

INEXPENSIVE SCIENCE MATERIALS
FOR THE INSTRUCTION
OF THE VISUALLY HANDICAPPED

by

JAMES A. BAUGHMAN, JR.
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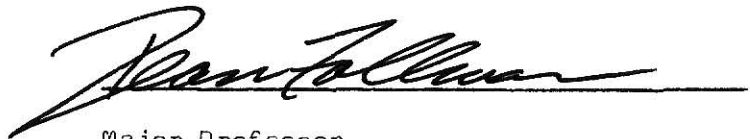
Department of Physics

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1975

Approved by:

A handwritten signature in black ink, appearing to read "Dan Feltman", is written over a horizontal line.

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CHAPTER I

INTRODUCTION

Man creates his own limitations of accomplishment by what he believes them to be, especially if he dwells on the physical handicaps he might have. This is very true with the visually handicapped who, when given the correct motivation, find that they can surpass the limits which they impose upon themselves. This motivation is one of the basic purposes of a recent operation occurring in the field of educating the visually impaired called "Mainstreaming." More and more, these special students are channelled out of the institutions and into a classroom situation where the majority of people are sighted. This is done as soon as they are prepared with the essential skills needed for them to function and have growing self confidence in an environment of people with vision. Thus, the education of the blind and partially sighted, especially at the secondary level, has increasingly become the responsibility of the public schools.

However, a very serious problem exists. In most cases, the public schools do not have the proper facilities and preparation to deal with this type of student, except, perhaps, for the presence of a special education counselor. The sciences have particularly suffered with respect to this problem, especially the physical sciences. In order to give these students the best chance to learn, special equipment and instructional aids must be purchased by the public schools. In many cases, the cost of specialized materials is quite high. This may seem to be an impractical expense for most typical public schools. Since there are usually only a few visually handicapped enrolled each year, the cost per student would be rather large. Also, with the high cost of education, it may be nearly impossible for many schools to purchase this equipment without outside financial assistance

or without taking funds from other programs. Handicapped students also have access to government allotments of money, but still it would be desirable to use these resources for other purposes, if possible. Already there are over 100 such students in junior and senior high schools in Kansas alone.

With this in mind, it is the purpose of this research to develop and test some common and basic teaching aids for the visually handicapped high school science student. More specifically, the problem to be considered is the alteration of measurement instruments already existing in the laboratory classroom. The difference between this work and previous developments in this field is that the construction of the equipment is left to the individual instructor. Thus, it is an important aspect of this paper to present techniques of construction which are simple and not time-consuming. Also, to alleviate high costs for the schools, inexpensive materials are used to alter the tools. These materials can usually be found in most department stores. It should be emphasized that the basic measuring devices to be changed, such as wooden meter rulers, open-faced clocks, and so on, must be obtained from the science laboratory.

A rewarding feature about this work is that, after the equipment is altered, it need not be used only for visually impaired students. All of the devices designed in this project can be used by sighted students as well. Hence, the special equipment does not remain on the shelf to collect dust when there are no special students to use it. The materials developed here need not be used for a physical science class alone. Since most of the tools in this project are measurement instruments, other disciplines, especially the life sciences, mathematics and home economics, could find the work useful.

In this report, a discussion of the equipment construction is given as

well as an analysis of how useful it was to the students in regard to accuracy, efficiency, and simplicity. Also, two general physics experiments are designed in order to have the students use the instruments in a practical application. In most studies of this sort, little emphasis has heretofore been placed on students interested in a somewhat advanced physical science curriculum. It will be shown here that, with a little time and effort on the part of the instructor and/or student aid, visually handicapped students can partake in many physics laboratory experiments with a similar degree of comprehension as sighted students. There has been a common misconception among people about the capabilities of the blind student. This is why many public school counselors direct the visually impaired student out of the physical sciences and into other non-laboratory disciplines. If the student is allowed to participate in a physical science course, he usually ends up memorizing facts and concepts without being able to practically apply his knowledge. Even in many institutions, the laboratory work is kept at a bare minimum. This project creates an extensive laboratory atmosphere in order for the student to apply his knowledge in a practical sense. This is well in line with the educational philosophy of the times in relation to needing concrete practical learning experience for a student to retain knowledge.

One must be aware of the problems when dealing with this type of special student. A common situation is that many visually handicapped people have other handicaps or retardation as well. Also, the degree of impaired vision varies so much with each individual. To simplify the nature of this study, the author has geared the project primarily for Braille-reading students. Also, the emphasis is upon the junior and senior high level of physical science. Three students were chosen with this in mind and

fortunately they were all freshmen in high school with only a visual defect. This greatly simplifies the matter at hand, even though it does tend to single out only a particular type of student.

Homework assignments and quizzes are given in an attempt to evaluate the efforts and accomplishments of the students. It is felt that these results are very helpful in determining whether or not the instruments were useful and reliable. The type of examination used is explained in Chapter III of this work.

