UNESCO PILOT PROJECT

on New Methods and Techniques

in Physics Teaching.

Annual Report
July 1963 - August 1964

by

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and

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São Paulo, 1964

UNESCO Pilot Project

on New Methods and Techniques in Physics Teaching

(Sao Paulo, July 1963 - July 1964)

Summary.

This Pilot Project brought together a team of 3 UNESCO experts, 3 consultants and 26 physics teachers from 8 Latin-American countries. Their task was to analyse current ideas in physics teaching and search for new ones, to study modern methods and techniques, and specifically to apply all these to the development of a new physics course for secondary schools on the topic "Physics of Light".

The materials developed by the Project consist of: a programmed instruction text in 900 pages, 50 hours of student work (600 copies were printed in Portuguese, and 600 in Spanish); eight kits of inexpensive laboratory materials for experiments to be done by the students (200 sets of these were produced); twelve short silent films, 4 to 5 minutes duration each (35 sets of these were made); one half-hour film with sound (14 copies in Portuguese and 16 copies in Spanish were made); and eight television programmes which were broadcast (250 copies of the scripts were printed). All these materials have been distributed, mainly to the Project participants.

The resulting "Physics of Light" course was presented to, and was analysed and discussed by, another 36 physics professors teachers and administrators from Latin-America during a 4-weeks Regional Seminar held in Sao Paulo in July 1964 (14 countries were represented. At the same time, the course was given to a pilot class of 30 students. This Regional Seminar completed the first phase of the Pilot Project.

Recommendations.

We recommend support from UNESCO for continuation activitie to take place in the countries that have sent participants to th Project: both for further evaluation of the teaching materials produced by the Project, and for development of new materials.

Furthermore, in order to make the experience gained at the Pilot Project available to those interested in it, and also to stimulate further research in this field, we recommend that a publication on the Pilot Project, in the series "Educational Studies and Documents", be issued by UNESCO. We could assist in the preparation of this.

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for the Pilot Project:

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Introduction.

The development of society during the past decades has been dominated to an increasing extent by the advance of science and technology and their application to all aspects of living. The gap in scientific and technological advancement between developed and underdeveloped countries is therefore threatening to create a widening gap between the two as regards general standard of living. In training scientific and technical personnel of all categories in underdeveloped countries we are, however, faced with the problems of an extreme shortage of competent science teachers and a lack of experimental equipment for the laboratory classes, which are an essential part of science teaching. We are further faced with the need of adapting existing curricula to the demands of modern science, and the necessity of investigating the application of new methods and media to the teaching situation of these countries. We are also lacking experimentation with applying the results of learning theory and experimental psychology to the teaching of students in cultural and social environments different from those of the western world.

In an attempt to investigate possible solutions to the problems of science teaching in underdeveloped countries, UNESCO's Division of Science teaching, under the direction of Dr. Albert V. Baez, is launching a series of Pilot Projects on various topics of science and in various parts of the world. The first of these, the UNESCO Pilot Project on New Methods and Techniques in Physics Teaching in Latin America, concluded its first (one-year) phase in July 1964. The following is a report on the activities and out-comes of this year. It is divided in two sections: the first one gives a general outline of the Project; and the second one gives a detailed description of the materials produced by the Project, together with representative samples, as well as some notes on various aspects of the work done.

Section I.

General outline of the Pilot Project.

1. The objectives and activities of the Pilot Project.

The UNESCO Pilot Project on the Teaching of Physics was initiated on July 8, 1963, in São Paulo, Brazil, and its first phase concluded with a Regional (Latin- American) Seminar on New Methods and Techniques in Physics Teaching, July 6 to July 30, 1964.

The objectives of the Project have been to explore new methods and techniques for the teaching of Physics in Latin America and to train University staff at Teacher Training Institutions in the development, production and application of these techniques. This has been accomplished by bringing together for one year 26 teachers from Universities and Pedagogical Institutes in 8 Latin American countries to develop a course of Physics at secondary school level under the guidance of three UNESCO experts and three part-time consultants. The topic chosen for this course, "The Physics of Light", is one of the important topics of modern physics. It is also a topic which is ideal as an introduction to an experimental physics course and which lends itself to illustrate most of the important aspects and principles of physics: the fundamental role of the experiment, the nature of physical laws, the use of theory for summarizing and predicting, the close connection between various branches of physics, and the limitations of simple and everyday concepts in accounting for complex physical phenomena.

The most important component of any physics course are the laboratory experiments, which should be performed by the [illegible] themselves. For this, simple and inexpensive equipment is needed; and one of the main efforts of the Project participants has been the development of such equipment. Eight "kits" containing material for a large number of simple experiments, all on the topic of "Physics of Light" have been developed, and 200 copies of seven of these kits have been produced. (Of the other kit, 20 samples were produced.) Some of the experiments represent an adaptation or simplification of existing material from other sources, some were developed from ideas in the literature, and some have sprung from original ideas of the participants.

The introduction of experimentation in the over-sized classes characteristic of regions with teacher shortage poses severe problems of instruction. Nor is the increasing number of students coming to school adequately compensated by increasing numbers of teachers. For this reason the development of self-instructional materials has become an urgent necessity. There are, in addition, many inherent advantages in the use of a self- instructional, or <u>programmed instruction text</u>. It ensures an active attitude of the student during his study, gives him immediate confirmation of his comprehension of the subject and allows him to follow his own rate of study. These advantages, which have been demonstrated in other areas of training (mainly in the U.S.A.), must be explored also in science teaching at secondary school level. The text for the "Physics of Light" course has therefore been developed by the Project participants according to the technique of programmed instruction, under the guidance of one part-time consultant on Learning Theory and one full-time specialist in programming. The preparation of the text has also included repeated testing on students and subsequent revisions. A preliminary mimeographed version in five units (six volumes), totalling more than 900 pages or 50 hours of student instruction, is now ready in Portuguese and Spanish (1000 copies) for further testing under classroom conditions.

There are many important experiments, however, which are beyond the possibilities of simple inexpensive "kits". They may require too expensive or elaborate equipment or be otherwise too difficult or dangerous for the students to perform. Ideally such experiments should be performed as demonstrations by the teacher. But the teacher mostly has too little time or equipment to prepare such experiments. This brings our attention to the use of educational films in science teaching. A film of an experiment, performed under ideal conditions, sometimes utilizing the possibilities of the medium to contract or expand space or time, has become a powerful aid to the classroom teacher. We may consider two different types of teaching films, however. One is the silent, short (3 to 5 minutes) film which shows one experiment or a series of experiments illustrating a single concept. The other type of film is the long sound film (20 to 30 minutes) which usually is a filmed lecture by an outstanding teacher showing a series of experiments and presenting an extensive argument. For several reasons the short silent film seems a more flexible and versatile tool. The absence of language makes it immediately applicable in all countries. The teacher is left as the master of the class, he chooses the context in which to show the film, he may stop the film at any moment to ask questions or give explanations. The possibilities of 8 mm projection is a further advantage as 8 mm projectors and films are relatively inexpensive and handy to bring into the classroom, and as there are projectors on the market which facilitate repeated projection as well as stopping the film at a critical moment. As part of the course on "The Physics of Light", the Project produced (with the help of two part-time consultants on film production and of local film makers) 12 short silent films as well as a half-hour sound film, the latter in two versions: Portuguese and Spanish. Detailed Teachers Guides have been prepared for each of the short films, with suggestions as to their use, subjects for discussions, etc.

The showing of the films to a larger audience should be one of the tasks o educational television. Television classes, showing a teacher on the screen, may also serve as models to other teachers on how to utilize simple experiments and short films in giving a physics class. With this in mind, the Project participants have prepared 8 television programs to become an integrated part of the "Physics of Light" course. These programs showed live experiments and also utilized the films produced by the Project as well as films from other sources. The programs were broadcast in São Paulo, on channel 4, in July 1964. The scripts of these programs have been mimeographed.

In experimenting with the above mentioned teaching tools and techniques: laboratory experiments, programmed instruction texts, short silent films, long sound films and television programs, the Project participants have at all times attempted to pursue and integrated use of all techniques. It has been the basic philosophy of the Project that none of them is self sufficient.

The resulting "Physics of Light" course was given to a pilot class during July 1964, and simultaneously presented to physics professors, teachers and administrators from Latin America during a Regional Seminar on Physics Teaching. This Seminar also discussed the experiences of the Project on the development and production of teaching materials, and on the continuation of the Pilot Project activities in other countries.

2. <u>List of staff and participants of the Pilot Project.</u>

Staff.

Dr. Albert V. Baez, Director of Science Teaching, UNESCO, Paris.

Dr. Pär Bergvall, Department of Physics, University of Uppsala, Sweden. (Director of the Project)

Dr. Nahum Joel, Departamento de Física, Universidad de Chile, Santiago, Chile. (Assistant Director of the Project)

Mr. Le Xuan, Department of Education, UNESCO, Paris. (Expert in programmed instruction)

Dr. Francis Mechner, Basic Systems, New York. (part-time consultant on programmed instruction)

Mr. Herman Engel, New York. (part-time consultant on films and TV)

Mr. Peter Robinson, New York. (part-time consultant on films and TV)

Participants.

Argentina:

Mrs. Alicia Scaparoni de Andrada, Instituto del Profesorado Secundario de Azul, Provincia de Buenos Aires

Mr. Rafael Eduardo Ferreyra, Instituto de Matemáticas, Astronomía y Física, Universidad de Córdoba

Mrs. Carmen Roby de Ferreyra, Instituto de Matemáticas, Astronomía y Física, Universidad de Córdoba

Brasil:

Mr. Claudio Zaki Dib, Departamento de Física, Universidade de São Paulo

Mrs. Gita K. Ghinzberg, Departamento de Física, Universidade de São Paulo

Mr. Manoel Jorge Filho, IBECC, São Paulo

Mr. Fuad Karim Miguel, IBECC, São Paulo

Miss Taiko Kishimoto, IBECC, São Paulo

Mrs. Jesuina Lopes de Almeida Pacca, Departamento de Física, Universidade de São Paulo

Mr. Liacir dos Santos Lucena, Colegio Estadual do Ateneo, Natal

Mr. Alberto Mello, Departamento de Física, Universidade de São Paulo

Dr. Paulus Pompeia, Instituto Tecnologico de Aeronautica, São José dos Campos

Miss María Teresa A. Silva, São Paulo

Mr. Antonio de Souza Teixeira, IBECC, São Paulo

Mrs. Therezinha Wagner de Campos, Departamento de Física, Universidade de São Paulo

Chile:

Mr. Héctor Muñoz, Departamento de Física, Universidad de Chile, Santiago

Mrs. Irene Villaroel de Muñoz, Departamento de Física, Universidad de Chile, Santiago

Mr. Fernando Veas, Escuela de Ingenieros Industriales, Universidad Técnica del Estado, Santiago

Mr. Juan Westphal, Departamento de Física, Universidad de Chile, Santiago.

Cuba:

Mr. René J. Montero, Instituto de Superación Educacional, Ministerio de Educación, La Habana

Ecuador;

Mr. Gonzalo Flores, Universidad Central, Quito

Mr. Osvaldo Proaño, Colegio Normal Juan Montalvo, Quito

Honduras;

Mrs. Alma Aída García, Escuela Superior del Profesorado, Tegucigalpa

Perú:

Mr. José Donayre Flores, Universidad Nacional de la Amazonía, Iquitos

Venezuela:

Mr. Gustavo Alcalá, Instituto Pedagógico, Barquisimeto

Mr. Oscar Colmenares, Instituto Pedagógico, Barquisimeto

3. Institutions associated with the Project.

The host institution of the UNESCO Pilot Project in Brasil has been the Instituto Brasileiro de Educação, Ciencia e Cultura, IBECC, São Paulo. The experience of IBECC under the direction of Dr. Isaías Raw and Mrs. Maria Julieta Sebastiani Ormastroni, in promoting science teaching in the whole of Brasil and its unique workshop facilities for the production of simple inexpensive laboratory equipment was one of the main reasons for choosing São Paulo as the site of the Project. IBECC has also contributed with laboratory and office space, Brazilian participants and technical personnel, and free television time for the broadcasting of programs. IBECC provided the contacts with other Brazilian Institutions and contributed to solving the transportation and other local problems.

T. project has been geographically located at the Physics Department of the University of São Paulo (Cidade Universitaria). Here we have been given generously of laboratory and office space, and granted the use of lecture rooms. The interest of the Department staff in our Project has been a constant source of stimulation to the Project participants.

For the production of educational films, early contacts were made with the Serviço de Recursos Audio-Visuais at the Centro Regional de Pesquisas Educacionais, also located at the Cidade Universitaria, São Paulo. This group, under the technical direction of experts from Michigan State University under a United States AID Program, has generously cooperated with the Project in the production of three short silent films and the long sound film.

Our main source of fellowships for participants has been the Centro Latino- Americano de Física, CLAF, which granted 6 fellowships of approximately US $ 100 monthly each to non-Brazilians. This valuable help is deeply appreciated. Further fellowships have been provided by the Brazilian Government through IBECC, the Argentinian National Commission for UNESCO, the Venezuelan Ministry of Education, USAID program, University of Chile, and UNESCO.

4. List of materials developed by the Pilot Project for the course on the "Physics of Light" (Description and samples are given in Section II).

(A) A programmed instruction text in five units (Portuguese and Spanish versions):
   0. Experiments and graphs
   1. Some fundamental properties of light
   2. A particle model for light
   3. A wave model for light
   4. Electromagnetic waves. - Photons.

(B) Eight kits of inexpensive laboratory equipment:
   1. Experiments and graphs
   2. Some properties of light
   3. Light and particles
   4. Photometry
   5. Pinhole camera
   6. Ripple tank
   7. Diffraction and interference
   8. Photons

   The students will do experiments with these kits as they work through the programmed text.

(C) Twelve short silent films (average time, 4 to 5 minutes each):
   0. Cock with mirror image
   1. Two experiments with images
   2. Reflected light: glass in liquids
   3. Rectilinear propagation (of light, drops in air, atoms in vacuum and electrons in vacuum).

4. Reflection of light and particles, I (flat and parabolic surfaces).
5. Reflection of light and particles, II (elliptic surfaces).
6. The pinhole camera
7. Pulses
8. Infrared radiation
9. Light, X-rays, and gamma rays
10. The photoelectric effect
11. Light and electrons

A booklet containing Teachers Guides for these films has also been produced.

(D) A 16 mm. film with sound, 30 minutes duration, on the subject "Light ... is it a wave?", showing single slit diffraction experiments with ripple waves on water, sound, radio waves and light, (Versions in Portuguese and Spanish have been produced).

(E) Scripts for eight television programs on which items (A) to (D) were used together with live experiments and some other materials:

1. Images
2. Some properties of light
3. Light and particles
4. Photographing without a lense
5. Waves
6. Is light a wave?
7. Beyond the visible
8. Electromagnetic nature of light. - Photons

5. The Regional Latin-American Seminar on New Methods and Techniques in Physics Teaching.

This Seminar took place in São Paulo between July 6 and July 30, 1964. It was organized jointly by the Pilot Project and UNESCO's Science Cooperation Office for Latin America (Montevideo).

The objectives of the July Seminar were to present the materials developed by the Project participants to a group of University professors, High School teachers and Education administrators from Latin America, and discuss this material with them. Furthermore, it was intended to make the materials and experiences of the Project known to a larger number of physicists and physics teachers and stimulate activities of science materials development in other countries. The participants to the Seminar, together with the Project participants, constituted a representative group of 60 physics teachers from 14 Latin-American countries. Parallel to the presentation of the course of the Seminar, a test with secondary school students was conducted, and the test results were discussed.

The activities of the Seminar included:

a) Following the course on the "Physics of Light" by going through the programmed instruction text and performing the experiments, viewing the films and the television programs.

b) Discussions of the above materials, of the test results and of the reactions of the students.

c) Attending classes and group exercises, directed by the Project participants, on the problems and techniques of writing programmed instruction texts and of making films, television programs and kits of laboratory equipment. The programming course included frame-writing exercises and the film course the filming of an experiment with 8 mm equipment.

d) Conference sessions on various topics of physics and physics teaching, presentation of work going on in the various countries of the participants.

e) Visits to IBECC, the research groups of the Physics Department and the reactor of the Nuclear Energy Commission.

The reaction of the Seminar participants to the work of the Project was very favourable, and the following statement drafted by an elected committee, was issued.

6. Statement issued by the participants of the Regional Seminar.

1. The UNESCO-IBECC Pilot Project on the Teaching of Physics has accomplished a profitable and fruitful task and constitutes a valuable experience.

2. The Project has demonstrated the possibility of using new methods and techniques in physics teaching; but some large scale experimentation and evaluation would be necessary before their validity can be fully assessed. With this aim in view we recommend that these methods and techniques be further tested and evaluated throughout Latin-America.

3. The Pilot Project has achieved its fundamental aim, as several countries have shown interest in the continuation of the activities initiated by the Project.

4. We hope that UNESCO will give moral and material support for the continuation of the activities that will take place as an outcome of the Pilot Project, promote the exchange of infor-tion on the activities to be carried out, and help to maintain the links established at the Project.

We, the participants of the Pilot Project and of the Regional Seminar, are aware of our responsibility in the efforts to be made towards the progress of physics teaching, not only in continuing the activities initiated by the Pilot Project but also in spreading them on a national scale. We hope that these efforts will be assisted by the appropriate authorities.

We wish to express our thanks to UNESCO, to UNESCO's Science Cooperation Office for Latin America, to IBECC, to CLAF, to the University of São Paulo, and to the other institutions that have contributed to the Pilot Project and the Regional Seminar".

7. List of participants of the Regional Seminar.

Argentina:

Dr. Alberto P. Maiztegui, Director del Instituto de Matemáticas, Astronomía y Física, Universidad de Córdoba.

Mr. Félix Caricio Bosatta. Escuela Nacional de Educación Técnica, La Plata.

Mr. José Manuel Calvelo, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires.

Mr. Eduardo Hardoy, Universidad Nacional del Nordeste, Salta.

Mr. Heraclio Ruival, Facultad de Ingeniería, Universidad de Buenos Aires.

Bolivia;

Mr. Armando Gantier, Escuela Nacional de Maestros, Sucre

Mr. Angel Gustavo Pérez, (CLAF fellow)

Brasil:

Miss Lêda Araujo de Moura, Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro.

Mr. Geraldo Hélio Coelho, Faculdade de Medicina da Universidade de Minas Gerais, Belo Horizonte

Mr. José Augusto Cordeiro, Colégio Coração de Jesus, São Paulo.

Mr. Ernani Fernandes Barbosa, Colégio Estadual do Amazonas, Manaus.

Mr. Angelo Ferro, Colégio de Aplicação da Universidade de São Paulo.

Miss Beatriz Gonçalves de Alvarenga, Faculdade de Medicina da Universidade de Minas Gerais, Belo Horizonte.

Mr. José Pereira Pinto, Secretaría de Educação, Goiás

Mr. Oscar Alex Rebello, Colégio Estadual do Paraná, Curitiba.

Mr. João Augusto da Silva, Colégio Municipal, Natal.

Miss Aiko Tanonaka, Instituto de Educação Conde J. V. de Azevedo, São Paulo.

Mr. Raimundo Vasconcelos, Instituto de Educação do Pará, Belém

Dr. José Walter Bautista Vidal, Faculdade de Filosofía da Universidade da Bahía, Salvador

Mr. Isidoro Wasserstein, Colégio Visconde de Porto Seguro, São Paulo.

Chile:

Mrs. Rosa Jiménez, Instituto de Ciencias, Universidad de Chile, Santiago.

Mr. Roberto Morales, Instituto de Ciencias, Universidad de Chile, Santiago.

Dr. Darío Moreno, Jefe del Departamento de Física, Facultad de Filosofía y Educación, Universidad de Chile, Santiago

Mr. Roberto Núñez, Departamento de Física, Facultad de Filosofía, Universidad de Chile, Santiago

Colombia:

Mr. Emiro Alfonso Fabregas (CLAF fellow)

Ecuador;

Mr. Luis Felipe Almendáriz (CLAF fellow)

Mr. Galo Fabián Soza (CLAF fellow)

Mr. Manuel Humberto Villaviconcio (CLAF fellow)

México:

Dr. Manuel Diego Castillo, Comisión Nacional de Energía Nuclear, México

Nicaragua:

Mr. Oscar José López Jiménez (CLAF fellow)

Perú:

Mr. Carlos A. Bravo, Ministerio de Educación, Lima.

