.L. rolls	Sound tracking available
8	Sears Color 7271 Indoor Type A		Color	25(a)	40	25 ft. D.L. rolls	
	Superior Bulk Film Co.						
Dbl. 8	Superior Color, Daylight Type		Color	10	3	25 ft. D.L.	Subtractive dyed image type; screenless
Dbl. 8	Superior Color, Tungsten Type A		Color	10(a)	16	25 ft. D.L.	Subtractive dyed image type
Dbl. 8	Speed XX	(s)	Pan	....	200	25 ft. D.L.: 200, 400, 1000 ft. B.	Fine grain, soft contrast. Hardened emulsion for high speed processing at high temperatures. For home processing
Dbl. 8	Superior 40	(s)	Pan	32	20	25 ft. D.L.; 200, 400, 1000 ft. B.	Fine grain, wide latitude, non-halo base, good contrast; for home processing
Dbl. 8	Superpanex 64		Pan	64	40	25 ft. D.L.; 200, 400, 1000 ft. B.	Fine grain, wide latitude; good contrast. Specially hardened emulsion for processing at high temperatures
Dbl. 8	Super 500		Pan	650	500	25 ft. D.L.	Gray non-halo base; fine grain considering speed; wide latitude
Dbl. 8	Eastman Tri-X Reversal		Pan	200	160	25 ft. D.L.; 100 ft. B.	Wide exposure and development latitude. For home processing
Dbl. 8	Plus		Ortho	16	3	25 ft. D.L.; 200, 400, 1000 ft. B.	Extreme fine grain; medium latitude; blue non-halo base; high contrast for copying. Can be processed under red safe light
Dbl. 8	Positive		Bl. Sens.	5	....	400, 1200 ft. B.	Fine grain release positive for printing. Can be reversed. Clear base

FILM WIDTH (mm)	FILM NAME	TYPE	EXPOSURE INDEX (ASA or equivalent) Day	Tung.	LENGTHS in FEET AND PACKING (D.L.=Daylight Loading; Mag.=Magazines B=Bulk; L.P.=Laboratory Packed)	SPECIAL CHARACTERISTICS FEATURES, AND USES
Dbl. 8	Superior 36	Pan	325	250	8mm: 25, 100 ft., D.L.; 16mm: 100 ft. D.L.; both 100, 200, 400, 1200 ft. B	Reversed-type; high-speed; opaque backing.
Dbl. 8	Superior 30	Pan	80	64	8mm: 25, 100 ft., D.L.; 16mm: 100 ft. D.L.; both 100, 200, 400, 1200 ft. B	Reversal-type; medium-speed; fine-grain; backing opaque
	Western Cine Service					
Dbl. 8	Ektachrome ER Type B	Color	80(a)	125	25 ft. D.L. Mag.; 16mm: 100 ft. D.L.	Reversal type
Dbl. 8	Plus-X Reversal	Pan	50	32	25, 100 ft. D.L. rolls; 25 ft. Mag.; 400, 1200 ft. B	Same as above
Dbl. 8	Tri-X Reversal	Pan	200	160	25, 100 ft. D.L. rolls; 25 ft. Mag; 400, 1200 ft. B	Same as above
Dbl. 8	Superspeed	Pan	600	500	8mm: 25 ft., 100 ft. D.L.; 16mm: 100 ft. D.L.	Reversal type; also available in prestriped magnetic

NOTES:

*Free processing on D.L. and magazines only.
(a) With filter recommended by the manufacturer.
(b) As reversal film.
(n) Not recommended for use with illumination.
(s) Also available perforated one edge for sound, rolls only.
(w) Trial exposure on white card with no lettering.