To understand the scope of this project, it is helpful to examine the resources presently available for the visually handicapped student. There are over fourteen Instructional Material Centers for Handicapped Children and Youth, all of which deal with materials for visually impaired students. One of the most prominent ones is the American Printing House for the Blind which sponsors the Instructional Materials Reference Center (IMRC) headed by Carl W. Lappin.¹ This center operates around a seven objective purpose including the making of adapted science equipment available to visually handicapped people.² Another is the Illinois Center for the Visually Handicapped which deals primarily with the situation on a state level.³ Examination of catalogs⁴ from these places and various other specialized institutions indicates that most of the measurement instruments presented in this project are available commercially.

The nearest account of the physical science application of ideas similar to those of this work is presented in the Measurement in Science Kit⁵ devised by the IMRC. This is a commercialized set of measurement materials which especially exemplify the pan balance and ruler constructions discussed later in the paper. Even though there are many similarities in this project and the work of Frank L. Franks⁶, which describes the

development of the kit, the purpose of the author here is to put forth a method by which measurement instruments can be adapted directly in the schools without relying so heavily upon specialized, commercial equipment. The cost of such a kit is unknown, but for those readers who wish to purchase this specialized material and abandon the concept of "do-it-yourself", please feel urged to continue studying this report. It may well be quite beneficial towards devising new ideas and stimulating further creativity on the part of these people.

Another group working in this area of research is at Berkeley, California. They are presently testing the value of an entire curriculum called Adapting Science Materials for the Blind (ASMB), which is an adaptation of the Science Curriculum Improvement Study (SCIS) program.⁷ This deals not only with the physical sciences, but also with life science. Many of the ideas are in keeping with this author's purpose of using simple inexpensive materials for adaptive use by visually impaired students in a science classroom. Nevertheless, the work is basically at the elementary school level as is the SCIS program. Also, most of the quantitative measurement equipment is generally a commercialized product. Even so, several ideas were devised in the work here because of the inspiration received from the recent report and film discussing the results of the ASMB project.⁸ One particular idea is that of a syringe volume measurement device as seen later in Chapter II.

Still another project closely related to this endeavor is that of Dorothy Tombaugh.⁹ Her work is done in conjunction with the BSCS Green Version Program in Senior High biological studies. Most of the equipment used is non-specialized, such as, half-inch-mesh hardware cloth for graphing and wax pencils for drawings detectable by touch. Again, though, it

seems that most of the measurement equipment is of the specially manufactured type.

Further investigations yield little else in regards to the specific research in adapting science measurement instruments for the blind directly in the classroom. However, there are other related articles which are of some assistance in developing the project at hand. According to Schiff¹⁰, two basic principles are necessary to keep in mind when dealing with raised dot and line alterations on equipment. These are contrasting texture and simplicity. Contrast can be dealt with in several ways. Various textures of materials, such as different types of cloth or string, are usually good to use in order to emphasize contrast. Size can be a factor which portrays differences in measurement units. This is seen best of all in the construction of the meter rulers discussed in Chapter II. Finally, position can be a variable to show contrast and differences between items. Indentations can also be used to portray variations, but it is advisable to be consistent with a raised Braille-like alteration in order to alleviate confusion among the sightless students.

The distance between lines and raised marks is an important consideration when constructing tactile arrays. According to Wexler¹¹, a distance of about 2.5 mm. is required between two marks before they can be detected by the touch of a finger. Further studies by Schiff and Isikow¹² support this conclusion also. Attempts are made by this author to abide by these findings as much as possible. The closest any two marks come together is about 5 mm., referring to the pin head positions on the Braille rulers discussed in Chapter II. Finally, the raised marks must be a minimum of .022 inches thick for discernability, as suggested by Morris and Nolan.¹³ The thin transparency tape used on the clock timer, presented in this

study, is the only item which is perhaps below this accepted standard. Even though the relief of the tape is about half of that of a Braille dot, it is still quite detectable since it is used to depict lines rather than dots. Because of the extended surface area of the relief, the line can be easily detected and thus the minimum standard need not be met in this case. This statement is supported by the fact that the students were able to use the clock very efficiently by reading the tape marks on its face. (see Plate V)

Several other texts and articles were studied in order to form a basic understanding of the behavior and plight of the visually handicapped person. First, a knowledge of the social and behavioral patterns and problems of blind students was desired. Best¹⁴ gives a good discussion of the blind in the United States society and the development of programs and attitudes toward them throughout the passing years. Cutsforth¹⁵ and Bishop¹⁶ narrow the scope to the specific topic of dealing with behavioral attitudes and programs in the realm of education. These books are a good preparation for understanding the situation of blind people, especially if one has no background in the field of special education, as is the case with this author.

The works of Loomis¹⁷ and Ashcroft¹⁸ are quite valuable in learning the Secondary level of Standard English Braille. This type of study need not be a necessary requirement for instructors in order to do the things suggested in this paper. It is well worth the time to investigate these works, though, because they help one have a deep understanding of how Braille-reading students think and operate. The least that is necessary is found on several pages of one of Loomis' works¹⁹ to be used as a reference. Also, Nemeth²⁰ presents an important exposé of his recent development in Braille mathematics, the Nemeth Code. This is basically the same

as the Standard English Braille except for a down shifting of dot positions in the numeral characters and a series of new dot arrangements for mathematical symbols. It is important to be familiar with this work since the Nemeth Code can be easily intermingled with the Standard English Braille without confusion on the part of the reader. Hence, most advanced students will work with both systems, instead of using the more tedious Standard method of representing numbers and mathematical symbols.