Miss Elvira Salazar de Puertas, G. U. E. "María Parado de Bellido", Lima

Salvador;

Mrs. Ethelvina Morillo de Escobar, Escuela de Medicina, Universidad de El Salvador, Centro-América.

Uruguay;

Mr. Juan Carlos Arruti, Dirección de Enseñanza Secundaria, Montevideo.

Mr. Alejandro Brunetto, Consejo Nacional Escuela Secundaria, Montevideo.

Venezuela:

Dr. José Alejandro Rodríguez, Jefe del Departamento de Matemáticas y Física, Instituto Pedagógico, Caracas.

(The staff and participants of the Pilot Project also took part in the Regional Seminar).

8. Continuation of Pilot Project Activities.

After this first year of the Pilot Project, the participants of the Project returned to their home countries with samples of the materials they have produced. Each full-time participant received five sets of the kits, fifteen or more copies of the text, one 8 mm film projector with a set of all the films produced by the Project, and in addition a set of ripple-tank films from ESI, USA. (The participants to the Seminar received one sett of the kits and one set, in some cases a few sets, of the texts). The participants have acquired during the year considerable experience and training in the development and production of teaching materials. The possibilities of continuation, along the lines initiated by the Pilot Project, of activities by the participants will of course vary very much from country to country, depending on the facilities available and on the number of participants. In response to a questionnaire, 3/4 of the participants considered their possibilities of continued work good or very good, only 1/4 judged them as doubtful. The continuation activities planned are of the following kind:

a) Testing of the materials developed and produced by the Pilot Project. This is possible for all the participants, even on a small scale. It is planned to collect and distribute the resul ts of these testing activities.

b) Revision of the preliminary version of the text based on the test results, and printing of a new version.

c) Further production of the Pilot Project kits for extended testing or for sale to students and teachers.

d) Development of new kits, texts, films and television programs, covering other parts of the physics curriculum for testing and distribution.

Testing and further production of the Project materials have already begun in Brasil, and concrete plans for testing and for development of new materials have also been presented by most of the non-Brazilian participants of the Project.

The forms of support UNESCO can give to the continuation activities are several. The distribution of copies of kits, texts and films, etc, to the participants as mentioned above, already represents a value of more than US $ 10 000 (cost price). To assist in further development work and coordination of the activities in the different countries, UNESCO is considering extending the contract of one of the Physics experts until 1965. Through the Centro Latino-Americano de Física (CLAF), UNESCO is supporting regional promotion of physics teaching. A provisional committee for the advancement of physics teaching in Latin-America consisting of five members has been formed under the auspices of CLAF. UNESCO is further considering supporting continuation activities in some countries by contracts utilizing Regular Program funds and through the use of Technical Assistance funds for experts and fellowships.

Section II.

Description of the materials developed by the Pilot Project, and some notes on their production and application.

9. Choice of topic and level of the course.

The topic of the course "Physics of light" was chosen because of its importance in modern physics and because it gives a good opportunity to illustrate the interplay between theory and experiment and the use of "models" in scientific theory. It has further been recognized (by the PSSC group at MIT) that properties of light constitute a much better topic for the initiation of a physics course than the conventional topic of "mechanics". The subject lends itself to simple experimentation and also demonstrates how other branches of physics such as mechanics of particles and waves, or electricity and magnetism, are connected with the study of light.

In the majority of previous physics secondary school courses, the modern part of the study of light comes at the end of the whole course. This is unfortunate as it often means that there is no time to read those last chapters. The extension of the study of light over a long period also makes it more difficult for the student to get an overall view of the discussion. Against this may be said that for an understanding of the modern evidence for the electromagnetic nature of light and the quantization of light energy, a thorough knowledge of mechanics and electricity is required. The present course tries to treat even the modern parts on a low level of prerequisites, however It is intended as the first part of a "concentric" or "spiral" approach to the subject, by which first a somewhat superficial discussion is given, which, however, covers the whole topic, including the modern parts.

It has been attempted to develop the "Physics of Light" into a course which may serve as an introduction to physics to students who have never had any physics before, and also a course which should give the students a knowldege of some basic methods and principles of experimental physics, in case it is the only experimental course they take.

10. General characterisitics of programmed instruction.

The technique of programmed self-instruction has during the last few years developed into an efficient tool for teaching and training various categories of industrial and military personnel. Its use in primary and secondary school education has been very little investigated, however. The text developed by the Project represents a serious attempt to program a longer science course for secondary schools with an integrated use of experiments. The potentialities of programmed instruction for offering relief in the present situation of world-wide teacher shortage derive from its being self-instructional: the students can work on their own in large classes with no, or very little supervision, and will meet the teacher only every third or fourth hour for discussion. Programmed instruction has several other advantages as well: it maintains an active response of the student at all times, the student gets immediate confirmation of his comprehension at every stage of the course, and he is allowed to follow his own rate of study. In addition to this, the principles of learning theory and behavioural technology are applied to the presentation of the material in order to ensure maximum efficiency of learning. A program looks different from an ordinary book in that the material is presented in small quanta or "frames". Every frame contains a question to be answered or an instruction to be carried out by the student. The correct answer to each frame is given on the following page. A few sample frames taken out of the program on colours of unit 1, are given in Chapter 16.

11. Some objectives of physics teaching.

In applying the technique of programmed instruction to a science text it is important to bear in mind the objectives of modern science teaching such as they have been formulated in the recent discussions on curriculum reform. In fact, the specification of objectives is always the first step in the construction of a program. This is, however, one of the most difficult tasks. Physics teachers and educators often say that they want to teach their students to "think" and "work independently". We need, however, much more concrete and operationally defined objectives as a starting point for the construction of a program. What do we wish the student to be able to do after having taken our course? The easy and traditional answer is to specify a certain domain of factual knowledge which the student should master. But a knowledge of bare facts is the least important of the objectives of science education. A knowledge of the methods by which factual information is obtained is much more important. We may take an example from the frames given here; they teach the method (the program in fact teaches various methods) of spectral analysis. The spectral colours transmitted by each colour filter is not important knowledge, but the method by which one can find out this information, is. A more general objective is the following: we wish the students to understand the fundamental role of experimentation in physics, how all our knowledge stems from experiments and how experiments are used to verify scientific theories. Such an objective can only be attained by giving a long experimental course. An important objective, however, is to give an understanding of the role of theory in relation to experiment. The physicist always tries to obtain quantitative information from experiments; he analyses the results graphically and attempts to summarize the results as simple mathematical formulas, the "laws" of physics. The technique of graphical analysis is taught in unit 0 of the "Physics of Light" course and is repeatedly applied in later units. A number of laws are then summarized in terms of a hypothesis, which frequently is formulated as a "model", like the particle and wave models of light discussed in our course. The use of models for predicting results of new experiments, and the experimental test of the models, is an important part of the scientific method and the most important principle illustrated in the "Physics of Light". But to teach a full comprehension of the concept of scientific model we probably need more examples than those given in the course.

As long as the above objectives are sought, it is of little importance which area of physics is treated in a course. The physics of light is, however, one of the most important and exciting topics of modern physics. It serves to illustrate, as well, the close relation between different branches of physics; which in itself is a valuable objective. In the "Physics of Light" course, not only properties of light are studied; properties of particles and waves, electricity and magnetism, heat radiation, gamma rays and photochemical reactions, are also investigated.

An important objective in science teaching is to show the connections between the science taught at school and the wonders of nature and everyday life. This objective is best attained by a good choice of the examples for the teaching of concepts . Radio, radar, artificial satelites, x-rays, etc. are all well known phenomena of the modern world which are used in unit 4 of the course.

12. Physics experiments with programmed instruction manuals.

The emphasis on experimentation by the student is perhaps the most significant characteristic of modern curriculum reform. The student should learn from his own observations, as this is the only way we ever learn. By doing experiments the student will also experience personally the principle of cause and effect, which is a basic component of the scientific attitude. In teaching a concept, it is important to furnish many examples to enable the student to generalize, but also non-examples to furnish material for discrimination which is an important part of concept formation. In an experiment illustrating a concept, the situations obtained when significant variables are changed furnish the discriminations, whereas variation of insignificant quantities enable generalization. To produce a spectrum with a prism, for instance, a slit is required. Absence of the slit (or the prism) give situations which are non-examples of production of a spectrum. If the slit is high or low does not matter, the spectrum only becomes high and low, but it is still a spectrum. The position of the prism relative to the slit is (within limits) also unimportant, the spectrum will be of a different width. Thus the insignificant variables in this simple case furnish a generalization within the class of spectra (or situations which produce spectra). To experience these discriminations and generalizations by personal experimentation is probably a powerful aid to concept formation.

It is often pointed out, however, that in experimental classes the student should not be given "cookbook" instructions to follow slavishly. He must always be given the freedom to follow his own initiative and be allowed to "play" with the equipment. A student who for the first time is given experimental equipment (like the typical student who begins with the "Physics of Light" course) will not feel free, but lost, if he is not given sufficient instruction. He must be given precise instructions to begin with, instructions which are then "faded", so that in the end (referring to the sample frames again) we can give such a general instruction as: "Do a spectral analysis of the light transmitted through the pink filter". The technique of programmed instruction does not limit or smother personal initiative; on the contrary, as the student works on his own, taking his own time, he is free to perform any deviations from the program that he may wish to do.

13. Comments on the programming technique.

The authors of the "Physics of Light" program have all been aware of the above objectives of modern science teaching (several of us have been familiar with these ideas many years before). As we began to apply the technique of programming which had been taught during the initial months of the Project by the programming experts, Dr. Francis Mechner, Basic Systems, New York, and Mr. Le Xuan, UNESCO, Paris, we found no formal way of including these objectives in the programming work. The objectives for each chapter were stated in terms of subject matter knowledge, such as "How can a ray of light be bent" or "Which experiments with light can only be accounted for by a wave model". The overall objectives had to stay in the back of our minds to be used when the approach was chosen, the examples selected, and the frames written. From the point of view of programming technology, this solution is not very satisfactory, as it requires the subject matter specialist to be involved also in the last stages of programming. It is our opinion, however, that the present state of the programming art does not allow the subject matter specialist to withdraw after stating the objectives to a behavioural technologist. An experienced teacher and physicist who has acquired the essentials of the programming technique is probably hard to substitute by a clever programmer with a little knowledge of physics, at all stages of program production.

We shall not present here a detailed account of the various stages of the programming technique used by us. Such an account is of little value as the technique is at present in a state of rapid development. We shall merely enumerate them as follows:

Outlining and specification of prerequisites
Specification of objectives
Behaviour analysis of the objectives
Construction of flow chart from the analysis
Sequencing
Frame prescription
Frame writing
Testing and revision.

Units 0, 1 and 2 were tested and revised three times before the printing of the present "preliminary version". Units 3 and 4 have in parts been tested and revised twice, in parts only once. Unit 4 was never tested on students which had taken all the previous units.

During July 1964, Units 0, 1 and 2 were again tested on a pilot class of 30 Brazilian students. The results of the test are presented in a separate chapter.

14. Notes on the use of programs in the classroom.

Regarding the use of programmed instruction in schools, it should be emphasized that the program does not substitute the teacher; it must be ragarded as one of the aids he has at his disposal. If the teacher is relieved of some of his instructional tasks he will have more time to spend on the stimulation, motivation, and education of his students.

Two more remarks regarding the use of programmed instruction in schools should be made, however. The first regards a common criticism of all programs: they are too voluminous. The number of pages in relation to the content is too high. It is said that the programs will be too expensive for the students. This criticism is based on the misunderstanding that each student should have a program of his own to keep. Once a student has gone through a program, it becomes of little value to him. It is very difficult to make revisions of one's knowledge with a program; it is even difficult to find a certain piece of information. The programs, consequently, are used by generation after generation of students in the same way as the kits are used. Even though blanks are left to fill in and squares left to cross out in the programs, it is not intended that the students should write in the books. They should give their answers in a separate work-book, preferably a response-book specially designed for the purpose.

This brings our attention to the need of special review books for each student, summarizing the information of the program, perhaps in the form of questions and answers. The Project has not produced any such books, but we hope to be able to do so in the near future.

The second remark regards the time it takes for the students to go through the programs. The average number of frames per hour made by a student of our program is about 40, which means that the total number of hours for the whole course is above 50 hours. This seems a lot for only a part of a physics course. But it should be remembered that this time includes home-work in conventional teaching. The use of programs brings quite new aspects on home-work. If a student takes a kit and a program home, he will be doing his home-work more efficiently. Some of the experiments of the "Physics of Light" course in fact are easier to do at home. In two cases they require individual work in darkness and in one case a radio receiver is needed (available in most homes but not so often at school).

It should be pointed out, that in underdeveloped areas the shortage of teachers and classrooms enable only a few hours of school attendance for the students. There are often two or even three sets of classes attending school only morning, afternoon or evening. Programmed instruction promises the use of out-of-school hours for efficient study.

15. The programmed instruction text for the course on the "Physics of Light".

The programmed instruction text, of 943 pages, contains 2155 frames, and is divided in five "units" numbered from zero to four. Unit 1 is printed in multilith, with text on both sides of the leaf, the other units are mimeographed with text on one side only.

Unit 0. Experiments and graphs. 240 frames, 105 pages, 10 printed panels. This is an introductory unit designed to provide some prerequisites needed for the analysis of quantitative experiments to come in later units (for instance the sine law of refraction, and the inverse square law for intensity of illumination). The first chapter deals with how to read and obtain information out of graphs on millimeter paper. The concept of proportionality and its graphical representation is then taught with many examples, including an experiment which the student does himself with weights and a spring, arriving at Hooke's law. The third chapter, "Analysis of experimental results", shows how experimental data are presented graphically resulting in various curves, how the curves can be rectified into straight lines by change of the variables and thus be summarized in simple mathematical formulae: "laws" representing the results of the experiments. The student performs an experiment measuring the time of oscillation of a pendulum as a function of its length and makes the graphical analysis leading to the pendulum equation. An appendix teaches the use of tables.

This unit can be used independently from the following units of the course.

Unit 1. Some properties of light. 474 frames, 200 pages. This unit studies some fundamental properties of light. It starts with the question "How do we see an object" and shows with slits that the path of light coming from an object into our eyes is a straight line. With the use of a torch projecting narrow beams of light the rectilinear propagation in water and glass is established. Sometimes a beam of light is deviated, however, and the conditions producing regular reflexion, diffuse reflexion, refraction and diffuse transmission are studied experimentally. When light is deviated by regular reflexion or refraction, we do not see the object, we see images . The study of images includes many examples and leads to experiments relating to the position of the images formed by reflexion and refraction, showing the need for a more quantitative study of these phenomena. This is carried out in the following chapters, where the laws of reflexion and the sine law of refraction are derived from experiments mainly with light beams. Reversibility of the light path and total reflexion are included. A final chapter deals with colours. Spectral analysis of reflected and transmitted coloured light is made with the use of a prism, by direct vision or by means of a beam of white light. Absorption is amply illustrated. What is meant by monochromatic light is shown with filters and an experiment with a sodium flame.

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Unit 2. A particle model for light. 212 pages, 412 frames. The behaviour of particles is studied quantitatively by means of marbles and is found analogous to the behaviour of light, as far as regular and diffuse reflexion, refraction, total reflexion and reversibility of light path are concerned. The possibility of summarizing the behaviour of light by a particle model is then investigated. After treating the concept of generalization, the text shows how the model predicts new properties of light: the transport of energy and the inverse square law for the intensity of illumination as function of distance from a point source. The latter prediction is verified experimentally by a quantitative experiment using a paraffin photometer. However, it is found that the prediction of the model regarding the change of speed of light when refracted is not sustained, and that the model does not predict or account for the phenomena which are observed when light passes through a narrow slit. As a conclusion, the particle model is abandoned.

Unit 3. A wave model for light. 760 frames, 328 pages (2 volumes). The particle model failing, we turn our study to wave phenomena, with the intent of finding a better model to account for the behaviour of light. Experiments with strings and the ripple tank illustrate the concepts of pulses and waves, what is a medium, velocity of propagation, wavelength and frequency of periodic waves, and the relation between wavelength, frequency and velocity. Quantitative analogies are established between the behaviour of waves and the behaviour of light regarding reflexion and refraction. Diffraction is then studied in experiments with light: as observed through a single slit and the shadow of a needle. Other examples of light diffraction are shown. Diffraction of waves is then demonstrated by ripple tank experiments and the analogies between diffraction of waves and light are established. A wave model for light is developed and compared with the particle model. Interference with waves and light is then studied, the Young double slit and the Lloyd mirror experiments, as well as a thin film interferen ce experiment, are performed. A quantitative measurement of tne wavelength of red and blue light is made by the double slit experiment. Some limitations of the model are discussed.

Unit 4. Electromagnetic waves. - Photons. 269 frames, 98 pages. Light propagates in vacuum. But if light is a wave, what is it that vibrates in empty space? We know, however, that radio waves also propagate in vacuum. To illustrate the nature of radio waves, a few simple experiments with a compass needle, a magnet and a battery with a wire are made, to produce and register electromagnetic pulses and periodic waves. Some properties of radio waves are discussed and their diffraction and interference are cited to prove their wave nature. The fact that both light and radio waves propagate in vacuum and with the same speed suggests a common electromagnetic nature. The photoelectric effect also indicates electric properties of light. Other types of radiation with the same nature as light and radio waves, but different wavelengths, are presented: infrared radiation, ultraviolet light, x-rays, gamma rays, which all make up the electromagnetic spectrum. Experiments with photographic emulsions show that fairly intense red of orange light is incapable of producing photochemical reaction, whereas light from the blue or green parts of the spectrum even with very low intensity does carry the energy sufficient to initiate reaction. An argument relating to the photoelectric effect: expulsion of electrons from zinc by weak ultraviolet light but not by intense light from an ordinary bulb, similarly suggests that light behaves as if its energy were divided in packets, which have higher energy the higher the frequency of light (photons). Conclusion: neither a simple particle nor a simple wave model suffices to summarize all the behaviour of light. Light as a phenomenon is too complex for its behaviour to be summarized in such crude models as particles or waves, even though these models have been shown to be very useful for discussing certain types of light phenomena.

16. Sample frames from the text.
(Unit 1, Chapter VI, Colours)

The 46 first frames deal with how light can be decomposed into a spectrum of colours, using, among other things, a glass prism. Absorption, and reflection of light by black and white surfaces has been discussed (transmission was dealt with in an earlier chapter).

Here follows an English translation of the next 25 frames. It should be noted that in the Portuguese and Spanish originals the answer to each frame (and the text of the next frame) always follow on the next page and not to the right (and below) as they are printed here. In the original, therefore, the student cannot see the answer, nor the text of the next frame without turning a page, and the text of the previous frame is hidden as well.

47.	Connect the projector and place the screen about 20 cm from the slit. If the projection of the slit on the sreen is very wide or irregular, adjust the lamp filament like you did before. (Frames 3 and 4 if you do not remember). Produce a spectrum on the screen with the prism. Write down again the sequence of colours of the spectrum, starting from the red end. (6 colours)	red orange yellow green blue violet

48.	Now you shall do some experiments to find out how objects other than black and white come to look coloured to the eye. In your kit there are five pieces of transparent coloured plastic, which we call filters. Look in turn through each of them at the white light from the lamp or from a white paper. The white light becomes coloured when it passes through the ______________ Write down the five colours you see.	filters red orange green pink blue
49.	Place the green filter in the path of the beam of white light coming from the slit of the projector. What happens to the beam?	It becomes green.
50.	Now look what happens with the spectrum when the filter is inserted in the white beam of light. Insert and remove the filter several times. For a direct comparison, place the filter so that it covers only the upper half of the slit. Choose carefully the sentence below which best describes what you see (a) The filter makes all the colours of the spectrum turn green. (b) The filter lets only the green part of the spectrum through and removes all the other colours.	(b) If your answer is (a) repeat the adjustment of the filament (frame 3,4) and repeat frame 50.