Appendix E   Audio Visual Instruction at Purdue University



Audio visual instruction at Purdue University[1]

The system used to teach freshman botany at Purdue was first conceived by Dr. S. N. Postlethwait six years ago. He was confronted with the age-old problem of presenting an interesting and motivating lecture to a group of students with a wide range of background preparation and ability. In order to allow the ill-prepared student to compete more effectively in the class, Dr. Postlethwait decided to prepare a special lecture on audio tape, file it with the tape library, and invite any student who felt he could use this extra help to do so. Of course the taped lecture was specifically for the student with a poor background who needed to hear the information given in a normal lecture hour either at a slower pace, or several times, in order to fully comprehend the material. But it wasn't long before two very exciting things became apparent to Dr. Postlethwait: First, the more adequately prepared students were *willing* to listen to the tapes and seemed to *learn as much* even though they were excused from coming to lecture; second, it seemed logical to provide the students with related materials so that when an object is studied, the student can see and hold the object in his hand as he is being told about it. Consequently, the students were asked to bring their text and lab books, and various other materials were provided, such as microscopes, prepared slides, charts, photographs, living plants, 2x2 slides, and any other material which aided the student in his learning the lesson. The tapes were prepared with all of these aids sitting before Dr. Postlethwait, and he pretended to be guiding an individual student through the week's lesson—thus the student-teacher ratio was reduced to 1:1, and the system has become known as the Audio-tutorial Approach to Teaching.

In the last five years much as been done in an effort to improve the system. I would like to describe the way the method is presently operating, and conclude with a discussion of how the method is utilizing what is known about the learning process.

The course structure involves three major study sessions:

1. A General Assembly Session (GAS), one hour per week
2. An Integrated Quiz Session (IQS), one half hour per week
3. An Independent Study Session (ISS), approximately four hours per week.

GENERAL ASSEMBLY SESSION (GAS)

All students in the course assemble in a large auditorium one hour per week. The instructor in charge of the course directs the study during this session. It includes the giving of general directions and announcements, movies, guest lectures, and items of this nature; but most importantly, it is the occasion for integrating and orienting the subject matter so that the student may appreciate its significance. The main objective in this session is to project to the student a personality for the course and to set an intellectual tone. The major effort is directed toward motivating the student.

INDEPENDENT STUDY SESSION (ISS)

The independent study session is done in a learning center which is open from 7:30 a.m. to 10:30 p.m. each week day. A teacher is on duty at all times to give directions and personal assistance to students as they may require it. The student may report to the learning center at his convenience and study as long

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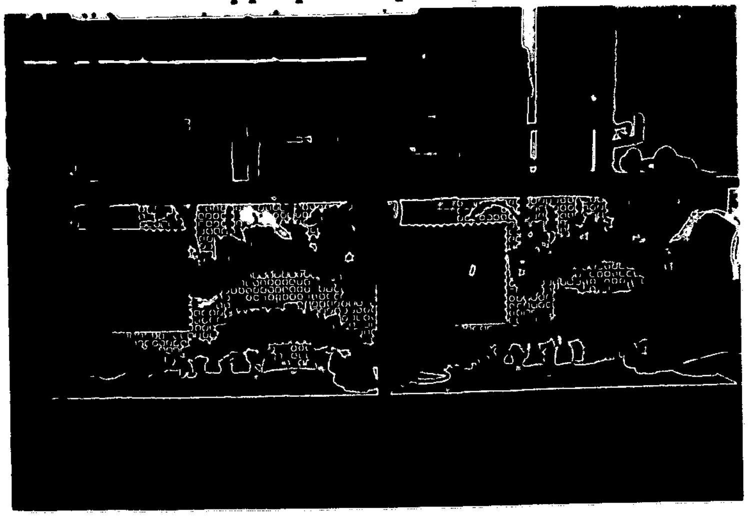
[1] This is an excerpt from an unpublished paper by David D. Husband of the Department of Biological Sciences titled "A Challenge to Educators."

as he wishes. He is welcome to repeat each session as many times as he feels necessary and to the depth he may desire. Thus the student is allowed to make adjustments to suit the pressures of other campus activities. The ISS involves a variety of study activities, including study of specimens, photographs, charts, slides, reading of text, performing laboratory exercises, observing experiments and demonstrations located on a centrally located table, conducting minor research problems, reading original research papers, conferring with students and teachers, and solving specific study problems related to the week's lesson. Students check into the learning center by signing a card and placing it in a slot on a "Booth Assignment File." This assigns them to a study carrel. All carrels are set up identically and contain material appropriate for the week's lesson. This may include a tape player with the week's tape, a microscope, clean slides and cover slips, prepared slides, materials for experimentation, plant specimens, excerpts from original research literature, diagrams, charts, 8mm movie projectors and loop films. Materials too bulky for inclusion in each carrel are placed on a demonstration table in the center of the laboratory.