Methods of how to evaluate visually handicapped students in a laboratory situation are found in an article by Thier et. al.²¹ In the report, a basic format is presented to help teachers discover the most about their special students' capabilities and achievements. Other ideas and formats are given by Bourgeault and Woodcock.²² Their work deals mainly with developing rigid, standardized types of examinations and how to do a statistical analysis of the results. The testing method in this study is more along the lines of the work initially mentioned, which deals more with an informal battery of skill tests and practical applications of theoretical ideas in the laboratory using the equipment available.

In conclusion, it is quite common to find that when new ideas and instruments are developed in this field of work, they are quickly patented and manufactured for the market of schools and instructors. In this study, however, it is the motive of the author to avoid this by presenting an informal method of developing the equipment directly in the classroom. In this way, each instructor becomes a cooperate inventor who, because of the creative opportunities, learns to deeply appreciate and understand the work he is undertaking.

CHAPTER II

EQUIPMENT: DESIGN AND ANALYSIS

In this section, a somewhat brief discussion is presented concerning the design of each basic piece of equipment and a list of parts needed for its construction. Next, an analysis of the apparatus is given in order to indicate its practical use, degree of accuracy, and the ease by which a visually handicapped person can manipulate it. Much of the critique is based upon firsthand observations in the Freshman general science class at the Kansas School for the Visually Handicapped in Kansas City, Kansas.

A. Braille Label Maker

Design

The basic operation of a regular Dymo label maker is identical to that of a Brailier. Therefore, if a student or instructor has access to a Brailier, he can make attachable labels without purchasing a special label maker, which is somewhat costly. This technique is employed extensively throughout the entire project here. As seen in Table I, very little is needed to accomplish this task.

Place a piece of Braille paper or regular stationery in the Brailier. Next transcribe the entire Braille cell, or the "for" symbol, all the way across the width of the paper. This sets up a guide so that the marks on this tape can be aligned and centered. Cut off the approximate length of tape to be embossed and place it over the guide. Scotch tape should be used to keep the label in place. (see Plate I) Finally, transcribe over the label in the standard way; then, it is ready to use. Many labels may be made using the same guideline transcribed on the paper. Before the embossed tape is set in place on the device, the surface of the apparatus

TABLE I. Quantity and price list of materials needed to
operate the Braille label maker are shown,
including the approximate time to make a label.

TABLE I
BRAILLE LABEL MAKER

<u>Materials</u>	<u>Quantity</u>	<u>Approximate Cost</u>
Perkins or Lavender Brailier	1	rent*
1/2" vinyl embossing tape**	1 roll	\$1.27 each
scotch tape	1 roll	\$.59 each
scissors	1	school ***
Total Cost:		\$1.86

Approximate Construction Time: 1-3 minutes per label

*Arrangements can be made by the instructor to borrow or rent a Brailier from a state institution for the blind or from the visually handicapped student if he has one in his possession.

**Two rolls of Dymo vinyl embossing tape contain enough to be used for nearly all items in this project.

***It is relatively safe to assume that most tools and other types of common materials can be found in the laboratory or elsewhere in the school without much problem or extra expense.

PLATE I: The Perkins Brailler is shown with a piece of vinyl embossing tape lined up on the paper with the Braille cell guide.

PLATE I



should be thoroughly cleaned with alcohol or acetone in order to insure a more permanent adherence. Also, if there are many small labels to be made, it is wise not to space between separate words or numbers. It allows for more symbols on the single piece of tape. When they are cut, they still appear to have a sufficient marginal boundary.

Analysis

This method is perhaps the most valuable approach discovered in this project, since many labels are needed for the alteration of public school science equipment. It takes only a few minutes to perform the operation for a sighted instructor or student aide. Visually handicapped people can also make labels on their own with very good accuracy in centering the words on the tape. Even so, it naturally takes longer for them to learn how to align the tape on the paper.

Another aspect of this method is its inexpensive use. A Dymo Braille Tapewriter²³, from the American Foundation for the Blind, costs \$28.70, and it only contains the letters of the alphabet plus some punctuation marks. Hence, it can only be used in a capacity to write out words in full. The Brailier method, however, can emboss tapes using contractions, partial word forms, Nemeth code, and all other symbols used by the advanced unsighted person. Even a slate and stylus, which is usually more accessible than a Brailier, can be used for the purpose of embossing vinyl tape labels.

Another advantage is that the marks on the tape are long lasting and can withstand much handling by students who read Braille. This is much better than having the student make labels from Braille paper where the symbols are not quite as firm.

It is felt that all visually handicapped people should be aware of this method so that they may have the opportunity to label personal items

in the home or business with little expense and with ease.

B. Measuring Rulers

Design

1. Meter ruler in centimeters

A blind student can use a common laboratory meter ruler when the subdivisional marks are highlighted with pin heads.