51. According to your experiment, the white light from the lamp becomes green when it passes the green filter, because the filter lets through _______________ and removes __________ which together make up the white light.	green the other colours
52. Now place the filter between the prism and the screen, so that the light first passes the prism and then the filter. Is the part of the spectrum the filter lets through the same now as it was when the filter was placed between the projector and the prism?	yes
53. What do you think you should see if you looked through the green filter (putting the filter close to your eye) at the spectrum of all colours? Try to think out the answer and then do the experiment to find out. What do you see?	The green part of the spectrum

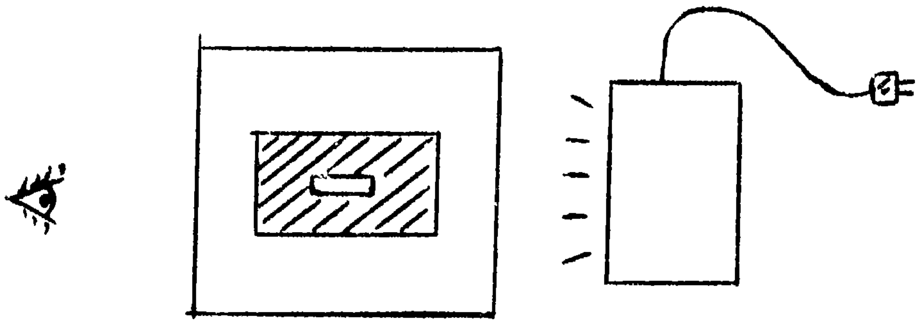
54.	Now take up the red filter. Observing the spectr ", you will find that the filter removes the following components of white light ___________ and lets through ___________________.	removes: orange yellow green blue violet lets through: red
55.	Try the blue filter and find out what it does to the white light. (Be careful, does it let through blue only?) According to your experiment the blue filter does the following to the white light:	It lets through blue, violet and green (a little yellow). It removes red.
56.	The mixture of colours which pass through the blue filter (blue, violet, green, a little yellow) looks pure blue <u>to the eye</u>. The human eye does not seem to be a very good instrument to distinguish the colours of the spectrum present in the light it receives. When you see the orange light coming through the orange filter, what colours of the spectrum does your eye receive? (You have to do an experiment to find out)	red orange yellow (a little green)

57. Note that the orange light you see when you look through the filter also contains red and yellow. The orange part of the spectrum, however, con - tains only orange light. But the eye does not notice the dif- ference. What is the difference between the blue light the eye sees (1) looking through the blue filter (2) looking at the blue strip of the spectrum	(1) contains also green and violet (2) contains blue only
58. Light which contains one colour of the spectrum only, and which cannot be decom- posed into other colours, is called monochromatic (Greek: mono = one, chromos = colour) Some of your filters let through mono- chromatic light. Which ones? (Find out by experiment)	the red one, the green one
59. Is the white light you see coming from the lamp monochromatic?	no

60. Now you should learn the scientific terms for what you have observed: We say that a filter <u>absorbs</u> the light it removes, just as we have said that a black object absorbs light. We say that the filters <u>transmit</u> the light they let through. The red filter _______ red light The green filter _______ red light The orange filter _______ red light	transmits absorbs transmits
61. The equipment you have used to find out which colours of the spectrum are transmitted by the filters, is an example of a <u>spectroscope</u>. You have been making <u>spectral analysis</u> of light. Make a spectral analysis of the light transmitted by the pink filter in your kit. The pink light transmitted by the pink filter is composed of: a, red d, green b, orange e, blue c yellow f, violet Is the pink light monochromatic?	a b e f no

62. You can also make a spectral analysis by looking at the spectrum through the filters (placing the filters close to your eye). Some of the colours of the spectrum are ________ by the filters and the others are ____________. Disconnect the projector.	transmitted absorbed
63. One useful way of making spectral analysis is to look through the prism. But only a prism is not sufficient: hold the prism close to your eye and look through it at a white paper in front of you. (Remember to hold it with an edge towards the eye as before, so as not to see the reflected image). Does the prism decompose the white light which comes from the centre of the paper?	no (only) the margins of the paper become coloured)
64. Remember that to produce a spectrum with a <u>lamp</u> and a <u>prism</u>, you used a narrow beam of light coming through a <u>slit</u>. In the same way, you must now look through the prism at white light coming from a _____ in order to see colours.	slit

65. Using the razor blade of the kit, cut a slit in the piece of black cardboard. The slit should be about 30 mm high and 1 mm wide.
Connect the projector and turn it over on the side so that the lamp illuminates a white paper in front of it.
Place the slit over the paper, like in the figure, so that you clearly see a strip of white paper through it. Go on to the next frame.



66. Place the prism over the slit, with a polished surface down, so that the upper edge is parallel to the slit.
Looking from above, how many images do you see? — two
Is (are) the image(s) formed by refraction or reflection? — refraction

67.	Observe one of the images and lift the prism slowly up to one of your eyes. May be you need to press the slit down to avoid shadows. Would it be correct to say that the experiment is a spectral analysis? Does the experiment confirm what you already know about the composition of white light? If so, what does it confirm?	yes yes it is composed of all the colours of the spectrm (or equivalent)
68.	The method to look at a slit through a prism is very useful for analysing light reflected from coloured surfaces. In the kit there are 9 pieces of coloured cardboard. Take the red one and place the lower half of the slit (cut in black cardboard) over the red, leaving the upper half over the white paper for a comparison. Make sure that the slit is well illuminated. Look at the slit through the prism like before. (If you have difficulties, start with the prism placed on top of the slit). The red surface reflects the _____ part of the white light and absorbs ________________.	red the other colours of the spectrum

69. Try other pieces of cardboard, always using the white as a reference. Observe which components of white light are reflected and which are absorbed by the coloured surfaces. Which two coloured cardboards (of very different colour) reflect the most monochromatic light?	a red and a green one
70. A surface absorbs red, orange, yellow, blue and violet. Which colour does it look like in white light?	green
71. From the experiments we may conclude that a coloured surface looks coloured when illuminated by white light because the eye receives part of the spectrum which is reflected - transmitted - absorbed (choose one) by the surface. The other parts of the spectrum are reflected - transmitted - absorbed (choose one) by the surface.	reflected absorbed

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17. Some notes on the kits of inexpensive laboratory material

Experiments, performed by the students, make an integral part of the "Physics of Light" text. The programmed instruction manuals represent, in fact, the textbook and laboratory guide fused into one. There are several reasons for experimenting with such an approach. It places the experiment (and observation) in its central position in the development of physics: the only source of information and the only means of testing theory and hypothesis. Furthermore, we can thus take better advantage of the experiment as a teaching aid for concept formation and make sure that the student understands the significance of each step as he is performing the experiment. It also becomes possible to introduce short, qualitative experiments in the middle of a longer theoretical argument. In addition, teaching classes utilizing only the blackboard and the copybook of the student, a type of class abundant in underdeveloped areas, are thus made impossible.

Instead of following purely "theoretical" classes, at intervals interrupted by intense experimental work, the students will do experiments all along as they follow the text. This is also a consequence forced upon us by the self-pacing of students following a programmed text. All students do not arrive at the same experiment at the same time. This becomes an advantage from the point of view of equipment cost: we do not need a complete set of equipment for every student. However, the experiments have to be designed so that they do not need spacious and elaborate laboratories. The student should be able to perform most of them in a conventional classroom or in his home. This requirement is a challenge to an optics course, where usually darkness is required. Several features of the kits of the "Physics of Light" course have been designed to enable work in an ordinary lit classroom with normal desk space, and all the experiments can be carried out at home.

Even considering the importance of the experiments, it might be considered a luxury to design a course where the student is experimenting almost all the time. All the units of the "Physics of Light" have their kits, and there are few chapters without experiments. This is in part due to the experimental and exploratory nature of the Pilot Project and the need to investigate the application of programmed instruction to purely experimental teaching. The future will show whether this "luxury" is economically feasible for an entire physics course.

The cost of the equipment is crucial to the applicability of the course. The cost (including the assembly) of the first version of the eight "Physics of Light" kits comes out very high, approximately US $ 30 for a set. This cost can be reduced considerably, however. All the items bought commercially, such as lenses, glass prisms, plates and blocks, were bought at a price quoted for 200 units, still a fairly small number for obtaining a good price. Several of the workshop-made items can be further simplified and the technique for their production perfected towards less waste of time and material. The design of the equipment can in several cases be simplified. The projector for light beams of kit number 2, for instance, is made of aluminium with a variable slit width, and came out at a cost price of $ 2. Made with a block of wood and cardboard, the cost will become less than a fourth of this price. The brass pendulum of kit number 1 should be substituted by a stone. A great part of the cost of kit number 2 comes from the prism and block of glass, price about $ 2 together. If the two units are made into one piece the cost is reduced by almost half.

Savings can also be made, if, instead of selling the eight kits separately, they are sold as one kit. Much repetition is thus avoided. Two kits, "Pinhole camera" and "Photons", contain chemicals and equipment for developing of photographic film. Sockets on wooden bases and straight filament lamps are part of many of the kits. Going one step further, we may compose a "class" kit for say 30 students, taking into account the fact that all students are not using the same material at the same time. Such a kit need only contain a smaller number of the more expensive items or of the items used only for a shorter time. In addition, some experi ments, such as the photometer or pinhole camera, may be carried out by groups of students together. For the ripple tank experiments one or two ripple tanks mounted by the teacher may serve a whole class.

How much the total investment cost of laboratory materialfor each student in a class following the "Physics of Light" course can be pressed down is still subject to investigation. It is quite probable that it may reach $ 5, which is about the same as the investment cost for the programmed instruction texts.

It has from time to time been suggested that instead of providing a kit to the student, a list of materials which he could himself buy or construct, should be given. This way of transferring the costs from the school to the student does not seem a satisfactory solution.Furthermore, it is doubtful that it will imply any saving of time or money. Centralized large scale production of material of uniform quality is undoubtedly to be preferred.

18. Description of the Pilot Project Kits.

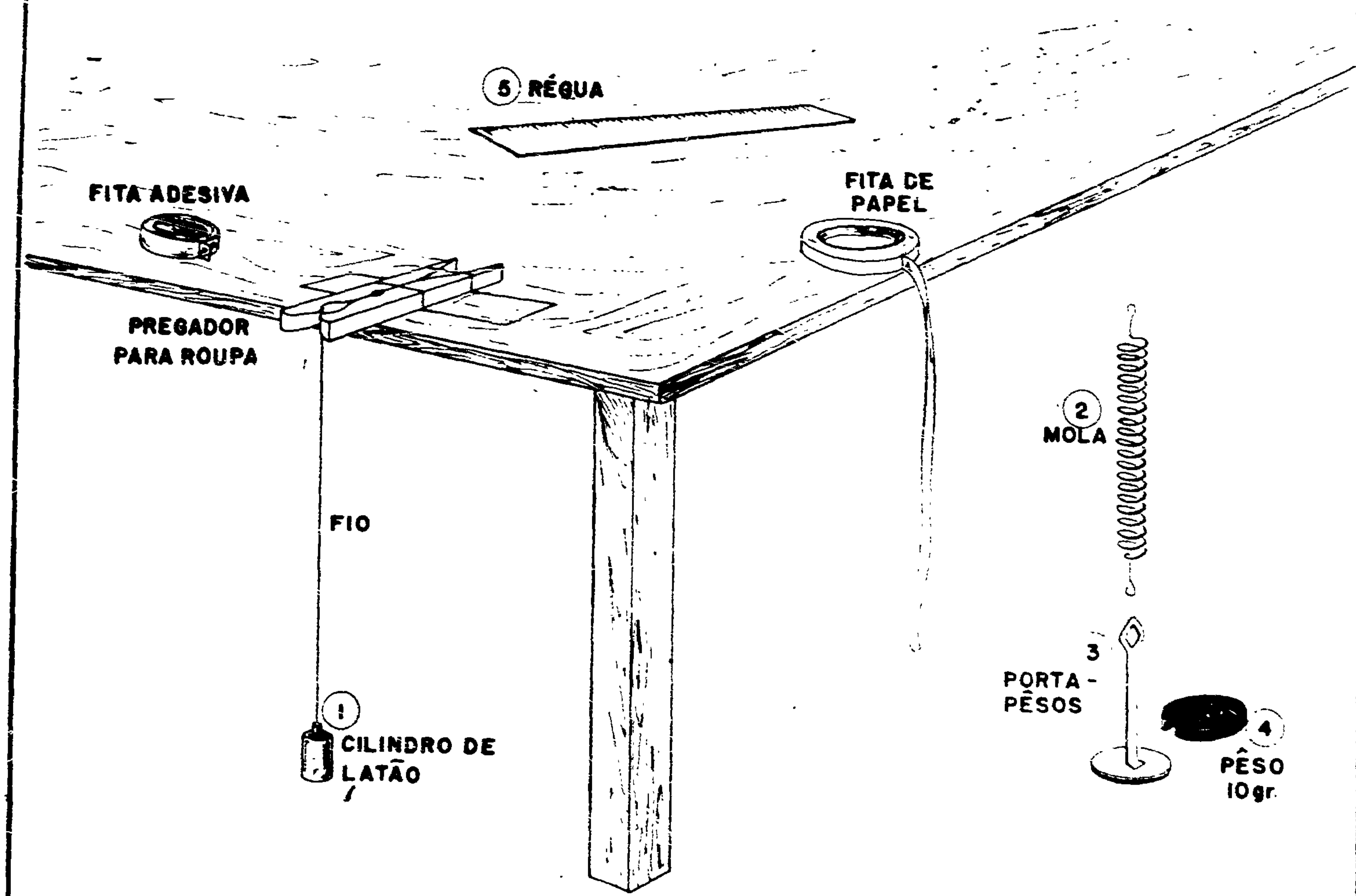
In the following pages lists are given of the contents of the eight kits developed and produced by the Project.

Following each list (except for the ripple tank) there is a detailed drawing of the components of the respective kit and also the cover of the box in which it is packed.

(1) Experiments and graphs (text: unit 0)

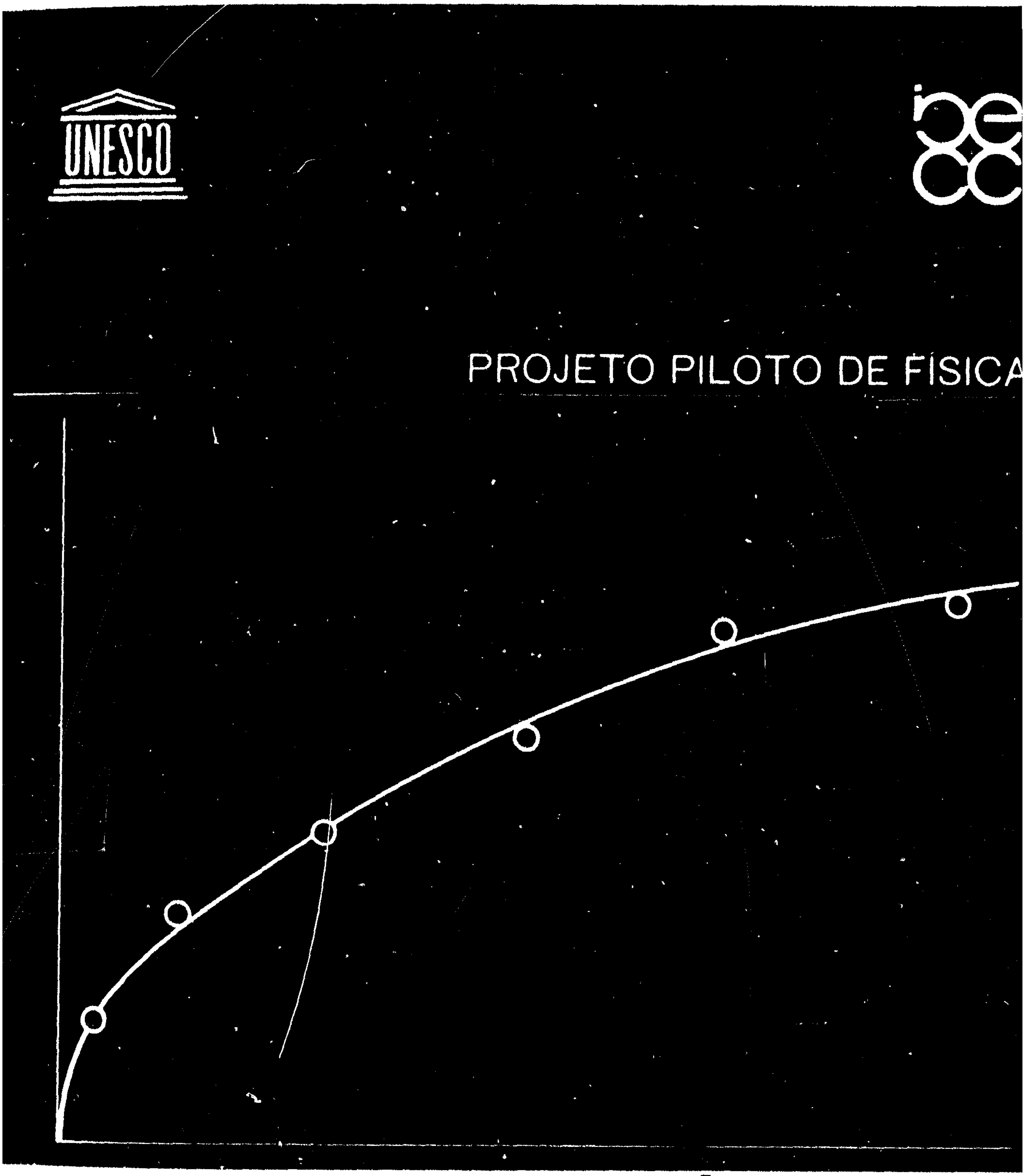
1 brass cylinder (for pendulum)
1 steel spiral spring
1 support for weights
10 brass weights of 10 grams
1 ruler 30 cm
1 roll adhesive tape
1 roll paper strip
1 string 1.50 m
1 clothes-pin.