The tape is prepared in a conversational tone by the senior instructor and tutors the students through a variety of learning events. The crux of the whole system depends upon the proper sequencing of the material to be presented. The first thing the student may hear when he listens to the tape is a brief lecture introducing the subject for the week and outlining the major objectives the instructor hopes the student will achieve in his study. The student may then be asked to read appropriate passages in his text or another source, and subsequently directed to perform an experiment or observe a demonstration which enforces that which he has just read. Once this piece of information has been mastered, the student is invited to pursue his study further. Each time he feels he has learned what is expected of him, he will go on to the next item. Each item builds upon the previous information, and when difficulty occurs the student is free to backtrack and review until he is no longer confused. An instructor is always available for special assistance.



Carrels are fully equipped with projectors, tape recorders, and specimens. (Courtesy of S. N. Postlethwait)

Although there is some similarity between this procedure and "programmed learning" advanced with teaching machines, there is at least one extremely important difference. Programmed learning involves dividing subject matter into tiny, discrete segments, and the student is allowed to progress one segment at a time—all segments being approximately equal in terms of difficulty and quantity of subject matter. In our course, the week's lesson is divisible, surely, but the student is the person who decides when to divide it—the decision being based on the individual's ability and prior knowledge. Therefore a student with a poor understanding of the laws of genetics may have to divide that week's lesson into rather small, discrete segments, whereas during the lesson on ecology this same student, having had an ecologically oriented high school course in biology, may safely perform the week's lesson by leaps and bounds! All activities which can be done under the conventional system can also be done under this system with the added feature of self-pacing by the students while being tutored by the senior staff member in the course.

Laboratory allows students to study at their own pace and to avail themselves of assistance. (Courtesy of S. N. Postlethwait)

INTEGRATED QUIZ SESSION (IQS)

For this session students are scheduled in the conventional pattern for a one-hour recitation. A group of 16 students is divided into two groups of eight and are assigned to an instructor to meet one-half hour each week. Although an oral quiz is given in this session, there is an informal atmosphere, with students and instructor seated around a table. Various items which were included in the Independent Study Session the preceding week are placed on the table and each student in turn is handed one item and proceeds to talk about it in a specified pattern. He begins by identifying the item, then he tells the role the item played in the week's lesson, and finally he discusses how it fulfilled that role by giving specific details about the item and the objective it satisfied. For example, if a student is handed a 3 week-old kidney bean seedling at the end of the first lesson his discussion might be as follows: "This is a 3 week-old kidney bean seedling. One of the objectives this week was for us to learn the structures of a young seedling of four different kinds of plants, and to be able to relate these parts to the structures of the corresponding seed." (Now, pointing to the structures, he begins to name them). "This is the hypocotyl, this is the cotyledonary node, these are the cotyledons, . . . etc." In addition to simply identifying the structures, the student would be expected to tell what he has learned about them as well, i.e. when he points to the hypocotyl he may add "since the hypocotyl has elongated and brought the cotyledons above the soil surface, this plant has epigeal germination."

The instructor evaluates each student on the basis of 0 to 10 by placing him into one of three categories. If the instructor is satisfied that the student has learned and understands well all the information which was expected of him, then the student is placed in the category of excellent and receives a score of nine. If the response was somewhat incomplete but yet it was obvious that the student had acquired some meaningful knowledge about the object, the student is placed in the mediocre category and is awarded seven points. If the instructor is sure that little learning has taken place on the part of the student, he is placed in the poor category and receives five points or less. Six points is passing. During the progress of the half-hour discussion, any student may alter his score upward by contributing information concerning the item under discussion when the student who is being quizzed is unable to provide all the answers.