The basic indications on this rule are the "10 cm." mark, the "1 cm." mark, and the ".5 cm." mark. (see a, b, and c respectively in Plate II) A piece of masking tape can be used as a straightedge to align the various sets of pins. Plate II depicts the layout of the subdivisions on a typical meter ruler. The dotted lines show where the top of the masking tape should lie in order to line up the pins.

Position "a" is occupied by the pins with large plastic heads. The small-headed dressmaker pins are used in position "b"; and for "c", the straight pins with standard heads are used. (refer to Table II and Plate II) As it can be seen, the visually handicapped person can determine length digits from the various positions of the pins and the different sizes, or textures, of the pin heads.

Before the pins are situated in place, several steps should be taken first. For ease of setting the pins, each potential mark should be bored with a slender awl. The hole should not be too deep, yet enough so that a minute length of the pin stem can be inserted. It is necessary to do this in order to avoid having to hammer the pins into the wood. The plastic heads of the pins tend to shatter under such a force. Next, the stem of each pin is clipped off with a wire cutter so that there is a small stub left on the head. This small extension helps stabilize the pin head on the ruled stick. Finally, the pins are glued in place with epoxy. A long-nose

PLATE II: Shown is an expanded diagram of the pin head positions on the metric scale of the meter ruler. Dotted lines indicate the particular levels of fractional markings.

**THIS BOOK
CONTAINS
NUMEROUS PAGES
WITH DIAGRAMS
THAT ARE CROOKED
COMPARED TO THE
REST OF THE
INFORMATION ON
THE PAGE.**

**THIS IS AS
RECEIVED FROM
CUSTOMER.**

PLATE II

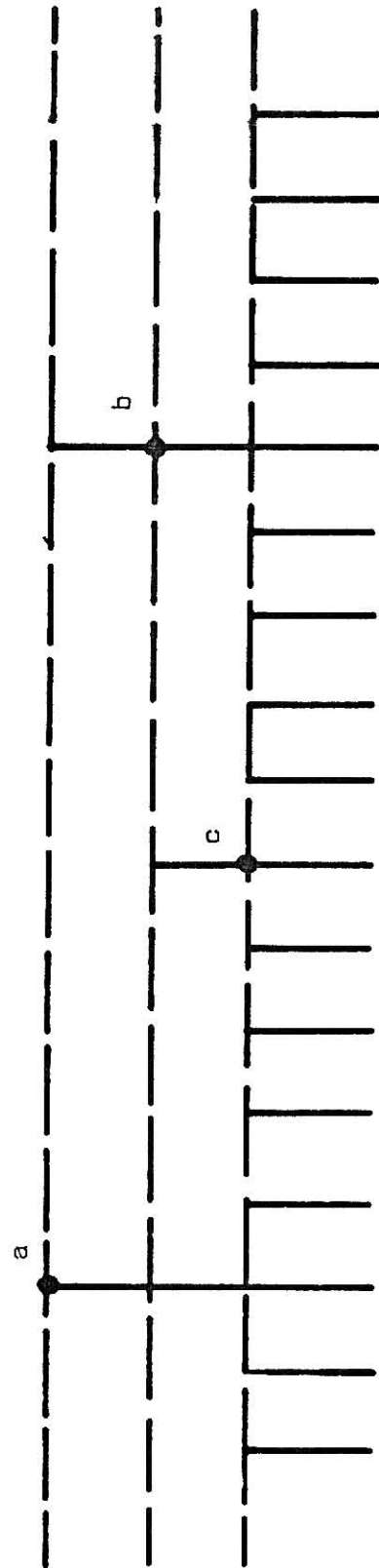


TABLE II. Quantity and price list of materials needed to construct the measuring rulers are shown, including the approximate time of construction.

TABLE II
MEASURING RULERS

<u>Materials</u>	<u>Quantity</u>	<u>Approximate Cost</u>
wooden meter ruler in inches	1	school
wooden meter ruler in centimeters	1	school
plastic foot ruler with raised marks	1	school
stainless steel strip ₃ 4.8 x 2.5 x .05 cm.	2	school
cardboard strip 6 x 1 cm. ²	1	school
epoxy glue*	1 set	\$.98
dressmaker pins (large plastic heads)	100	\$.89
dressmaker pins (small plastic heads)	250	\$.89
straight pins (standard heads)	200	\$.69
hammer	1	school
awl	1	school
wire cutters	1	school
long-nose pliers	1	school
1/2" Dymo vinyl embossing tape	70 cm.	\$1.27 per roll
Braille	1	see Table I
Total Cost:		\$4.00

Approximate Construction Time: 2 - 3 hours per meter ruler

*Epoxy glue is used for several types of equipment. One set of resin and activator is enough to cover most of the work in this entire project.

pliers may be helpful in this operation. A light tap with a hammer will assist in setting the pin so that only the head is visible on the surface of the wood. This procedure is followed for all three types of pins. It is also wise to set the pins in a consecutive order so that it is not so difficult to arrange them. In other words, put the pins in the 5 cm. position, then the 1 cm. position, and so on.

After the glue dries, the numbers from 10 to 90 are transcribed on the Dymo embossing tape in steps of ten. These are then applied to the surface in such a way so as to depict each "10 cm." mark. Also the words "meter ruler" and the unit "cm." are situated at the far left and far right of the stick respectively.