EXPERIÊNCIAS E GRÁFICOS P.P/O



MATERIAIS

Nº		QUANT.
1	CILINDRO DE LATÃO	1
2	MOLA	1
3	PORTA-PÊSOS	1
4	PÊSOS DE LATÃO 10gr.	10
5	RÉGUA 0-30cm.	1
	RÔLO FITA ADESIVA	1
	RÔLO FITA DE PAPEL (serpentina)	1
	FIO (1,50m.)	1

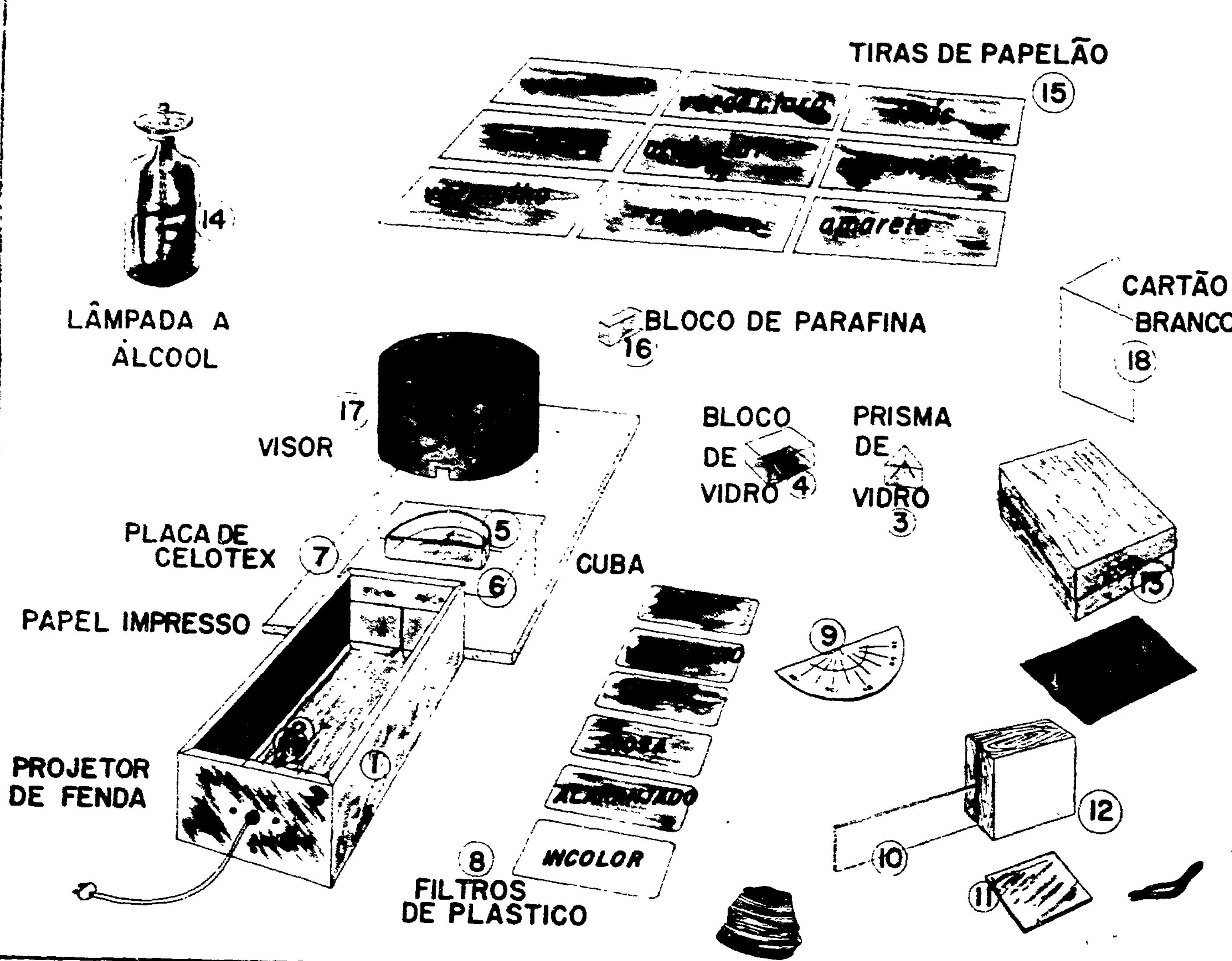


EXPERIÊNCIAS E GRÁFICOS

(2) Some properties of light (text: unit 1)

1 light-beam projector with socket, leads and plug
1 110 V 40 W lamp with straight filament
1 glass prism, 60º-60º-60º, triangular surfaces unpolished.
1 glass rectangular block, 2x3x3.5 cm^3, one surface unpolished
1 semicircular plastic tank
5 paper sheets with printed 360º divided circle
1 thick cardboard stage, 27x18x1.2 cm^3
6 plastic filters 5x6 cm^2, red, orange, green, blue, pink, colourless
1 180º plastic semicircle scale
2 glass slides (microscope slides) 2.5x7.5 cm^2
1 mirror 4x4 cm^2
1 block of wood with groove to hold glass slides, one side painted white
1 cardboard box
1 alcohol lamp: glass bottle and wick with holder.
9 strips of coloured cardboard 2x6.5 cm^2
1 paraffin block, 3x2x0.5 cm^3
1 black cardboard sheet 12x8 cm^2
1 black cardboard sheet 20x60 cm^2
1 white cardboard sheet 12x8 cm^2
1 piece of grammophone record, about 4x7 cm^2
1 wooden ruler, 30 cm
1 roll black adhesive tape
5 sheets millimeter paper
10 sheets white paper 16x22 cm^2
5 paper clips
10 pins
3 rubber strings
1 razor blade
1 steel strip 2x1x0.05 cm^3 (screwdriver for projector).

PROJETO PILOTO - KIT UNIDADE I (PP/ I)



Nº	MATERIAIS	QU.
1	PROJETOR DE FENDA	1
2	LÂMPADA DE FILAMENTO RETO 40W	1
3	PRISMA DE VIDRO 60°	1
4	BLOCO DE VIDRO (2x3,5 x 3cm)	1
5	CUBA SEMI-CIRCULAR, DE PLÁSTICO	1
6	CÍRCULOS GRADUADOS DE PAPEL	5
7	PLACA DE CELOTEX (27x18x1,2cm)	1
8	FILTROS DE PLÁSTICO (4,5x6,5)	6
9	TRANSFERIDOR	1
10	LÂMINAS DE VIDRO (2,5x 7,5cm)	2
11	ESPÊLHO (3,7x 3,7 cm)	1
12	BLOCO DE MADEIRA 1 FACE BRANCA	1
13	CAIXA DE PAPELÃO	1
14	LÂMPADA A ÁLCOOL	1
15	TIRAS DE PAPELÃO (2x 6,5 cm)	9
16	BLOCO DE PARAFINA (0,5x2x3)	1
17	VISOR DE CARTOLINA (20x60)	1
18	CARTÃO BRANCO (12 x 8)	1
	CARTOLINA PRETA (12 8)	1
	PEDAÇO DE DISCO DE FONÓGRAFO	1
	RÉGUA DE MADEIRA 30 cms	1
	FITA ADESIVA PRETA	1
	FÔLHAS DE PAPEL MILIMETRADO	5
	" " BRANCO (16x22)	10
	CLIPS	5
	ALFINETES	15
	ELÁSTICOS	3
	LÂMINAS "GILLETE"	1
	SERRA METÁLICA	1

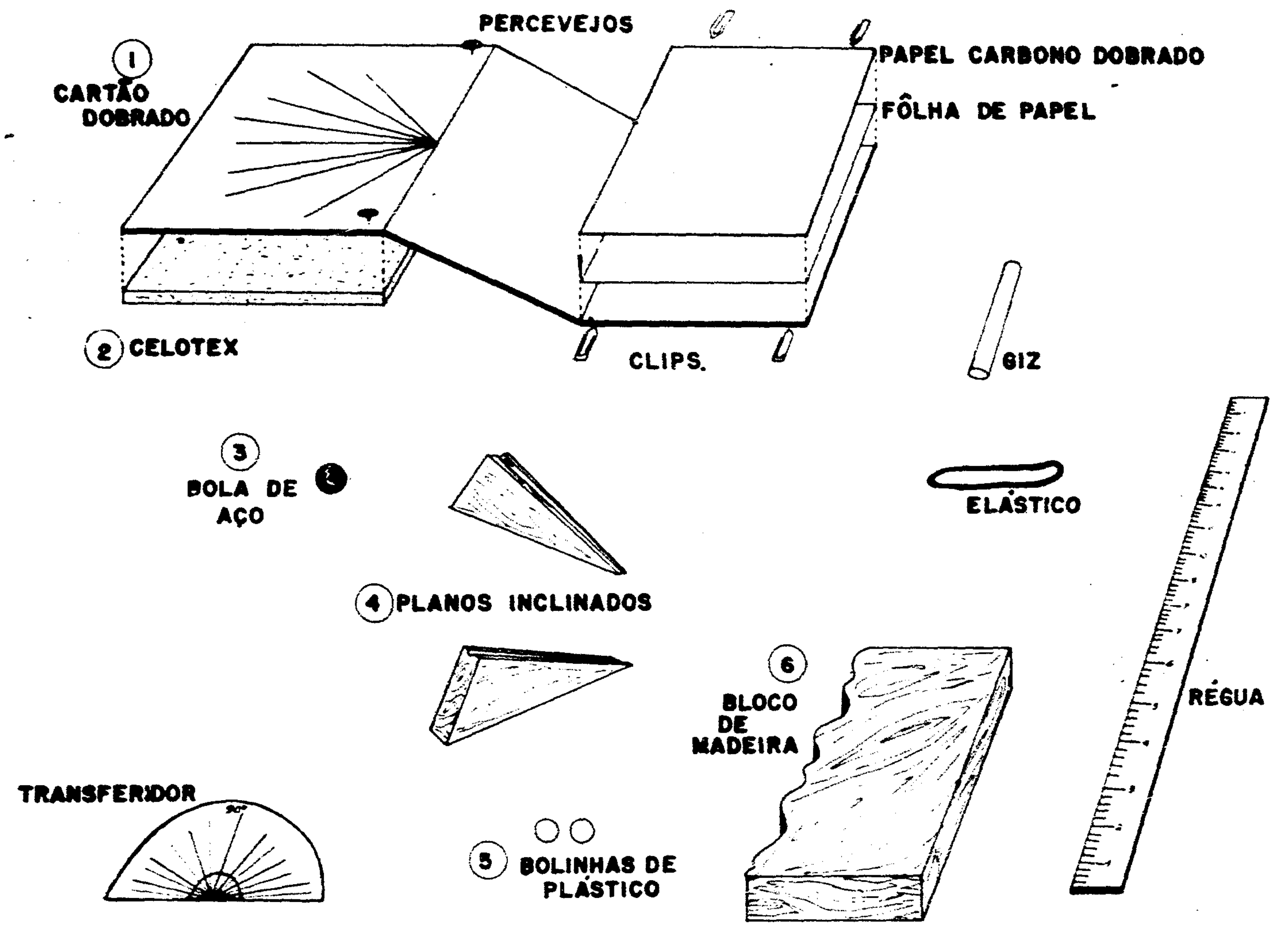
ALGUMAS PROPRIEDADES DA LUZ

(3) Light and particles. (text: unit 2)

1 white folded cardboard 41x26 cm^2
1 thick cardboard plate (celotex) 26x17x1 cm^3
1 steel ball Ø 1.6 cm
2 wooden inclining planes with grooves
2 plastic balls Ø 1.0 cm
1 wooden block 17x7x2 cm^3, one side irregular shape.
1 180º plastic semicircle scale
1 ruler 30 cm
5 drawing pins
1 sheet of carbon paper 22x26 cm^2
5 sheets white paper 22x14 cm^2
1 piece of chalk
4 paper clips
1 rubber string

MODELO DE PARTÍCULAS (P.P/2P)

Luz e Partículas



MATERIAIS

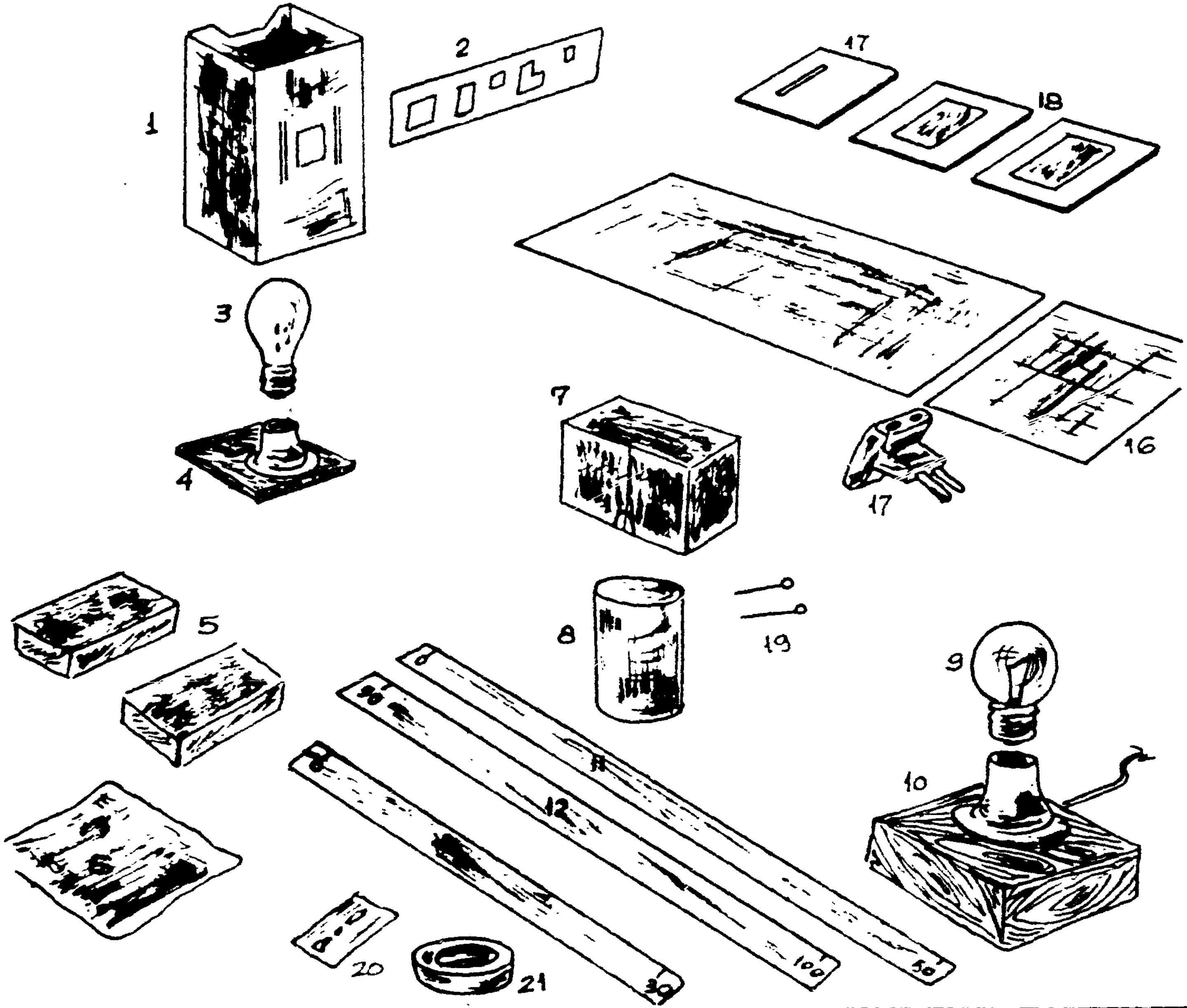
Nº		QUANT.
1	CARTÃO DOBRADO 41 x 26 cm	1
2	CELOTEX 17 x 26 x 1 cm	1
3	BOLA DE AÇO ø 16 mm	1
4	PLANO INCLINADO	2
5	BOLINHA DE PLÁSTICO ø 10 mm	2
6	BLOCO DE MADEIRA	1
	TRANSFERIDOR	1
	RÉGUA	1
	PERCEVEJOS	5
	FÔLHA PAPEL CARBONO 22x26 cm.	1
	FÔLHA PAPEL BRANCO 22 x 14 cm	
	GIZ	
	CLIPS	
	ELÁSTICO	

(4) Photometry. (text: unit 2)

(4) Photometry. (text: unit 2)

1 aluminium housing for lamp, with slit holder
1 brass strip with openings 4.00, 3.00, 2.00, 1.00, and 0.50 cm^2
2 sockets on wooden bases, leads and plugs
1 110 V, 60 W milkglass lamp
1 110 V, 40 W straight filament lamp
2 thin plastic rulers 50 cm
2 paraffin blocks 6x3x1.5, same colour, good cast.
1 electrical branching plug
1 cardboard box with lid, both 9x9x6 cm^3
1 aluminium foil 10x6 cm^2
2 mounted 35 mm photographic slides: single slits 0.11 and 0.21 mm.
1 roll adhesive tape
1 razor blade
1 millimeter paper
1 black cardboard sheet 25x50 cm^2
1 thick cardboard cylinder, Ø 5 cm, length 9 cm

FOTOMETRIA (P.P /2b)



1	projetor de alumínio
2	lâmina de latão c/ 5 orifício
3	lâmpada leitosa 60W.
4	base 9 x 9 com soquete
5	blocos de parafina 6x3x1,5
6	fôlha de alumínio 7,5x15
7	caixa de papelão
8	tubo de cartão
9	lâmpada de filamento reto 40W.
10	base de madeira 7x7x3
11	regua de plástico
12	" " "
13	" " "
14	tomada triple
15	cartolina preta 50x25
16	papel milimetrado
17	cartão preto c/ fenda
18	diapositivos
19	alfinetes
20	gillete
21	rolo de fita preta

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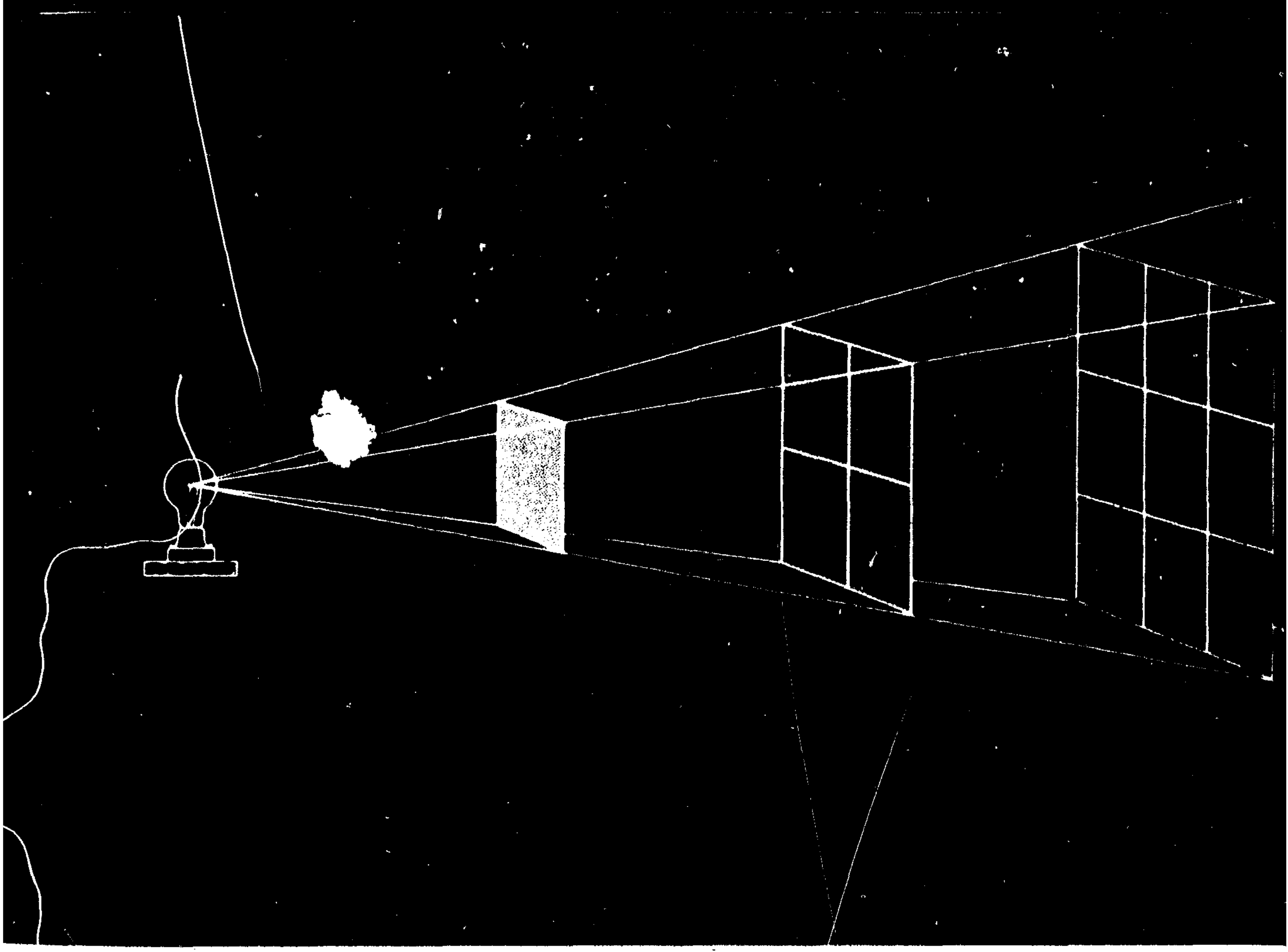
PROJETO PILOTO DE FÍSICA