Admittedly, this evaluation system is highly subjective. However, its virtues far outweigh its drawbacks. In the first place, I have found in actual experience that there is little question in my mind as to which category a student belongs after hearing his oral presentation. I have much more difficulty in evaluating an essay type question, even though I may have specific points I am looking for in the written answer. Secondly, this system of quizzing has been extremely rewarding in terms of feedback both to the students and the instructor. The instructor often becomes aware of those points which will enable him to restructure an improved program. But most importantly, the IQS gives the instructor an opportunity to reinforce the learned material by simply emphasizing the sequential pattern in which the material was presented to the student. This is why the session is called Integrated Quiz Session.

This, very briefly, is how botany is taught at Purdue University. The reaction from the students is that they highly favor the A-T Approach over the conventional method. Dr. Postlethwait has estimated that it has been possible to include 50% more subject matter without increasing the hours spent by the student in learning the material. Personal contact has been enhanced, interest has improved, and more students have been accommodated in less space and at a lower operating cost.

The critical reader will already have formulated several ways in which our system takes into consideration the learning process. Educational psychologists have known for many years that certain activities enhance the learning process. The Audio-Tutorial Approach to teaching utilizes every suggestion made by recent investigators. Listed below are a few of these activities.

REPETITION

Whereas it is unlikely that a student in a class of 300 will repeatedly raise his hand to ask questions on a particularly difficult area to him, he will hesitate little before rewinding the tape to hear something repeated. Thus the A-T Approach allows the individual to determine his own needs for repetition of subject matter and he can get the amount of repetition he needs with a simple turn of a button.

CONCENTRATION

Each student, being isolated in a carrel with earphones on, is less apt to be distracted with the movements and talking of other students.

ASSOCIATION

Meaningful learning is enhanced if the material being presented can be subsumed into the cognitive structure of the brain. Subsumption is enhanced if, when the material is presented, associations can be made which are meaningful. It is logical, then, that the learning about plants should be done where plants are available for observations. The A-T Approach provides the opportunity for the student to have a plant available at the time he reads about it.

APPROPRIATE SIZED UNITS OF SUBJECT MATTER

With the A-T Approach to teaching, the student is allowed to decide for himself the size of the individual units of subject matter he can comprehend. Thus, the student can move at his own pace, commensurate with his ability and background. This is also a great psychological aid to the student, for he does not get a defeated complex if he is a slow learner, and, if he is especially proficient in one area, he is not forced to waste his time sitting in a lecture or laboratory as would be required in the conventional system.

ADAPT THE NATURE OF THE COMMUNICATION VEHICLE TO THE NATURE OF THE OBJECTIVE

Since botany is a complex of subject matter, it requires a great variety of learning experiences. "It is logical then that no single vehicle such as lecturing or a text book can achieve the full spectrum of objectives for this subject," says Dr. Postlethwait. He goes on to say, "A properly structured course, therefore, would carefully define objectives and not try to mold objectives to fit a favorite medium (lecture, for example) but instead would use the medium best adapted to the nature of the objective. The Audio-Tutorial system permits this kind of student participation and enables one to bring to bear the correct medium commensurate with the objective."

THE USE OF MULTI-MEDIA

Since a student may learn best via reading, or hearing, or seeing, or doing, or any combination of these activities, the A-T system is advantageous to the student since it provides the opportunity for subject matter to be covered in a great variety of ways. The student is free to exploit the medium which best suits him as an individual.

THE PROPER SEQUENCING OF SUBJECT MATTER

We have become increasingly aware of the importance of integrating the material such that the student is made aware of the relationships between the principles being taught. When mastery of one item is necessary for understanding of a subsequent item, it stands to reason that even the spatial proximity of the items to one another is important in enabling students to subsume the relationships. In the conventional system, many times such items are separated in time as well as in space, and the relationships are infinitely more difficult to decipher. The A-T system lends itself well to analyzing one's sequencing of learning events. The method of evaluating students (IQS) is a constant source of feedback in this regard.