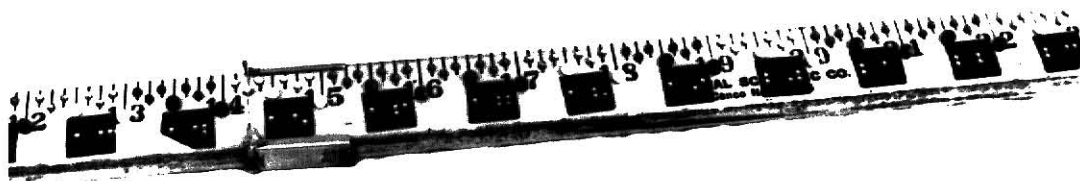
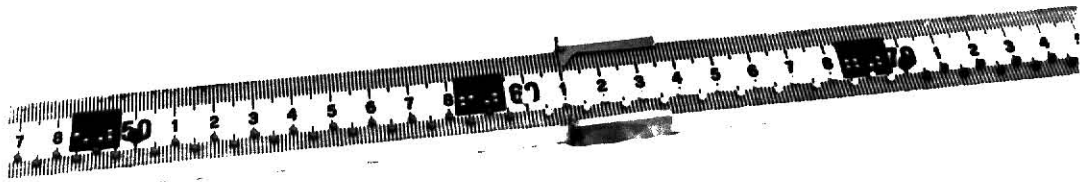
The metal "hairline" slide as seen in Plate III, can easily be made by someone who has access to the shop equipment at school. Essentially, it is a stainless steel strip, which is approximately $4.8 \times 2.5 \times .05$ cm.³. It is bent in such a way so that it saddles the meter stick. Caution must be taken so that the lips on the open end do not extend too far so as to interfere with the pin heads when the slide is moved. A piece of bent copper strip is strapped on the inside of one of the outer edges of the slide for use as a spring tightener. This is commonly seen on "hairline" slides from most slide rules. Finally, two pin stems and a thin piece of stainless steel wire stretched between them are placed on one end. The wire must be elevated enough so it can clear the top of the largest pin head. The slide can be fixed together by soldering, brazing, or epoxying the pieces. For obvious reasons, be sure all sharp edges and points are smoothed out or filed down.

2. Meter ruler in inches

The method previously described is the same one used for this

PLATE III: A comparison of the two meter rulers is presented along with a close-up view of the hairline slide.

PLATE III



measuring ruler. As seen in Plate IV, the arrangement of the pins gives an accuracy of $1/8$ of an inch. Pins in position "a" are of the standard head variety. Small-headed pins are used in position "b" and the large heads occupy the "c" and "d" positions.

When the pins are in place, the whole numbers from 1 to 39, referring to the number of inch markings on a meter ruler, are embossed on a piece of label tape and situated on the ruler in the vicinity of the corresponding mark. Also, the word "in." is placed on the far left end to indicate the proper units. In this case, there is no room to put the words "meter ruler" as was done in the previous case. A hairline slide is also used to help determine an accurate reading.

3. Foot ruler

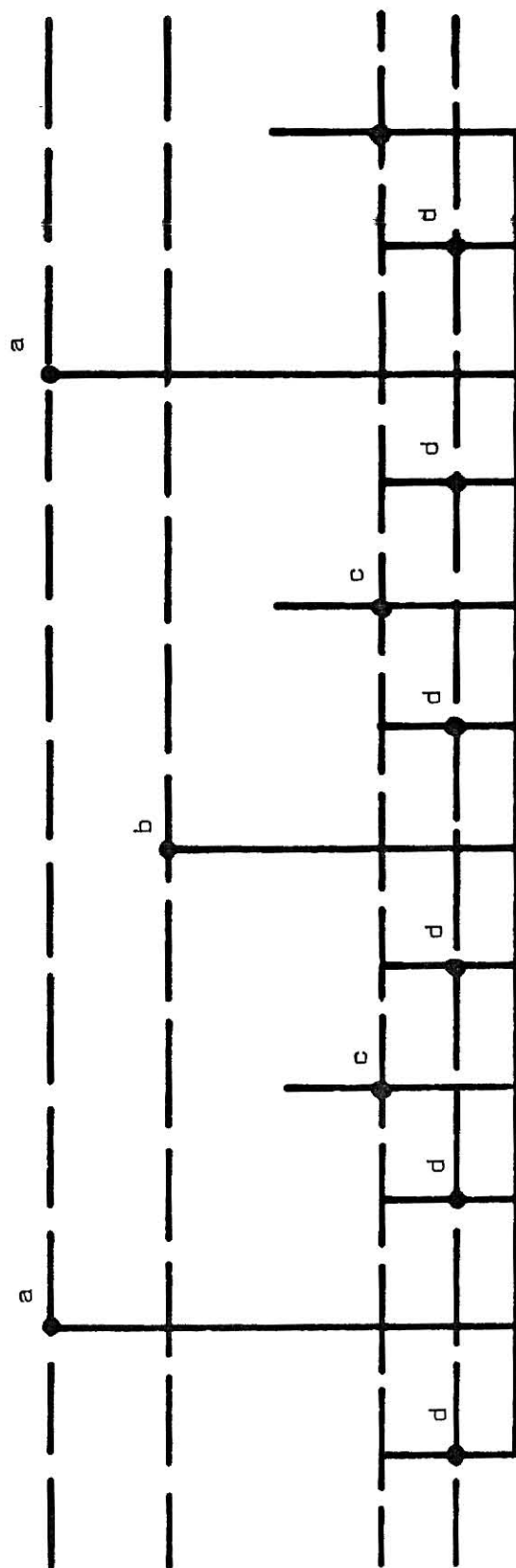
Some plastic foot rulers have subdivisional markings which are elevated above the surface. Many visually handicapped students have enough tactile perception to recognize these marks by running their fingernails over them. Both the English and metric scales are perceptible. To assist in accuracy, a slide indicator can be made by obtaining a piece of plastic gel or cardboard 6×1 cm.² and wrapping it around the ruler and fixing with scotch tape. It should be snug yet loose enough to be moved freely.