FOTOMETRIA

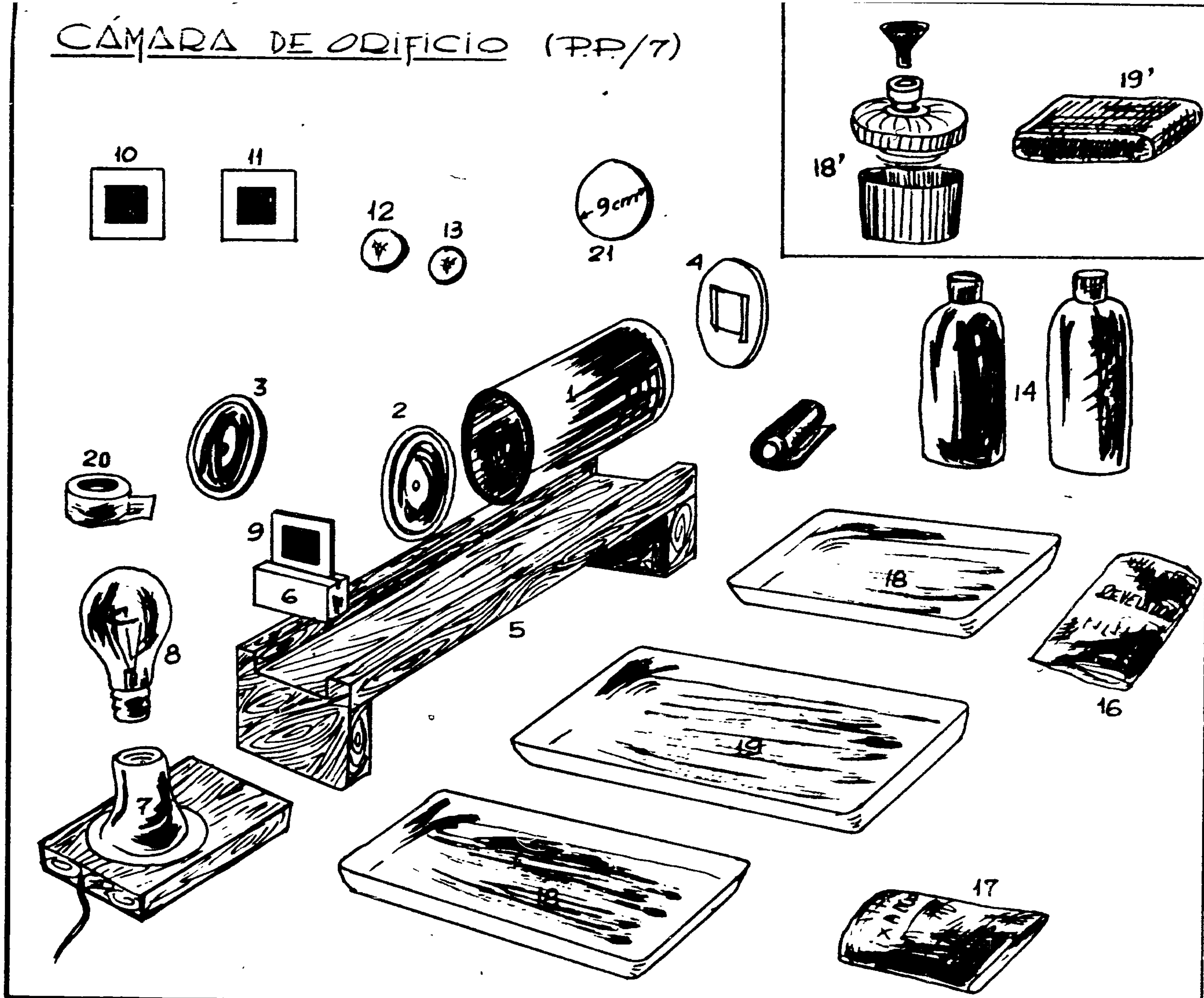
(5) Pinhole camera.

Instructions for this kit are not included in the "Physics of Light" text as the experiments are optional and not all students supposed to do them. The loop "Pinhole camera" shows the experiments performed with this actual kit, and a plate showing the photographic results is included in this booklet in the chapter on our films. Working with a camera made of a cardboard "tin" with lids on both ends and photographic emulsions, students register the images formed through a series of pinholes. With decreasing pinhole diameters the resolution of the image improves at first and then begins to deteriorate again. The kit therefore serves to introduce the concept of diffraction. The student may then take pictures with the largest hole using a lens and will obtain sharp images (one lens for short distance and one for "infinity" are supplied). He will finally take a picture with the largest hole covered with a Fresnel zoneplate, again giving a sharp image. This kit is based on an article by Albert V. Baez in the American Journal of Physics (1957), volume 25, pages 636-638.

- 1 cardboard "tin" Ø 10 cm, length 14 cm
- 5 lids
- 1 wooden support for camera
- 1 wooden holder for mounted slide
- 1 mounted 35 mm slide with text LUZ - OPTICA - FOTOGRAFIA (object)
- 1 mounted slide with photographic pinholes Ø 1.00, 0.60, 0.35, 0.15, 0.07 mm
- 1 mounted slide with Fresnel zone plate Ø 3 mm
- 2 glass lenses
- 1 socket on wooden base, leads and plug
- 1 110 V, 100 W milkglass lamp
- 1 bag developer for film, sufficient for 1000 ml
- 1 bag hypo, sufficient for 750 ml
- 2 polyethene bottles for developer and hypo solutions, 200 ml

2 plastic trays 15x12x2 cm^3 (for developer and **hypo**)
1 plastic washing tray 20x16x3 cm^3
1 roll of 35 mm film
1 roll adhesive tape
1 black cardboard sheet

CÁMARA DE ORIFICIO (P.P./7)



MATERIALES	
1	Cuerpo de la cámara
2	Tapa con orificio central ø 2 mm.
3	Tapa con orificio central ø 3.5 mm.
4	Tapa con soporte para película.
5	Banco.
6	Soporte.
7	Base lámpara.
8	Lámpara 100 W.
9	Diapositiva.
10	" 5 orificios ø 1, ø 0,6, ø 0,35, ø 0,25, ø 0,13 mm.
11	Diapositivo Placa donas do Fresnel f : 6.7cm
12	Lente
13	Lente
14	Frasco plástico 200 cm^3
15	pelicula 35 mm BOLSA
16	Revelador
17	Fijador
18	Bandejo plastico 9 x 12 cm
19	Bandejo plástico 16 x 20cm
20	Cinta adhesiva
21	Pedaso de papel vegetal
18'	tanque para revelado a plena luz 35mm
19'	Bolsa negra con mangas para proceso a plena luz.

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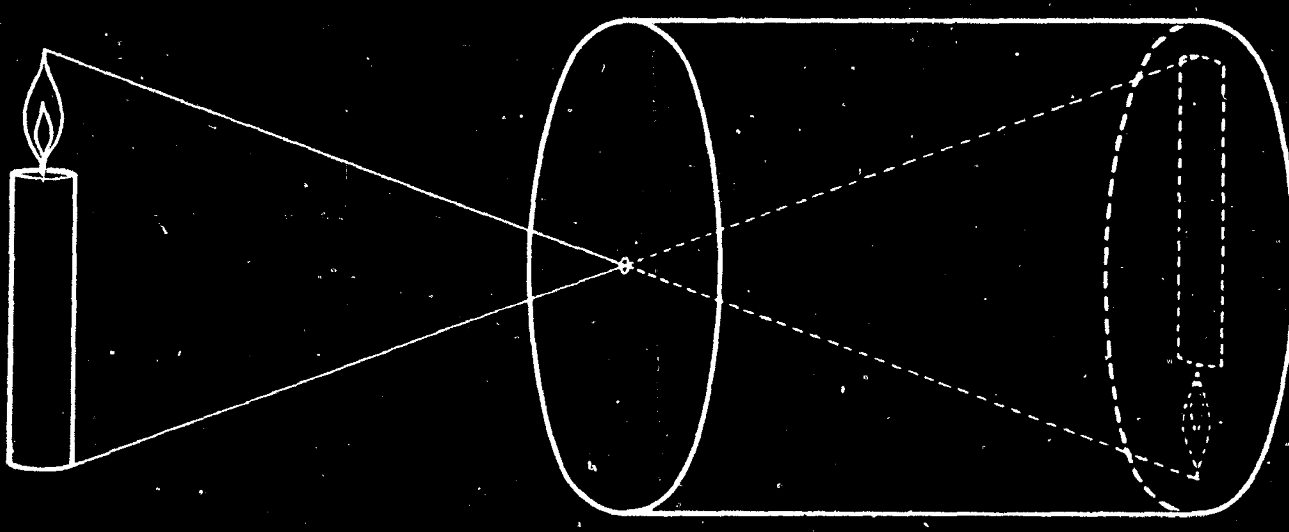
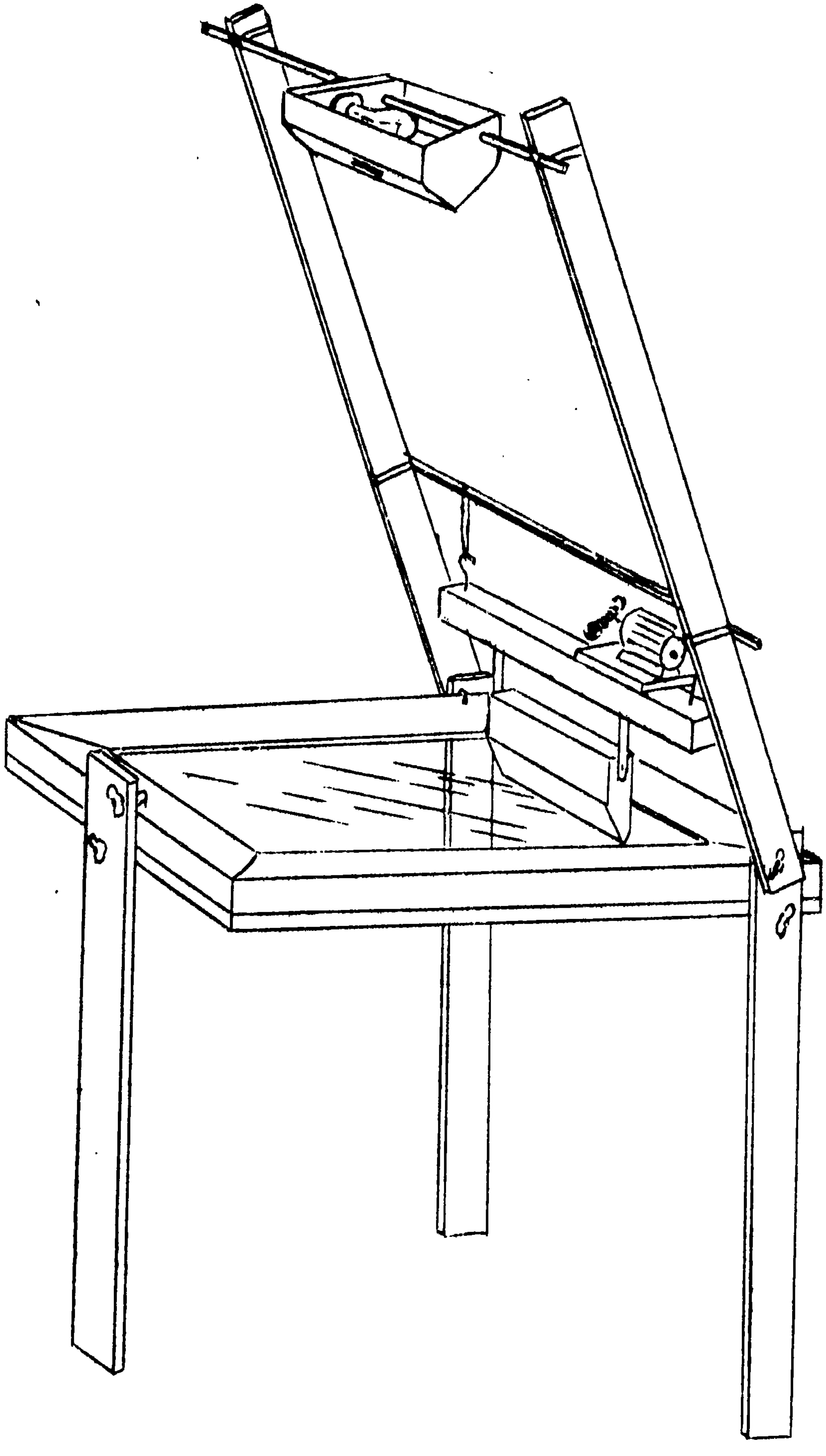
PROJETO PILOTO DE FÍSICA



CÂMARA DE ORIFÍCIO

(6) Ripple tank (text: unit 3)

This ripple tank was developed with the aim of obtaining a model to be cheaper and easier to assemble than previous ones. It is smaller, but nevertheless serves to demonstrate reflection, refraction, diffraction, interference, etc. clearly and with good focus on the table or with ceiling projection. "Beaches" on the wooden frame, optimized to eliminate wave reflection, enable the use of the whole free surface of 25x20 cm^2. The height of the tank above the table is 35 cm and the overall height 90 cm. There are three wooden 40 cm legs, each screwed to the frame with two simple clamps enabling an adjustment of height within 2 cm. The lamp and agitator are mounted on the same support: two wooden 60 cm sticks fastened to the frame by the same clamps as the legs. The agitator, driven by an off-balance 1.5 V motor, can be changed from plane waves to circular waves, from one to two sources, by a flick of the wrist. A 10 cm resistance wire is furnished to change the frequency. The tank is assembled and adjusted by one person within 5 minutes, and should, apart from the motor and a few accessories, be easy to manufacture by any wood workshop. A drawing of the assembled tank is given on the next page.



(7) <u>Diffraction and interference.</u> (text: unit 3)

1 socket on wooden base, leads and plug
1 110 V, 40W straight filament lamp
1 glass plate, high quality cast, 20x5x0.5 cm^3
8 mounted 35 mm photographic slides (microfilm):
3 single slits 0.21, 0.11, and 0.07 mm width;
4 double slits, width and separation 0.13 and 0.62, 0,06 and 0.28, 0.037 and 0.19, 0.013 and 0.065 mm respectively,
1 statistical distribution of triangles
1 lens focal distance 70 mm, Ø 20 mm
1 fine mesh piece of cloth
2 plastic filters, red and blue, 5x6 cm^2
2 wooden supports, for lens and for pins
1 aluminium foil 6x6 cm^2
1 rope, 5 m length, 3 mm thick (clothes-line)
1 ruler 30 cm
2 clothes-pins
2 pins.
1 black cardboard with slit

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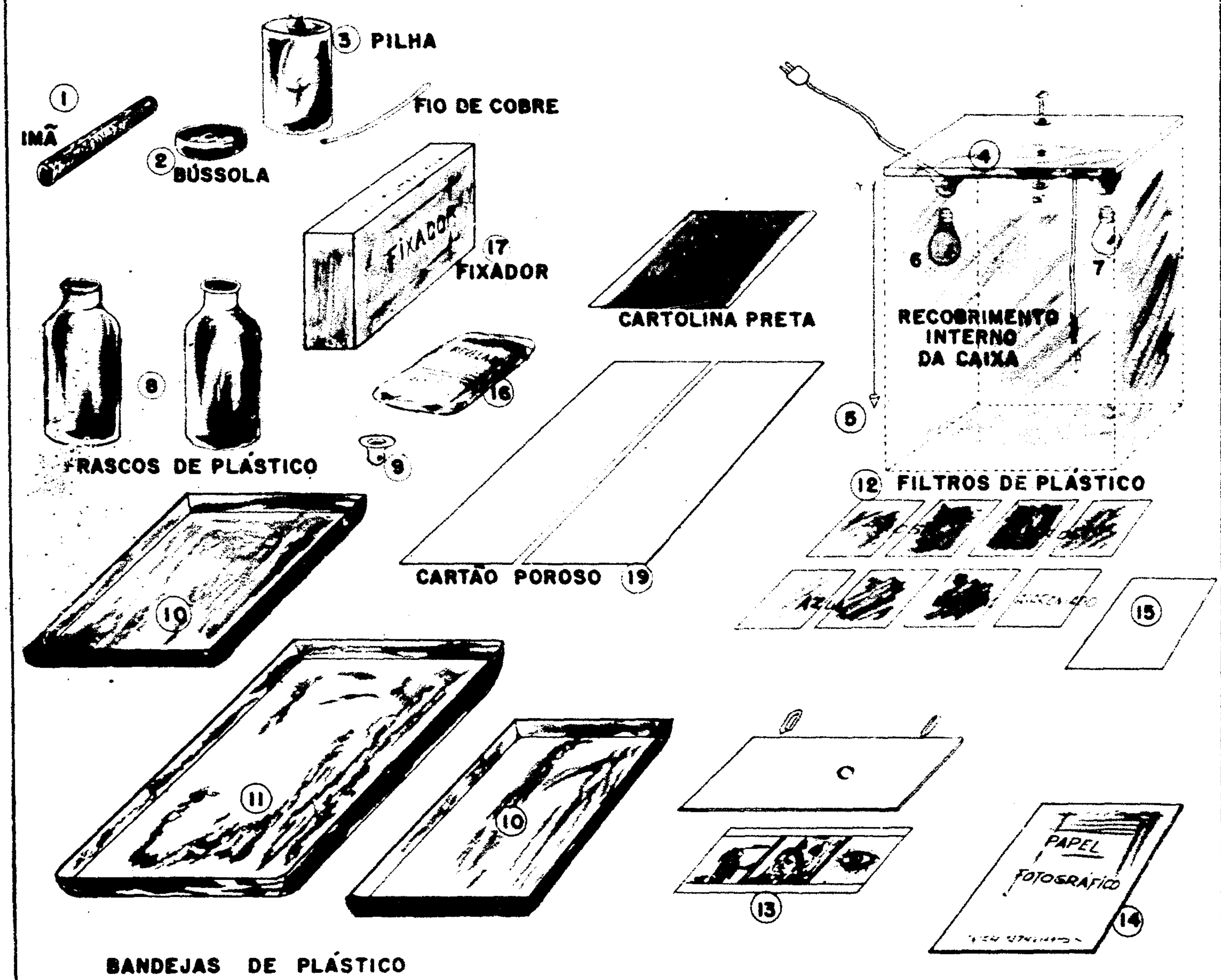
PROJETO PILOTO DE FÍSICA

DIFRAÇÃO E INTERFERÊNCIA

(8) <u>Photons.</u> (text: unit 4)

1 bar magnet, 10 cm
1 compass
1 battery 1.5 V
1 copper wire 15 cm
1 thick cardboard plate (celotex) with two sockets, leads, plug and switch (connected to switch off and on <u>one</u> of the sockets) mounted and fixed with a screw on one of the inside walls of the kit box.
1 pendulum 25 cm
1 red safelight lamp 110 V, 15 W
1 clear lamp 110 V, 5 W
2 polyethene bottles 200 ml
1 plastic measuring cup
2 plastic trays 15x12x2 cm^3 (for developer and fixer)
1 plastic washing tray 20x16x3 cm^3
8 plastic filters 6x5 cm^2: red, orange, blue (2), green (2), pink (2).
1 photograph (3 pictures: original and two successive enlargements)
20 photographic papers, 9x12 cm^2, high contrast.
1 bag developer E 72 for 1000 ml solution.
1 bag hypo for 750 ml solution.
25 paper clips,
1 drawing pin
1 black cardboard sheet 10.5x7.5 cm^2
2 white cardboard sheet 10x7 cm^2 and 27x17 cm^2

FOTONS (P.P/4)



MATERIAIS

Nº		QUAN
1	IMÃ RETO	1
2	BÚSSOLA	1
3	PILHA 1,5 V.	1
	FIO DE COBRE	
4	BASE DE CELOTEX COM 2 SOQUETES, CABO E INTERRUPTOR TUDO FIXADO COM 1 PARAFUSO NA CAIXA	
5	PÊNDULO	
6	LÂMPADA VERMELHA 15 W.	
7	LÂMPADA TRANSPARENTE 5 W.	
8	FRASCOS 200 cc. DE PLÁSTICO	2
9	MEDIDA DE PLÁSTICO	1
10	BANDEJA DE PLÁSTICO 9x12 cm	2
11	" " 16 x 20 cm	1
12	FILTROS DE PLÁSTICO 3,5x4,5	8
13	FOTOGRAFIA	
14	FÔLHA DE PAPEL FOTOGRÁFICO	20
15	CARTOLINA BRANCA 10 x 7 cm	
16	REVELADOR E 72	1 L
17	FIXADOR	1 L.
18	CARTOLINA PRETA 10,5x7,5 cm	1
19	CARTÃO POROSO 17 x 27 cm	1
	CLIPS	25
	PERCEVEJO	

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PROJETO PILOTO DE FÍSICA

FOTONS

19. Objectives and brief description of the short silent films produced by the Pilot Project.

Our film program followed the same outline as the rest of the materials, as they are all part of the same course. However, the wave model for light received less attention in our series of short silent films, for two reasons: first, there are quite a number of short silent films already available on wave experiments in a ripple tank; and secondly, we produced a half-hour film (with sound) on the single-slit diffraction of water-waves, of sound, of microwaves and of light.