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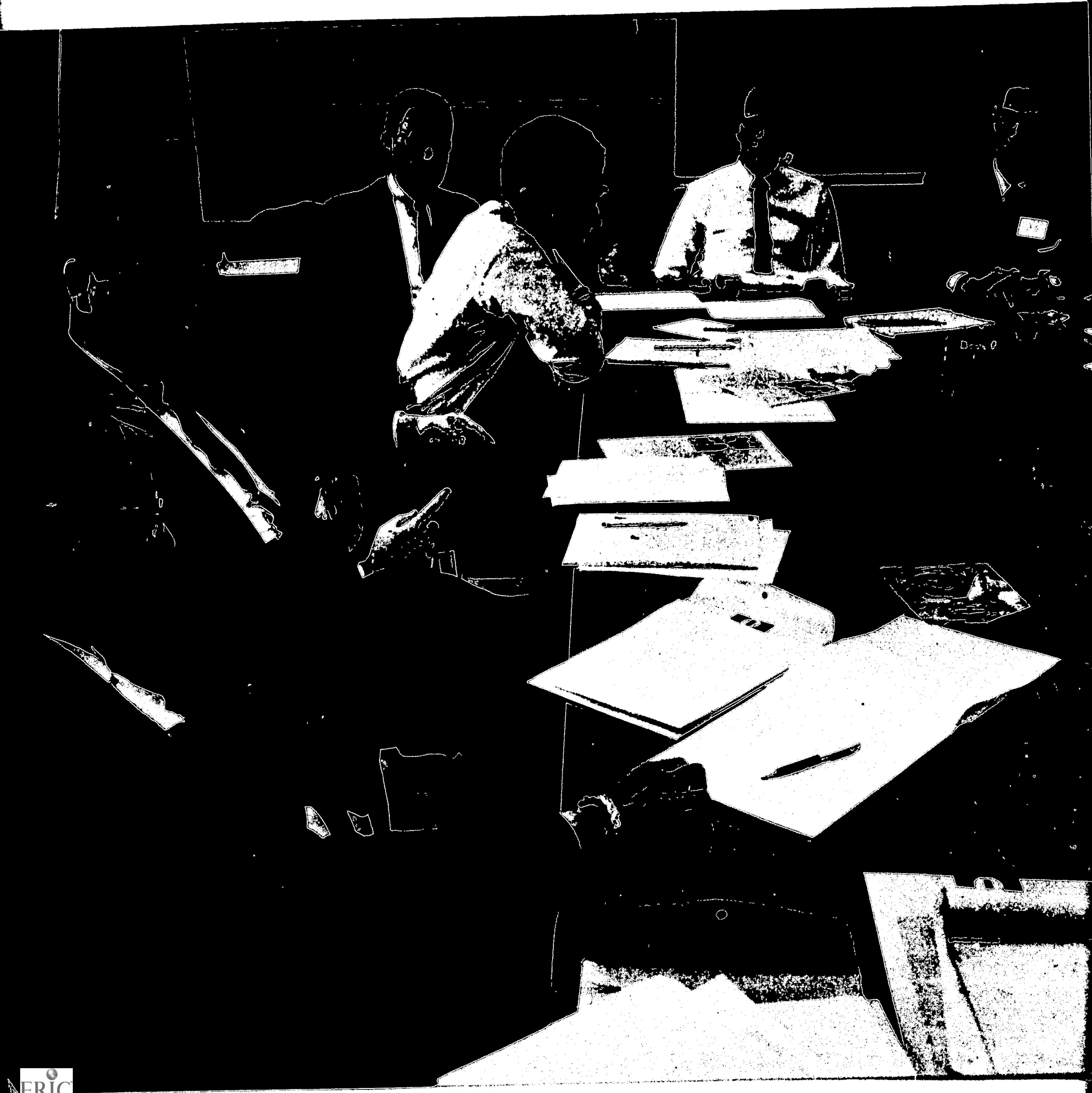
Appendix F List of Participants