Analysis

Even though these rulers require the most time to assemble of all the items in this project, they are quite effective and operative in the classroom. The ruler is normally placed on the object to be measured so that the starting end is put on one edge and the slide is moved up to the other edge. The ruler can then be removed to a better position for the student to read it. The speed with which this can be done is less than a

PLATE IV: Shown is an expanded view of the pin head positions on the English scale of the meter ruler. Dotted lines depict the particular levels of fractional markings.

PLATE IV



sighted person, of course, but it is still only a matter of seconds after some practice. Also, the accuracy is the same if not better than the most common measuring rulers found in the catalog of tools for the blind. The majority of these devices range from \$5.00 to \$20.00 in price.²⁴ Some of them, however, do have an accuracy of $1/16$ to $1/64$ of an inch. They work primarily on the basis of a rotating nut down a long threaded rod.²⁵ Each turn specifies a certain unit of distance. It is felt that this type of ruler can also be made by the instructor without much trouble even though it is not attempted in this project.

The measuring tools devised here are quite accurate for most general purposes in the laboratory. A foot ruler most commonly found in institutions has the same degree of accuracy as the meter stick described in this paper: $1/8$ inch and $1/2$ centimeters. As one can see, the meter ruler marked in centimeters is not as complicated as the one marked off in inches. This is verified from the classroom experiences where the students learned to use the metric ruler more quickly than the one marked in inches. Actually, the measuring stick marked in English units was only used during the period of time in which a comparison of metric and English systems was taught. The metric ruler was used throughout the rest of the laboratory endeavors. The plastic foot ruler can only be used by students with a high degree of tactile ability. Also, it takes a little more time and patience to count the small intervals. If it can be done by the student, the degree of accuracy is increased to $1/10$ centimeter or $1/16$ inch, depending on the scale used.

One minor difficulty could occur if the rulers are not handled with some care. With hard use, the pin heads can be shattered and also the slide could be damaged. Nevertheless, if built correctly, these rulers

will last through a good amount of use.

C. Clock Timer

Design

This particular idea is taken from that of a wrist watch for a visually impaired person. First, the face of the clock should be wiped clean with a cloth dampened with acetone. Then, the transparency tape, described in Table III, is placed over each subdivisional line so that a long piece is put at each major division and a small piece at the others. (see Plate V) This produces a series of raised marks with an accuracy of one-tenth of a second for the timer used here. These marks are easily detected by touch alone. The transparency tape can be cut to size by placing it on the surface of the clock and scoring it with the Exacto knife. To make the major divisions more noticeable, a small section of a toothpick or a matchstick can be glued at the end of the tape.

The words "clock timer" and "sec." can be transcribed on the Dymo tape and placed on the timer somewhere. For this particular timer, the numbers from zero to nine are also embossed on the vinyl tape along with the number ".5" which is placed between each whole number. These are then situated on the clock in such a way so that they can be read without interfering with the motion of the hands of the clock.

Analysis

Many different clocks, watches, and timers are found in the equipment catalog from the American Foundation for the Blind. Most of them are fairly inexpensive, but the more accurate timers range in price from \$18.00 to \$40.00.²⁶ A little money can be saved by altering any open-faced clock timer already available in the lab, especially if the school's expense budget for materials is somewhat restricted. This is particularly true

TABLE III. Quantity and price list of materials needed to construct the clock timer are shown, including the approximate time of construction.