In the following paragraphs, the objectives of the short silent films produced by the Project will be briefly outlined.

(0) Cock with mirror image.

This is a two minute film showing a cock in front of a large vertical mirror. He is puzzled by his image, becomes uneasy and finally fights with it. An unexperienced viewer is deceived at first, as the film begins with some close-ups that do not allow the edges of the mirror to be seen. In later shots the cock can be seen to be disconcerted by the disappearance of "the other cock" as he goes past the edge of the mirror. This is a motivational film to serve as an introduction to the study of images. It was planned, and used, as an insert in our first television program; and is not included in the series of eleven short silent films that have been distributed by the Project.

(1) Two experiments with images.

In the first experiment a tele-kaleidoscope -consisting of three mirrors and a lense - is used. External moving objects are viewed through it, giving rise to interesting moving patterns showing various symmetries.

In the second experiment a cylindrical lense consisting of a large transparent bottle filled with water is used. The bottle is first held vertical and then rotated round a horizontal axis. The image seen through it rotates by an angle equal to twice that of the bottle.

This film is rather different from the other ten films of the series in that it is intended to be mainly motivational. No details on the formation of images are taught, but two rather unusual and interesting cases of image formation are shown with the necessary visual description of the apparatus used. The aim is to stimulate the pupils to repeat the experiments, do other experiments, and become interested in their explanation.

(2) Reflected light: glass in liquids.

This is a demonstration of how bits of broken glass, clearly visible in air, become less visible in water, and invisible in a liquid of the same refractive index as the glass.

The aim of the film is to show that the intensity of light reflected at the boundary between two transparent, colourless media is higher when the difference between the refractive indices is greater; and no light is reflected when the indices are equal. An important connection between reflexion and refraction is thus illustrated.

This film can also be used to get the pupils interested in investigating other factors that affect the reflectivity of a boundary between two transparent media. For instance the angle of incidence.

(3) Rectilinear propagation.

This film is part of the study that leads to the building up of the particle model for light. Four experiments are done on the formation of shadows. First with light, and then with three different types of particles: droplets of paint in a spray-jet, aluminium atoms evaporated (and condensed) in vacuum, and electrons in a Crookes' tube. The analogy is emphasized by using a similar geometry in these four experiments.

(4) Light and particles I.

The analogy between the reflexion of light and that of moving particles is shown, thus reinforcing the particle model for light. The experiments are done with a flat surface and a parabolic surface.

(5) Light and particles II.

The general aim of this film is the same as that of the previous one, using this time an elliptic surface. One can see that a small sphere thrown against the elliptic mirror from one of the foci, goes through the other focus after being reflected. Similarly, a beam of light diverging from one of the foci is seen to converge on to the other focus after reflexion.

(6) Pinhole camera.

The use of the pinhole camera for image formation, both visual and photographic, is shown. A sequence of pictures is taken with different pinhole diametres. As the pinhole gets smaller one sees the pictures becoming sharper ... but only up to a certain point: the two smaller pinholes show considerable blurring due to diffraction.

One of the aims of the film is to show that light has some properties that cannot be interpreted adequately with the particle model. It can thus serve as a motivation and introduction to the study of diffraction, although in this film no attempt has been made to go beyond showing the existence of the effect and the fact that it is all the more notorious the smaller the aperture. It can also be used to illustrate the concept of "resolution" of an image and "resolving power" of an optical instrument. Finally, it may stimulate the pupils to take photographs with such a simple device.

(7) Pulses.

Various unidimensional pulses (disturbances) are shown, in order to illustrate the fundamental property of being able to transport energy to relatively large distances while the various parts of the medium perform only small displacements about their equilibrium position. Longitudinal, transverse and torsional pulses are illustrated.

This film should help the pupils learn that energy can be transmitted from a point A to a point B without any matter being transported from A to B. It contributes to the idea that even if light is known to carry energy it need not consist of a stream of particles; thus providing the first stage in the investigation of the wave model for light.

(8) Infrared radiation.

This film shows that the invisible heat radiation (coming from a hot solder-iron and detected with a Philips 61 SV) has several properties in common with light. The examples illustrated are: heat radiation propagates in a straight line, it is absorbed differently by different materials, it can be reflected, and it can be focused with a lens .

One of the aims of the film is thus to show that the spectrum of radiation is not restricted to visible light.

(9) Light, X rays, gamma rays.

This film is another attempt to present to the pupils other types of radiation. Three experiments are done which show the following properties of light, X rays and gamma rays: rectilinear propagation, aborption, and the ability to blacken a photographic film. Some of the differences between these radiations are also illustrated.

(10) Photoelectric effect.

Four experiments are done, using charged electroscopes and a source of ultraviolet light, to illustrate the photoelectric effect; and specifically to show that the electric charges expelled by the light are the negative ones.

The experiment is only qualitative, and it does not intend to prove the existence of photons. It can be used nevertheless as an introduction to an elementary study of the quantum theory of light.

(11) Light and electrons.

This is a set of four experiments showing electric effects produced by light (including invisible light) : the photoelectric effect, photoconductivity, photovoltaic effect, and optical switch. The devices used in the last three experiments are: Philips ORP 90, Philips OAP 12, General Electric GE L7U. These experiments illustrate how light can expel electrons from a metal, can control the flow of electrons in a solid and can give rise to an electric voltage; thus suggesting an electric nature of light.

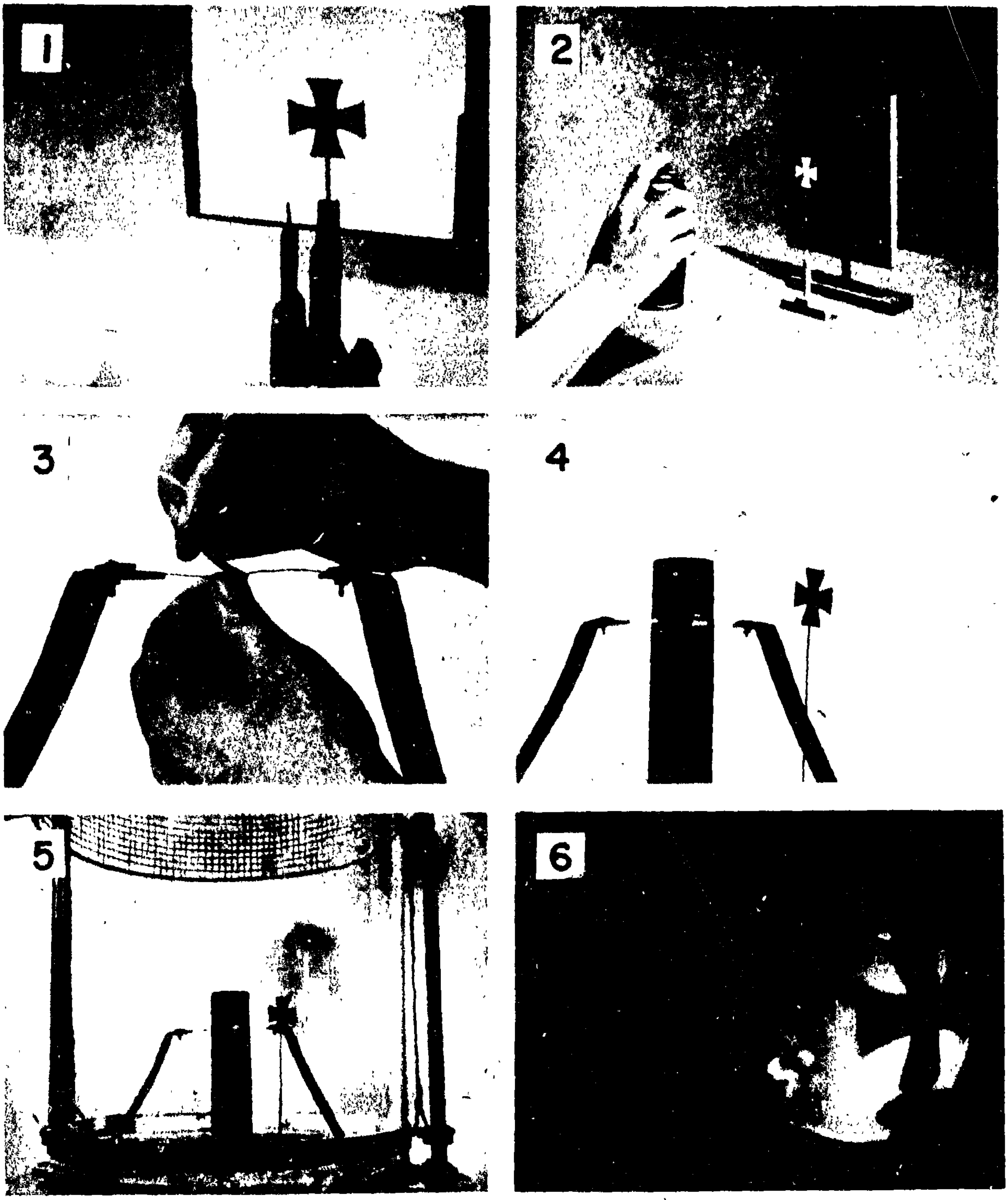
20. The role of the teachers guide to the films.

For each of the eleven short silent films produced and distributed by the Pilot Project, a Teachers Guide has been prepared. It was felt that such a Guide would be all the more necessary in the case of short silent films.

Each Guide begins with a statement of the objectives of the film, and a brief description of its contents. Seven of the eleven Guides also have a plate with photographs taken out of the films. Whenever it was felt necessary, technical data on how the experiments were done or how they could be repeated have been given. Also suggestions on the possible ways of using the film have been given, including hints as to where the projection could be interrupted for asking questions, and ideas on work to be done before or after projecting the film.

Some of the Guides elaborate more in detail on what might be called "the idea behind the film". For instance, the Guide to film nº 2 (Reflected light: glass in liquids) suggests that the teacher might insist on the fact that, while the direction of the light reflected back into the liquid does not depend on the refractive indices, the amount of light reflected does depend on them. It also suggests that the pupils should learn early that the study of the reflexion of light does not end when they know that "the angle of reflexion is equal to the angle of incidence". (Even this is not generally true if the first medium is birefringent.)

It was also considered of interest to include in some cases information of a higher level for the benefit of the teacher. For instance: in the Guide for film nº 2, the Fresnel formulae (and the graphs) which give the intensity of light reflected and refracted at the boundary between two transparent media for light polarized parallel and perpendicular to the plane of incidence; in the one for film nº 3, some information on vacuum, number of molecules per cm^3, mean free path, etc; in nº 6, some information on diffraction, an approximate calculation of the optimum pinhole diameter, some indications on the properties and uses of Fresnel zone-plates (and a print of a photograph obtained with a Fresnel zone-plate); in nº 11, circuits for three of the experiments; etc, etc.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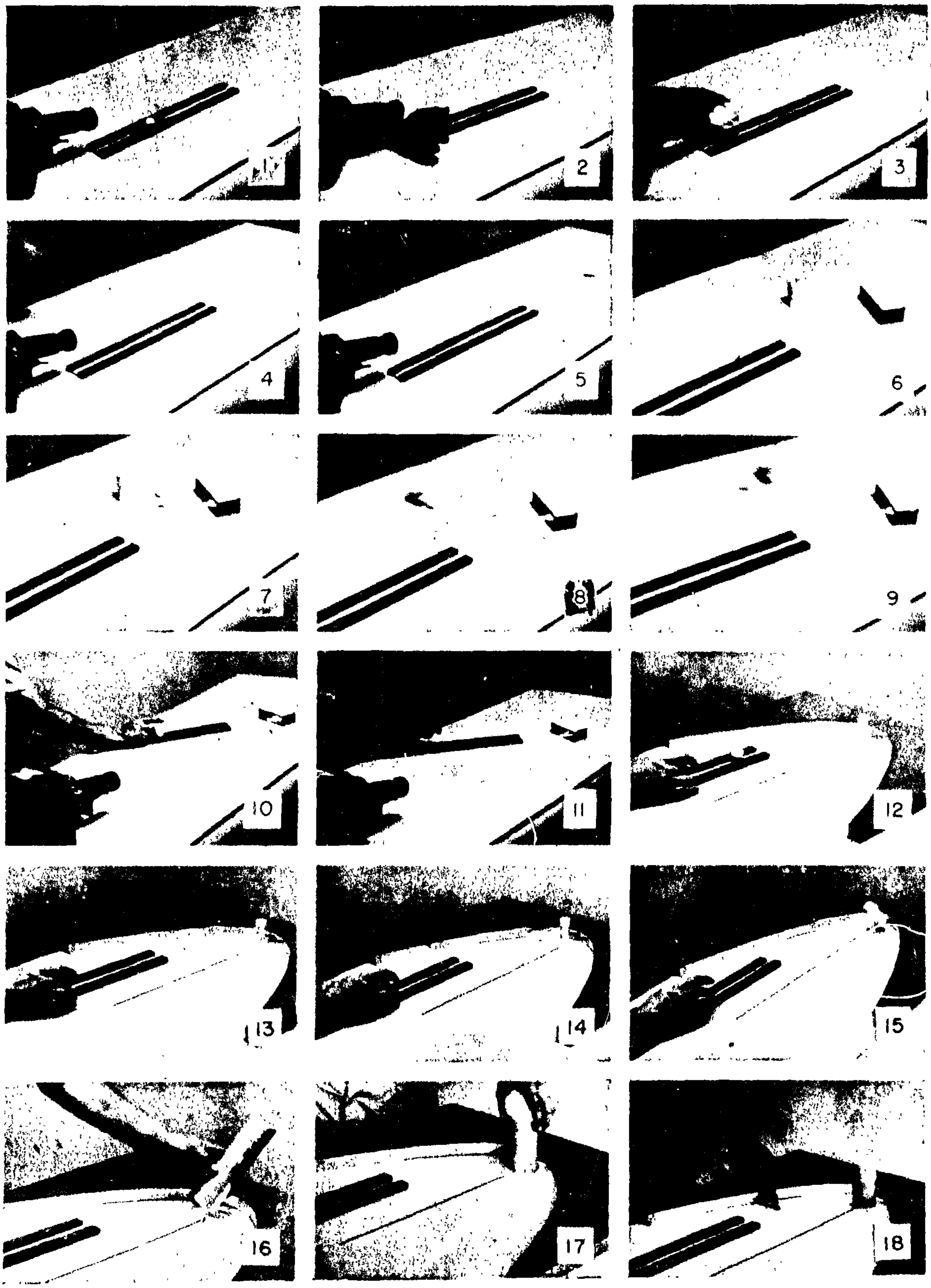
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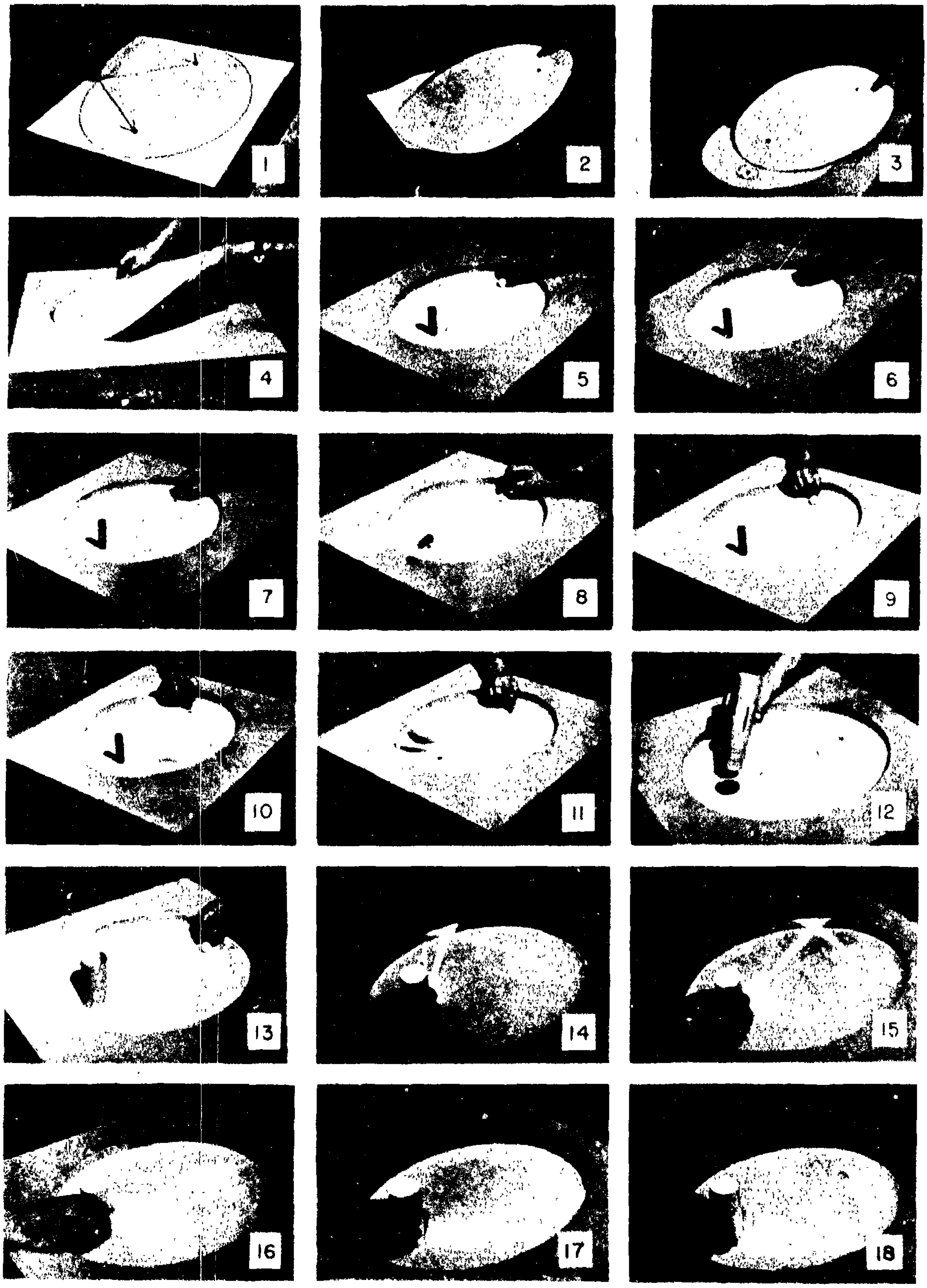
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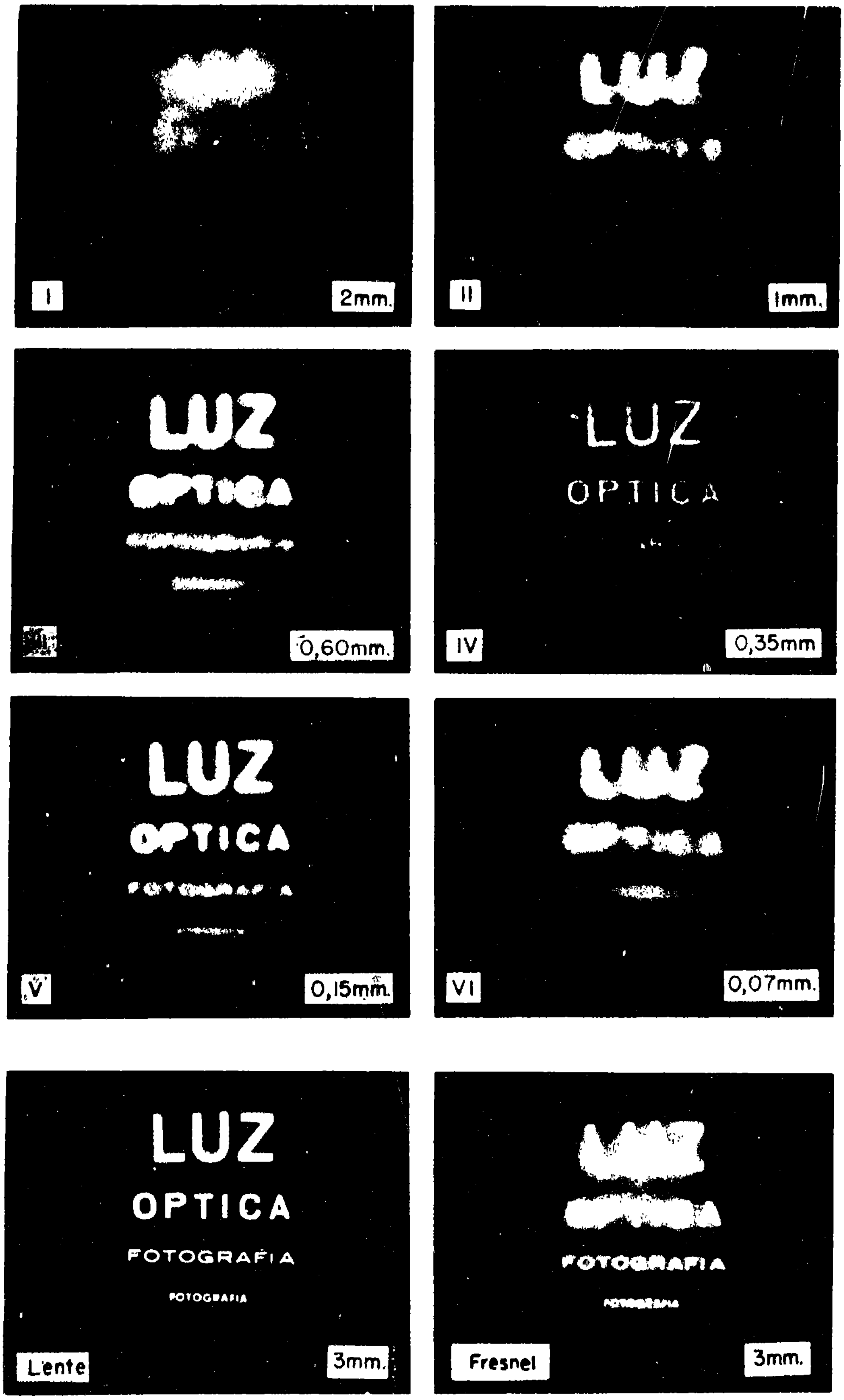