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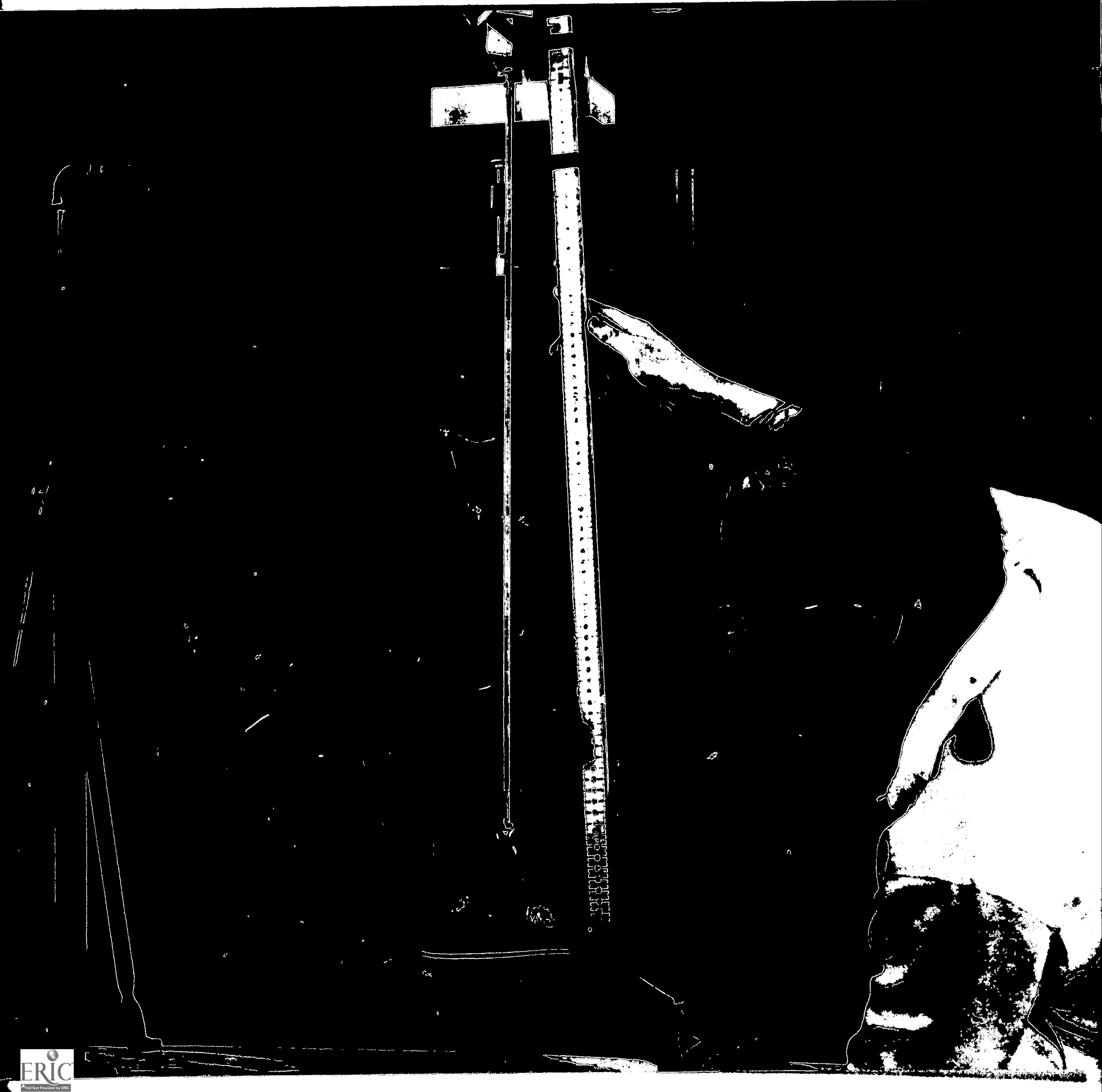
Appendix G Bibliography



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