TABLE III
CLOCK TIMER

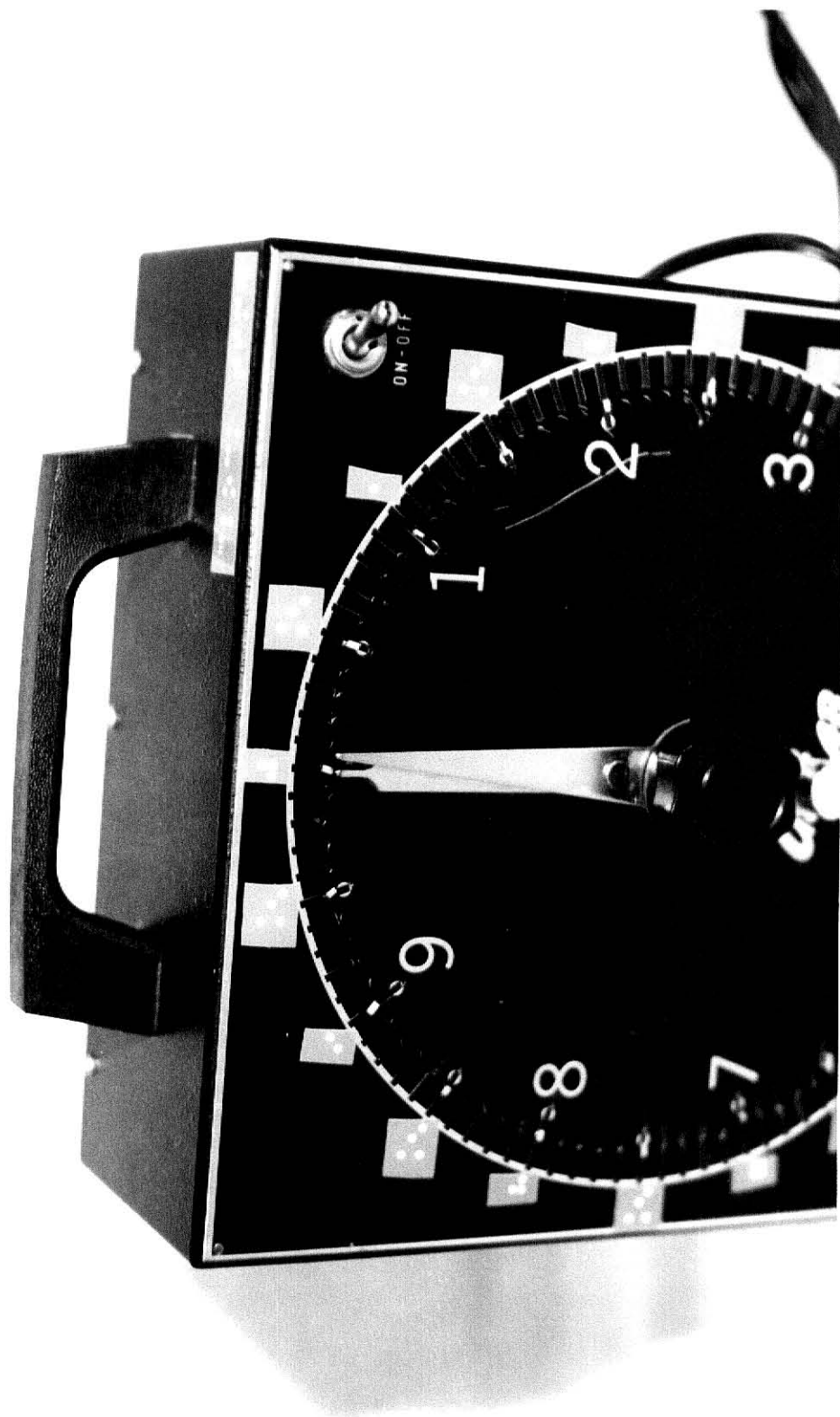
<u>Materials</u>	<u>Quantity</u>	<u>Approximate Cost</u>
Exacto razor blade knife	1	school
scissors	1	school
Braille	1	see Table I
1/2" Dymo vinyl embossing tape	25 cm.	\$1.27 per roll
laboratory timer with open face and sweeping hands*	1	school
1/16" x 650" glossy transparency tape	120 cm.	\$1.50 per roll
		Total Cost: \$.50

Approximate Construction Time: 1 - 1.5 hours per timer

*A Galab Micro-timer, which has a 10 second face subdivided into tenths of a second, is used in this project.

PLATE V: The face of the clock timer is shown after
Braille marks are applied.

PLATE V



since it will be convenient to have a couple such timers for laboratory use.

Also, it seems apparent that the most accurate timer in the catalog is a stop watch which is marked in one second intervals. Many scientific experiments require a greater accuracy than this in order for students to see the relationships between various concepts. For example, in the experiments concerning the pendulum and the velocity of an air car, the students need an accuracy of about $1/10$ of a second. The particular timer used in this project is very useful because it is accurate up to one tenth of a second. It is quite common to find a device such as this in most public high schools. Hence, not only is expense kept at a minimum, but the degree of accuracy is higher than any specialized timer on the market.

There are few disadvantages to this device. It does take a little practice for the visually impaired student to reset the hands properly. This is quite natural, though, and the time it takes for a blind person to read the clock is still about six to ten seconds, or sometimes less. Perhaps too, the time required to alter the face of a clock in this manner is somewhat of a disadvantage. Even so, one might want to choose to spend the time rather than the money. Other than these things, it is felt that this tool is very efficient and most valuable in educating the blind in the realms of science.

D. Volume Syringes

Design

The syringe is a very useful tool for visually impaired students to use when measuring small quantities of liquid. The idea here is to find some way for students to read the various fluid levels without having to insert their finger in the liquid. To do this, the stem of the syringe is notched to match the subdivisional markings on the outside of the barrel.