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II
Imm.
LUZ
OPTICA
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LUZ
OPTICA
IV
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LUZ
OPTICA
V
0,15mm.
VI
0,07mm.
LUZ
OPTICA
FOTOGRAFIA
FOTOGRAFIA
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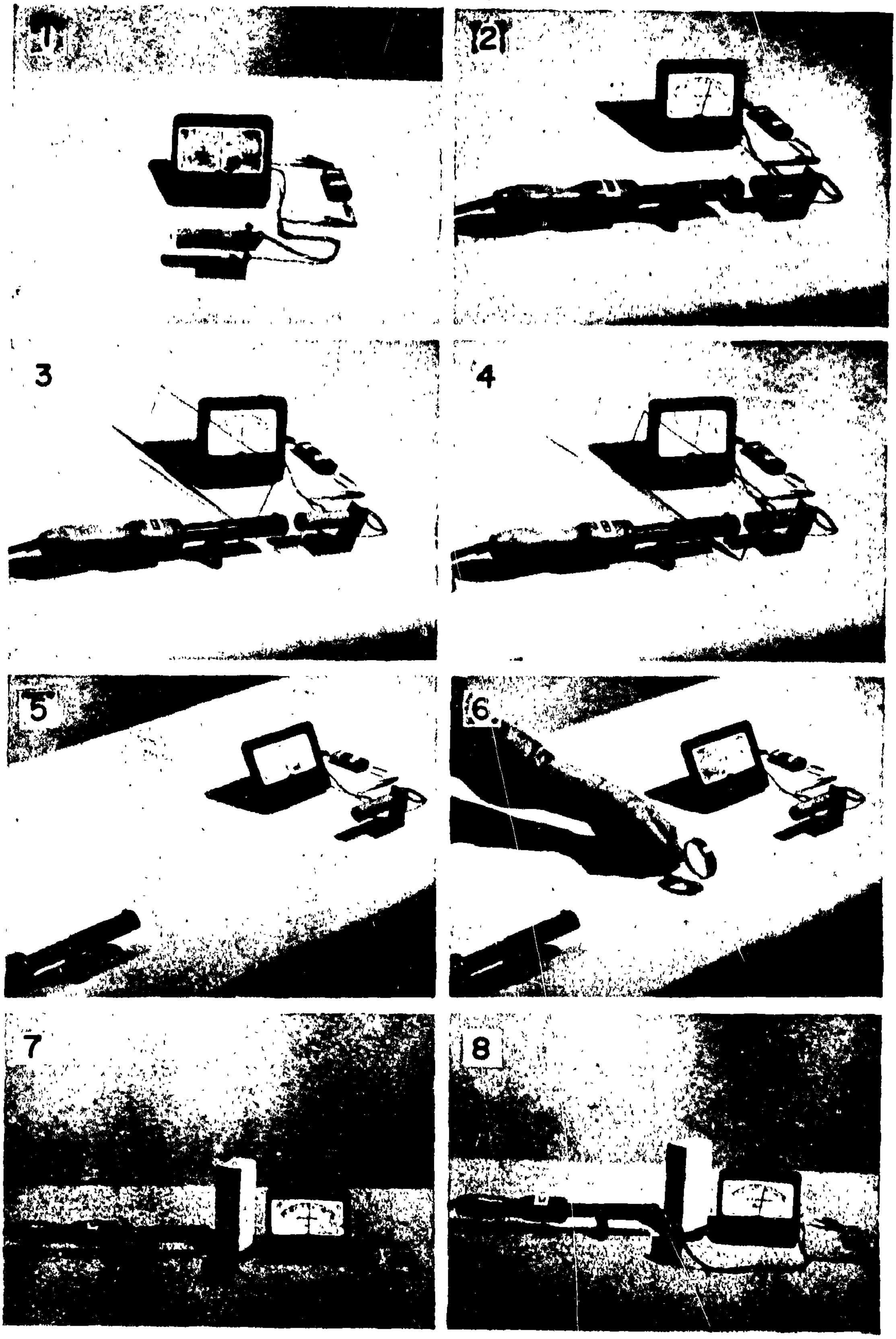
3mm.
FOTOGRAFIA
Fresnel
3mm.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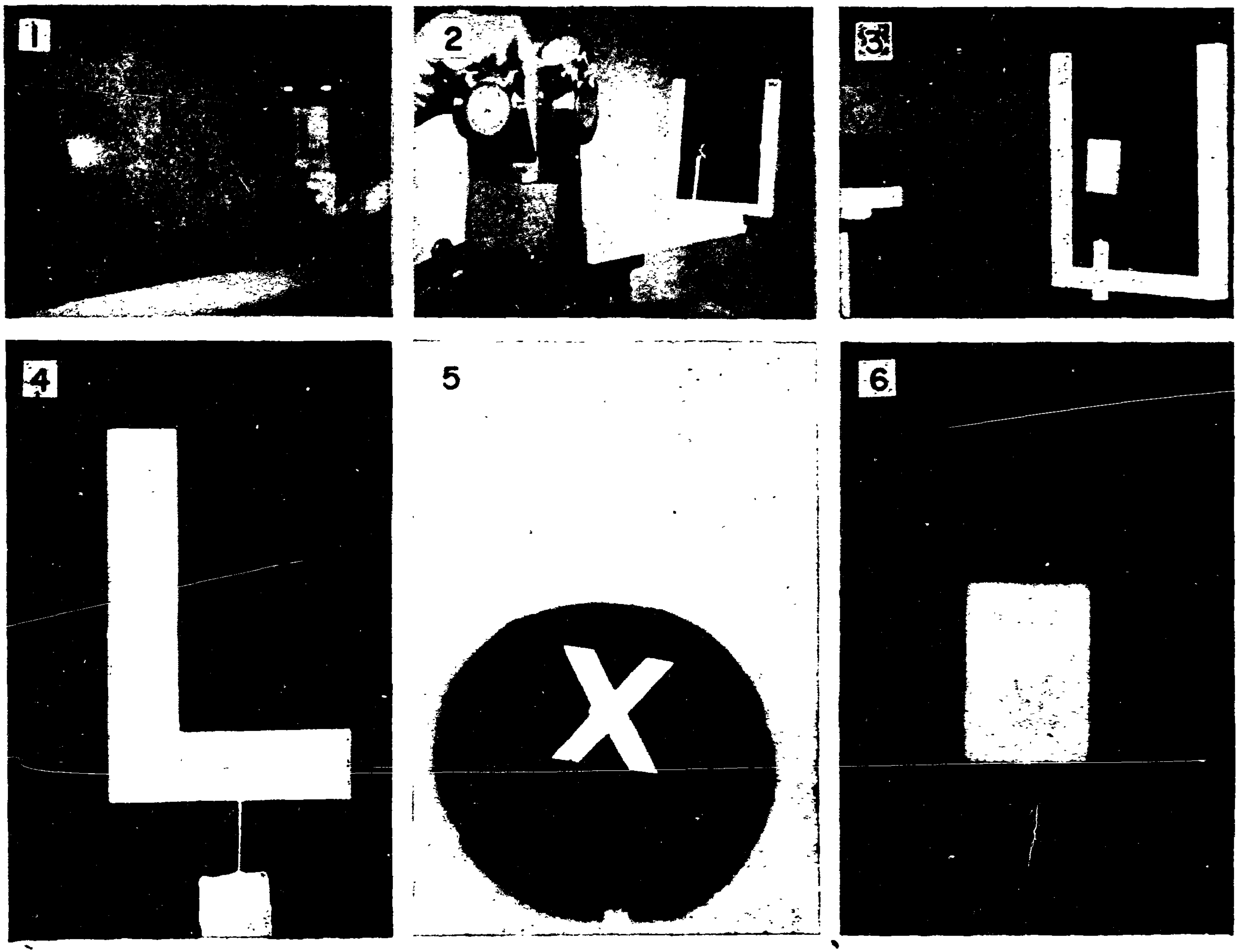
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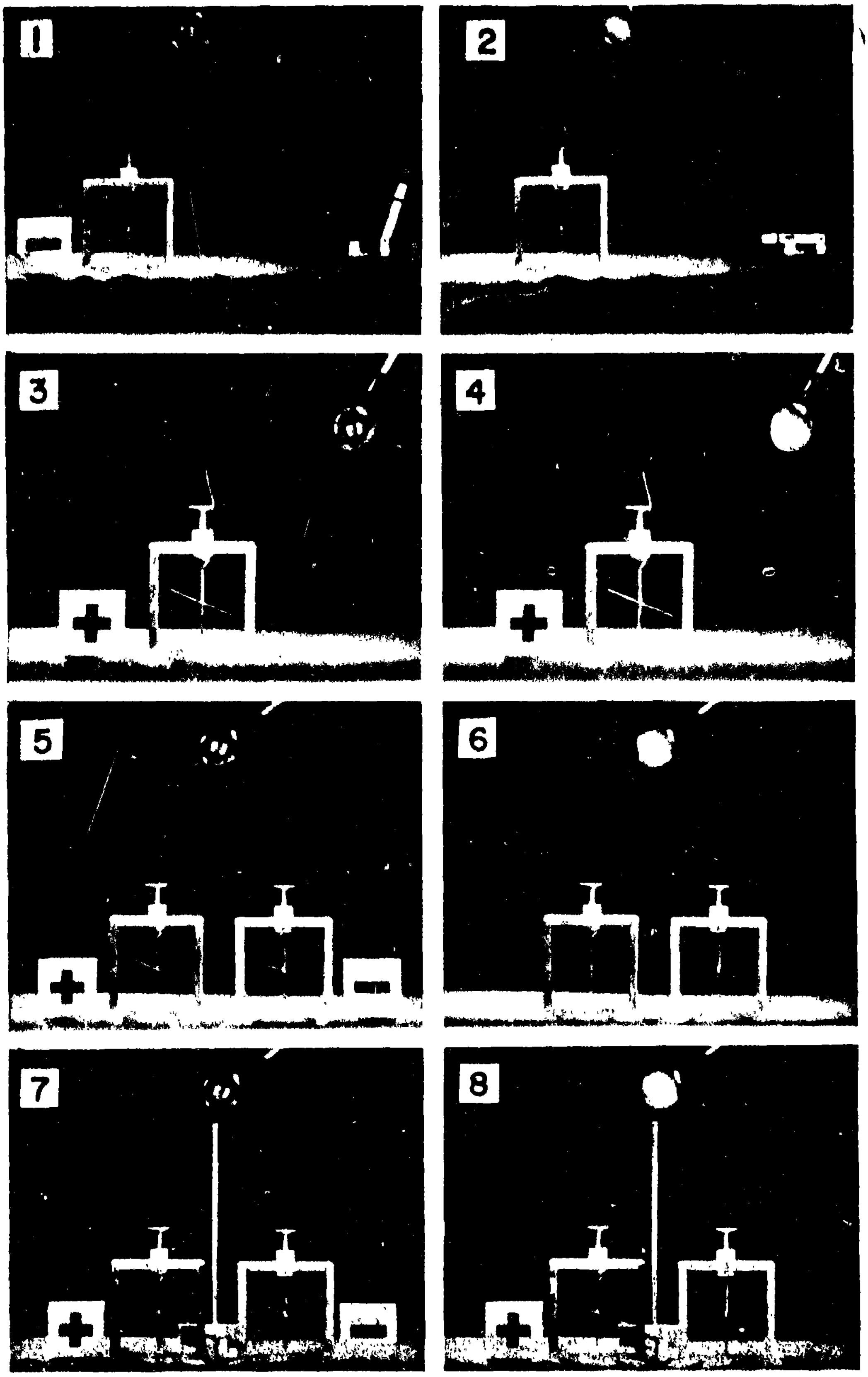
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The following seven pages are plates which show photographs taken out of seven of the films: (3) Rectilinear propagation; (4) Light and particles I; (5) Light and particles II; (6) Pinhole camera; (8) Infrared radiation; (9) Light, X-rays, gamma rays; (10) Photoelectric effect.

21. Use of the short silent films in schools.

The use of these films under class-room conditions can be very flexible indeed. It depends first on the objectives of the film, and then also on how the teacher wishes to attain them.

One can have a film that serves as an introduction to a new chapter; or as a motivation. Our films nº 0 and 1 are examples of such motivational films, designed to generate interest in the study of images.

There are those films which require preparatory work with the students as well as a discussion at the end. They may even be interrupted for questioning or for further analysis between viewing its various parts. Most of our short films belong to this category.

The learning value of many of the short silent films can be increased by viewing them twice consecutively. This is particularly simple if the film is in the form of loop. It may be interesting to encourage the pupils to make comments or ask questions during the second viewing.

There are then those short films which serve as a summary or as a synthesis. Some of our films might be used in this way.

Another interesting use of the short silent film is in the building up of a concept. If the learning of a concept implies generalization within a class and discrimination between classes, then a film that attempts to form a concept must give examples and counter-examples. Our film nº 7 belongs to this category.

There is also the film that can be used to encourage pupils to do an experiment. May be these films should be careful not to show all the results, so that the pupil will not have the sense of discovery taken away from him. In any case, films should not replace the experiments do be done by the pupil; they should encourage him to do more.

An additional advantage of the short silent film, parti - cularly if it is projected as an 8 mm loop, is that a film library can be set up for the pupils to use by themselves in the same way as they use books.

22. Format of the short silent films: 16 mm or 8 mm ?

The answer to this question depends mainly on the size of the audience. For a small class, and particularly for a group of pupils working by themselves, 8 mm is satisfactory. Larger audiences require 16 mm projection.

We have found, when using 8 mm short silent films, that to have them packed in cartridges for projection in loop form is a most convenient way of handling them. It has many well known advantages. So much so, that we have become accustomed to calling the short silent films by the name of loops.

The use of the 8 mm loop projector for educational purposes has in fact roused great interest in all of us working at the Pilot Project, as well as in most people who have had the opportunity to use the loop projectors which we had with us or to see them being used. Unfortunately we have found that loops sometimes get stuck and a frame or two get burnt. The damaged loop can be repaired, but sometimes this can be more difficult than repairing a film for conventional projection. It is therefore indispensable that the performance of the existing loop projectors and of the corresponding cartridges be improved if their use is to become more widespread.

In any case, it will take some time until these loop projectors are in general use. And this is particularly true of the less developed countries, which are precisely the countries where films are most urgently needed due to shortage of teachers, unqualified teachers, shortage of funds for extensive use of laboratories, etc.

Therefore, the films of the Pilot Project, which were shot on 16 mm, have been made available in the three following forms so that they may also be used in conventional projectors already available in many schools: 8 mm loops in automatic cartridges, 8 mm prints in conventional reels, 16 mm prints in conventional reels.

In any case, we feel that the major breakthrough that is taking place in the use of films for science teaching is not the use of a certain type of projector, or a certain type of format, but the generalization and intensification of the use of short silent films: they are a valuable tool in the hands of the teacher, and they help him to become a better teacher.

23. The half-hour sound film produced by the Project.

The film begins with a short motivational incident in which Sivia and Hector, the two students that appear in the film, approach a corner riding their bicycles along two intersecting streets. They do not see each other in time, and they collide. The scene is then repeated but this time Hector sounds the horn of his bicycle. Silvia hears this, before seeing him, and avoids the collision. So, sound can bend round the corner, says the narrator. And how about light ... does it? In order to investigate this they go to the physics laboratory.

Most of the film is then devoted to showing a teacher and these two students investigating together the diffraction of waves. They do single-slit diffraction experiments, first with waves on the surface of water (ripple tank), then with sound waves and radio waves, and finally with light. They investigate the effect that the width of the slit and the wavelength have on the diffraction phenomena. The students discover in this way that light shows the same diffraction effects as the water waves, sound waves and radio waves. This is another step in the building up of the wave model for light.

The film attempts to contribute towards the formation of the concept of wave:a wave is neither wet, nor noisy, nor luminous, etc. It is something abstract; is has several properties, diffraction being one of them. The film suggests that one can test if "something" is a wave by trying out diffraction experiments. This is a rather important point for the student to remember when he comes later to electron diffraction and neutron diffraction.

Another important objective of the film is to show how a teacher can lead his students to investigate a problem, and how he can answer some of their questions by suggesting experiments to be done by the students themselves. For instance, in the ripple tank experiments, Hector investigates the effect of changing the width of the slit, after which Silvia investigates the effect of changing the wavelength the two variables are analyzed separately. The students have an active participation in the experiments throughout the film.

The film gives information, but is also tries to show how this information is acquired. It tries to build up an active teacher-student relationship in which the elements of scientific discussion and scientific inference have been introduced.

A couple of examples, quoted from the script of this film, may serve to illustrate some of the points mentioned above.

After they completed the experiment with the radio waves, the teacher says:

160.	Silvia and Hector listening	TEACHER: So, radio waves also dif fract; in the same way that sound waves do, as well as the waves on the surface of water.
161.	Teacher, Silvia and Hector; in the laboratory.	TEACHER: But what was the question we asked ourselves at the beginning?
		SILVIA: Is light also a wave?
		TEACHER: And ... ? How are we going to decide it?
		HECTOR; We'd have to see if it dif fracts.
		SILVIA: But we already know that light travels in a straight line.
162.	Teacher listening	HECTOR: And the bicycles collided because light did not bend round the corner, it did not diffract.
163.	Hector listening	TEACHER: It seems as if it didn't...
164.	Teacher drawing on the blackboard.	... But it may have diffracted just a little, very little. May be something like this.

165.	Silvia and Hector, listening	TEACHER: And supposing the wave-lengh of li th were very small,... how could we try to see if it dif-fracts ?
166.	Silvia talking to the teacher. With two fin-gers she indicates a narrow opening	SILVIA: May be with a very small opening ... like this.

Silvia suggested a very small opening cause she re-membered that for the three previous experiments they had to have openings of different widths, according to the wavelen-gth used, and because they had learned from the ripple tank experiments that the diffraction is hardly noticeable if the slit-width is large compared to the wavelength.

They proceed to do the single-slit experiment and they see, first Silvia then Hector, that as the slit becomes nar-rower the coloured bands become wider. One sees on the screen what they see as they vary the width of the slit (the film is shot, however, in black and white). Then:

179.	Hector nods.	TEACHER: Then, light seems to dif-fract in the same way as the other ves do?
180.	Close-up of the ripple tank screen. Slit clo-ses gradually.	TEACHER: The same applies to light as to water. As we close the slit, there is more diffraction.
181.	Teacher pointing at the single-filament lamp used in the experiment.	TEACHER: So, then, ... is this light a wave ?

182.	Teacher, Silvia, Hector.	HECTOR: Well ... it seems so ... there is diffraction ... but, what do those colours have to do with all this?
183.	Teacher covering the slit with glass filters.	TEACHER: I shall answer your question with an experiment. Look, I'm going to cover the upper half of the slit with this red glass, .. and the lower half with this blue glass.
184.	Teacher places slit in position.	TEACHER: Let's leave the slit like this. Watch the diffracted light.
185.	Diffraction bands (what Hector sees); top ones are wider, lower ones narrower.	HECTOR: Oh ... the red light... above, diffracts more that the blue one ... below.
186.	Teacher showing a photograph of what Hector saw in previous scene. The words 'red' and 'blue' appear in the appropriate places; and he points as he talks.	TEACHER: Well, now that light seems to behave like a wave, what colour do you think has the longer wavelength? The red ... which diffracted more? Or the blue .., which diffracted less?

Then follows a brief recapitulation of what has been learnt throughout the film.

24. Interaction between the physicists and the film specialists.

At the Pilot Project we have had the opportunity to try out three different schemes for the film production. Of the twelve short films, three were done in collaboration with Prof. Edward McCoy and his staff at the Audio-Visual Center of the University of São Paulo, three were done in collaboration with a commercial film-producer; and six were done with Mr. Peter Robinson, one of our film consultants who came from New York to spend nine weeks with us. (Detailed credit is given in the booklet containing the Teachers Guides to all the persons who participated in the various aspects of the work). The half-hour sound film was produced at the above mentioned Audio-Visual Center. It would be unreasonable to suggest which of these three schemes should be prefered. It depends on local circumstances.

We learned a very important lesson during our film work, and this applies even more strongly to our half-hour film on diffraction. It is the following: a subject-matter specialist, in this case a physicist, who may or may not be the originator of the idea contained in the film, should not only have ample opportunity to criticize and to participate in the various subsequent stages of the work: script-writing, visual details, shooting, editing; he should also be taking decisions at various important stages of the work. Only if the film professionals happen to be very well acquainted with the subject of the film and with the approach to be given to the presentation of the material, can this rule be relaxed. Of course, this rule implies that the subject-matter specialist knows the essentials of film production, has a keen interest in the work, and is capable of showing the patience and tolerance that is always required for people with different backgrounds to work as a team.

25. Some notes on the television programs prepared by the Project.

The eight television programs prepared by the Project are also part of the course on the "Physics of Light". Each of the four units of the course has two programs, of 30 minutes each, and the structure of these programs is intimately connected with the general plan of the course, as one of the fundamental objectives of the Project was to experiment with the integrated use of several media.

The students perform individually their experiments with their kits as they work through their texts. If they have a projector and the films, and if a teacher is available for introducing the subjects, for conducting dicsussions and for giving them a more general view of the field, all the better. But, if the films and the teacher are not available? Television can then be of some help. The programs can reach a large number of students. And if the programs are good, they can constitute model classes (of a somewhat restricted scope, however, as the students follow the program rather passively).

But television was used not only because it makes it possible to reach a larger audience; also because the characteristics of this medium are such that a dynamic presentation of the subject can be made, and the viewer can be guided to concentrate his attention on the points one wishes to stress.

The teacher that appears on screen (Mr. Manoel Jorge, one of the participants of the Project) performs some "live" experiments; and shows other experiments by means of films, most of them produced by the Project. The teacher gives continuity to all this experimental and visual material, and provides the necessary explanations, questions and discussion.

In all these programs, short silent films were used as inserts. They were projected in two different ways. Some films were projected on a screen by the teacher himself utilizing the Technicolor 800 projector with the films in the form of 8 mm loops in automatic cartridges. The image on the screen was then picked up by the television camera. Other films were projected directly from the projection room of the television station utilizing 16 mm prints.

The second procedure gave us images of better quality; but the former (loops projected by the teacher himself) has great advantages: it allows for more flexibility in the use of the film, and it allows the teacher to point out things on the screen.

Considering the experimental nature of the Pilot Project, it was not considered advisable to aim for a uniform structure to the eight programs. For instance:

Program 1 has a rather motivational character, as an introduction to the course; and some concessions to the general public have been made in it.

Program 2 uses a film that has its soundtrack in English. It was projected without the sound, and the teacher narrated it as he watched it on the studio monitor. This is an interesting procedure, if one considers the cost of producing a translat d film. Of course, the teacher's narration, whether a translation or adaptation, was not improvised: it is part of the script.

Programs 3, 5 and 6 contribute to the building up of the particle model (3) and the wave model (5 and 6) for light. In their work with the kits and the text (units 2 and 3) the students go through this process very gradually and in great detail. These television programs constitute synthesis that will give the students a broader view.

Program 4 presents, through a series of experiments, one of the difficulties inherent to the particle model for light; and suggests the need to study waves. In this way it contributes to making the students understand why a model is abandoned and how the search is started for a more adequate one, one that can interpret more satisfactorily the results of the experiments.

In program 7 it was intended to experiment with the dialogued form: the teacher discusses the subject with a younger colleague. And program 8 includes at the end a brief discussion on the role that 'models' play in Physics.

The programs were broadcast in São Paulo on Channel 4, in July 1964, during the Regional Latin-American Seminar on New Methods and Techniques in Physics Teaching. The programs were seen by the 60 physics teachers that took part in this Seminar and by a pilot group of 30 High School students who followed in July the "Physics of Light" course. Obviously, the programs were also seen by a good fraction of the general public, though no survey of this could be made.

26. Brief description of the television programs.

(1) Images

The objectives of this program are mainly motivational. As an introduction to the subject of image formation, our short film on the cock with his mirror image is used. However, the cock is not the only one to be deceived by a mirror image: the teacher is seen to continue his class, but soon the television camera moves back and it becomes apparent that what was being seen was the teacher's image in a large mirror. Two rather interesting experiments with images follow next. First, images formed with a tele-kaleidoscope are seen, and the construction of this apparatus is shown; and then, images produced by a large transparent bottle filled with water are seen. For these two experiments, our film number 1, "Two experiments with images", was used. The program ends with an experiment in which some pieces of broken glass become completely invisible when they are immersed in a liquid .... This experiment will be carried out in detail, and explained, it is said, in the next program.

(2) Some properties of light.

This program makes use in the first place of the film "How to bend light" (Encyclopedia Britannica Films) of about 10 minutes duration. The narration in Portuguese was made by the teacher himself from the studio. This film shows various properties of light, among them: rectilinear propagation, reflexion, refraction. Then follows the experiment of the 'invisible glass' which was introduced at the end of the previous program. Our film number 2, "Reflected light: glass in liquids", is used; and live experiments.

(3) Light and particles.

This program shows several experiments which point out some of the analogies between the behaviour of light and that of moving particles, particularly rectilinear propagation and reflexion, thus leading to the particle model for light. Two of our short films are used: number 3, "Rectilinear propagation", and number 4, "Light and Particles. I".

(4) Photographing without a lens .

The program begins with a review of the particle model for light, using this time our film number 5, "Light and particles II". Then follows a series of experiments in which the rectilinear propagation of light is tested by means of a pinhole camera. Here our film number 6, "Pinhole camera", is used. The blurring of the images obtained with the smaller pinholes cannot be explained with the particle model, and it is suggested to take up the study of waves. The film "Focusing waves on water by diffraction", produced by the Audio-Visual Center of the Ministry of Education of Venezuela, was also used.

(5) Waves.

To begin with, a brief study of the propagation of pulses and waves in ropes and springs is made, and then of waves in water (ripple tank). Analogies are found between the behaviour of light and that of waves, and in this way a first step is made towards the building up of the wave model for light. In this program we used our film number 7, "Pulses", as well as parts from several of the ripple tank films produced by Educational Services Inc.

(6) Is light a wave ?

This program was the half-hour film produced by the Project. A description of it will be found in Chapter 23 of this booklet.

(7) Beyond the visible.

The aim of this program is to show that the spectrum of radiation extends on both sides of the visible spectrum. First, experiments with the invisible heat radiation coming from a hot solder-iron are shown: this infrared radiation can be reflected and refracted in the same way as light. Then, a fluorescence experiment shows the existence of ultraviolet radiation. The spectrum is then extended beyond the ultraviolet by showing some of the properties of X-rays and gamma rays. For those experiments that were not done live, our films number 8, "Infrared radiation", and number 9, "Light, X-rays, gamma rays", were used.

(8) Electromagnetic nature of light. - Photons.

There is first a reference to the previous program, in which a large part of the electromagnetic spectrum was explo red. Then, in relation to the functionning of television cameras, the photoelectric effect is demonstrated. Several experiments are done in which ultraviolet light expels electrons from a metallic surface. Then experiments are done in which visible light and infrared radiation also produce electric effects. In this way, the electric nature of light is established. There is then a discussion of the photoelectric effect leading towards the idea that there is something discontinuous in the nature of light, thus introducing photons. Finally, a brief discussion is presented on 'models' in Physics. In this program our films number 10, "Photoelectric effect", and number 11, "Light and electrons", have been used.

27. Testing of the "Physics of Light" course with students.

Testing of the programmed instruction text together with the kits was part of the development of the text and kits, the results of each test forming the basis for revisions. Students from three different São Paulo schools were used for these tests, which were primarily aimed at locating frames or frame sequences which were too difficult for the students to answer correctly, or so easy that the students regarded them as dull or obvious. Some chapters were totally rewritten after the first tests, in others new frames were inserted or frames were removed.

The first test to investigate how the students learn from the program was carried out on a class of 30 students during the month of July, a test which formed part of the activities of the Regional Seminar. The students were volunteers, selected from the first year of the scientific line of the "colégio", that is the ninth year of school. They had studied little physics and no optics before. They came from classes of the Colégio de Aplicação da Faculdade de Filosofía which is a representative São Paulo state school.

The students were first subjected to two intelligence tests, the "SEPEP" which is a dominantly verbal test of governmental use and the "Teste de dominoes D-48" which measures "abstract-spacial"reasoning.

The distribution of the test results, expressed as "mental level" (a T-scale with mean of 50 and standard deviation of 10) is illustrated in the histogram of diagram 1. It is seen that we were lucky to obtain a fairly normal distribution with a few brilliant students as well as a few of very low level.

Before starting with each of the units 0, 1 and 2, the parts of the course which were tested, a pre-test was given. The students then worked on their own with texts and kits (supervised by teachers) Mondays to Fridays 14.30 to 17.30 hours with a 20 minute coffee break. They also viewed the television programs twice a week. After having taken the respective units, the students were given a post-test (which was the same as the pre-test). The error-rates for each frame and for each student were recorded and also the total time each student needed to complete each unit. The result of the test of unit 0 was somewhat ambiguous, as it was found that many students already knew what was taught in that unit (proportionality, how to make graphical representation, and other mathematical prerequisites for the rest of the course). The error-rates of this unit were also too high. Table I shows the percentages of frames within certain ranges of error-rates for unit 0, 1 and 2.

The results of the tests of unit 1 and 2 are presented in Table II. The students are ordered with decreasing mental level from top to bottom in the first column. The second (and sixth) column gives percentage errors (average for the whole unit), and in the third (and seventh) column the time taken by the student to complete the unit is recorded. In the fourth and fifth (eighth and ninth respectively) columns are represented the results of the pre- and the post-tests, expressed in percent of the total score obtainable.

The number of students is rather small, and we cannot be sure that the sample is representative. The fact that the same test was given as pre- and post-test is not very satisfactory. The control over the work of the students was not complete; it is seen that several did not complete the three units. Neither was there present a control group taught by conventional methods. The intense work of three hours every day does not represent classroom conditions either. Nor was retention investigated.

More careful evaluation work will take place during the coming year, and has in fact already started in Brazil.

In spite of the above shortcomings, we think that some tentative conclusions can already be drawn. Looking first at Table I we see that the error-rates of units 1 and 2 are not excessive, only about 10 % of the frames have error-rates above 10 %. In some cases the error-rates are high: these frames need revision in the next version of the program.

From Table II we see that the error-rates of the students and the time they needed to complete the program are almost independent of their mental level. Also the scores of the tests seem surprisingly uncorrelated with intelligence. This is an interesting conclusion, which, if substantiated by further tests, would indicate that programs of this type can be used to achieve a uniform level of knowledge even in a non-uniform student material.

The time spent by different students on the same program does not show too much dispersion, although the fastest student finished unit 1 in half the time taken by the slowest one. The work of unit 2 was more uniform, the fastest student spent

7.5 hours, the slowest 11 hours. The greater dispersion of unit 1 is possibly due to that unit containing more experiments, which some students do very much faster than others.

The average number of frames done by the average student varies between the two units: in unit 1 the students make about 30 frames per hour, in unit 2 the average is above 40. This is most certainly due to the high experimental content of unit 1.

Comparing the scores of the pre- and post- tests shows a spectacular increase in the knowledge of the students as measured by the tests. As the test questions chosen are directly related to the terminal behaviour frames and hence to the stated objectives, it seems as if the program has succeeded in teaching the objectives the programmers set out to teach.

If some subjective observations may be added, it should be reported that the students worked happily and with great absorption and interest. It was very difficult to make them take coffee-breaks. The fact that 7 of them dropped out during the third week is not excessive considering that the course was taking place during their 4 weeks of winter holidays. The teachers of the students are reporting a strong interest of their students in continuing with the following units of the course, and in some classes this is taking place. Other teachers are borrowing kits for the students to use as models to assemble more kits of their own. Most promising are perhaps the reports of some teachers that students who have followed the "Physics of Light" course are now showing more interest, initiative and ability for reasoning than before the course. One teacher said: "They do not accept teaching without experiments now". It must be the aim of further investigation to see whether any such objectives can indeed be accomplished by programmed instruction in general or, in particular, the program "Physics of Light".

Diagram 1.

Mental level of 30 students
completing unit 1.

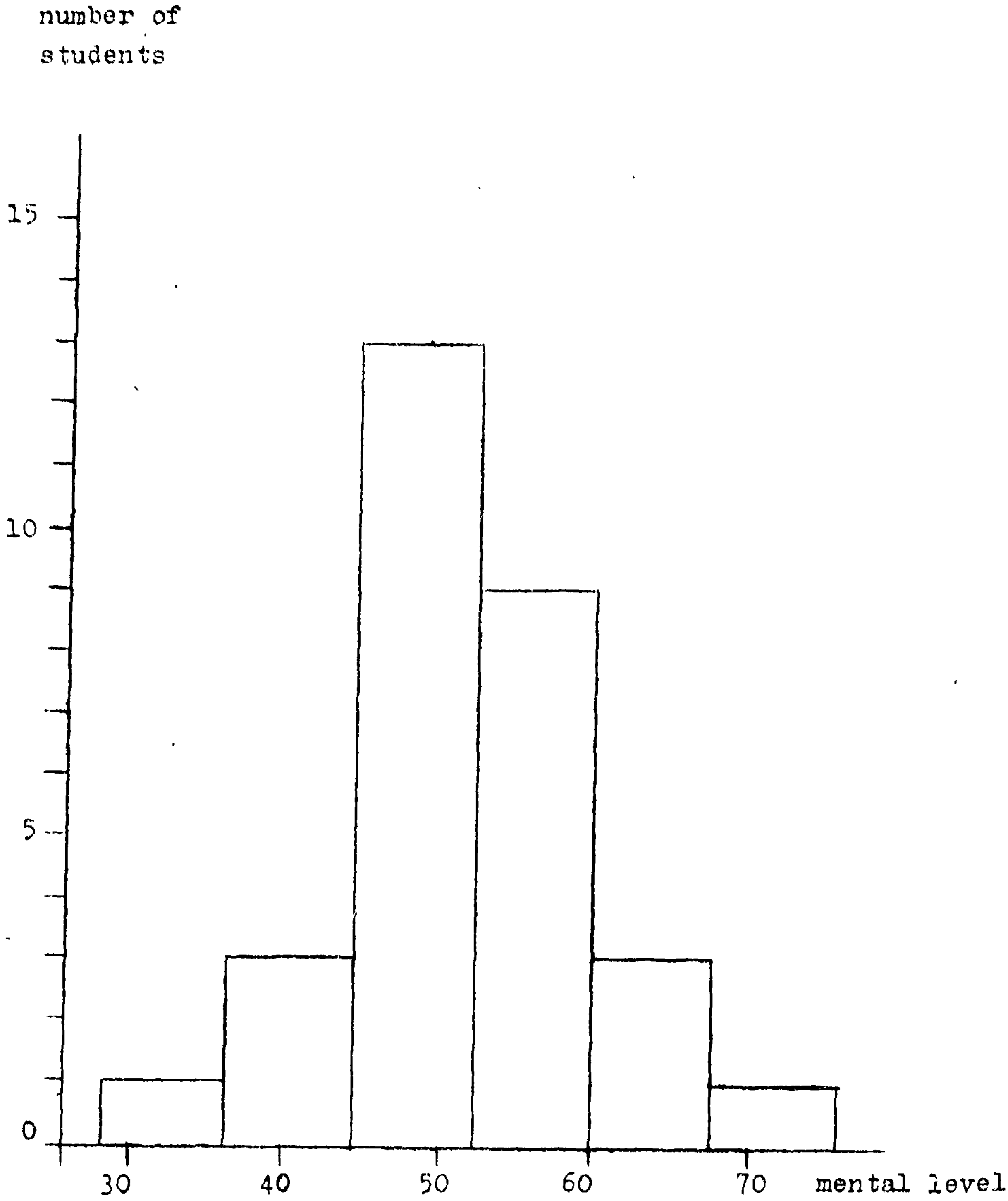

Table I.

Distribution of frames according to error-rates.

Error-rate interval,%	Unit 0	Unit 1	Unit 2
0 - 2	18	48	67
3 - 5	17	21	16
6 - 8	18	12	5
9 - 11	12	9	4
12 - 14	6	4	4
15 - 17	10	1	0.5
18 - 20	6	0,5	0.5
above 21	12	4.5	3

The high error-rates of unit 0 show that revision and further testing is necessary. (This unit has been tested and revised less times than units 1 and 2).

Table II. Units 1 and 2.

Total error-rate, and time for each student to complete the units. Results of pre- and post-test.

	Unit 1				Unit 2			
Student mental level	error %	time hours	pre	post	error %	time hours	pre	post
69	3	13.5	9	95	0	8	0	100
66	3	13.5	5	84	2	8	0	94
62	0	13.5	7	84	1	8	13	81
62	7	17	0	90	-	-	-	-
59	1	15	9	95	2	9	0	88
59	5	18	7	90	3	11	0	100
57	3	15		92	3	11	0	100
57	4	12.[illegible]	25	95	4	8	19	100
56	7	15	9	88	-	-	-	-
56	6	13.5	7	70	2	7.5	0	81
55	2	16	0	90	3	8	0	75
53	8	13	7	84	6	7	0	94
53	3	13.5	2	86	5	8	0	75
52	2	15	0	64	2	11	13	56
52	5	18	5	66	5	11	0	44
52	6	15	11	84	4	8	0	-
50	1	15	9	90	-	-	-	-
50	3	19.5	5	59	-	-	-	-
50	3	16	7	88	6	8	6	81
49	3	18	-	[illegible]	2	11	0	100
48	7	17.5	0	95	4	11	0	75
48	8	15.5	7	88	7	9	0	100
47	5	16	2	88	4	9	6	43
46	7	15	14	88	4	10	6	-
46	2	14	5	72	1	9	0	75
45	1	16	0	64	-	-	-	-
41	1	14	0	70	-	-	-	-
38	1	25	2	88	-	-	-	-
38	3	15	9	84	2	9	0	63
31	4	19	0	68	2	1[illegible]	6	94