This is easily accomplished with plastic syringes, (described in Table IV), which are also cheaper and safer than the glass type.

First of all, the stem is pushed all the way down the barrel and marked on one of the inside ribs with the overhead transparency pen. Then, the stem is removed and placed along the outside of the barrel. The rib is marked using the scale on the barrel as a guide until each major division is duplicated onto the rib of the stem. Next, the Exacto knife is used to make notches where these marks have been made, as seen in Plate VI. It is wise to make some indication at the top of the stem to show which of the four ribs is notched.

Various degrees of accuracy depend on the different types of syringe. For instance, the 60 cc syringe is marked in steps of 5 cc, where as the 12 cc syringe is divided into intervals of 1 cc. Also, some syringes have divisional markings indicating ounce units. This is typically found on the 60 cc syringe which is also marked as having a two ounce capacity. Thus, the stem of one of these can be notched to correspond to intervals of one-fourth of an ounce. This dual nature of the 60 cc syringe is useful when studying and comparing the relationship between the English and the metric units of volume.

When the marking is completed, a Dymo label may be made indicating the total capacity of the syringe, the units involved, and the subdivisional steps, such as: "60 cc 5". On the larger syringes, this label is wrapped around the barrel. It may be necessary to place it lengthwise on the smaller barrels. Nevertheless, in each case, place scotch tape on the ends of the label in order to keep them from fraying.

The needles are discarded to insure the safety of the student unless acids and corrosives are being measured. In this case, the sharp tip of the

TABLE IV. Quantity and price list of materials needed to construct the syringes for volume measurement are shown, including the approximate time of construction.

TABLE IV
VOLUME SYRINGES

<u>Materials</u>	<u>Quantity</u>	<u>Approximate Cost</u>
Exacto razor blade knife	1	school
scotch tape	1 roll	school
scissors	1	school
1/2" Dymo vinyl embossing tape	35 cm.	\$1.27 per roll
3-M audio-visual pen	1	\$1.00
Braille	1	see Table I
disposable plastic Monoject		
syringes: 60 cc	2	\$.75 each
12 cc	1	\$.50 each
3 cc	1	\$.50 each
(insulin) 1 cc	1	\$.50 each
Total Cost:		\$4.50

Approximate Construction Time: 5 - 10 minutes per syringe

PLATE VI: The 60 cc and 3 cc metric syringes are shown
with emphasis on the notched plungers.

needle can be sawed off and the rest of it be used as an extension to keep the harmful liquid off of the barrel. A saw is used rather than a wire cutter because the cutter will tend to crimp the hollow needle and close the opening. This method should have close supervision; and, extreme caution should be enforced.

Analysis

The most important feature of this device is not necessarily the low expense, but the safety, accuracy, and cleanliness involved with its use. Other methods of measuring volume have been devised which hinge mainly upon the idea of a measuring cup. These tend to be messy due to the fact that the container is filled until the liquid flows over into a pan underneath it. A discrepancy of two to five milliliters, even up to ten in many cases, is found when using the "overflow" method. The smallest syringe described in this project has notches corresponding to intervals of one tenth of a milliliter with a discrepancy of only about five hundredths of a milliliter. This gives sufficiently accurate volume measurements for most basic physics and chemistry experiments requiring a precise quantity.

However, in many cases, a multiple number of syringes must be used to measure various quantities of liquid. This was put into practice by the three students involved in this study.

For instance, 47.7 ml. can be obtained by using the 60 cc syringe to get 45 ml. and using the 3 cc syringe to get 2.5 ml. Finally, by using the smallest one, .2 ml. can be measured. This, of course, adds more uncertainty in error but the reading is still easily within one to two milliliters. The fact that different combinations need be used in many measurements presents several problems, but ones which can be readily overcome with a little practice on the part of the student. First of all,

the student must be able to take a given volume and break it up into the most efficient components in order to use the correct syringes with the least amount of error. This part of the operation takes the longest for the student to effectively grasp. Secondly, more time is needed to make a single measurement when different syringes have to be used. It takes roughly five to eight times as long as a sighted person using the same method. Also, the "mess" factor increases somewhat as more and more syringes are needed.

There is another advantage to this method, however. Using a blunt needle as an extension, the syringe can be placed in a caustic or acidic liquid and filled without the students' hands coming in contact with it. The safety is even more increased if a wide shallow pan is used as a reservoir. In this way, the syringe can be put nose down all the way to the bottom. Now the student is assured of having the opening completely submerged without having to feel for a liquid level. In most cases, it is wise for the student to put in more fluid than necessary and to turn it upright to force out any air. The particular example of measuring corrosive liquids was not dealt with in this work.

This method is only practical for small volume measurements. Anything over a half of a liter is awkward to obtain using only a 60 cc syringe at the most. There is another method for measuring larger volumes, but it is not substantially developed in this project. However, the idea is discussed in a later section of the paper.

E. Scale Balance

Design

The pan balance is easily altered for the use of a sightless person. Table V presents the materials needed for construction. The needle is

TABLE V. Quantity and price list of materials needed to construct the scale balance are shown, including the approximate time of construction.

TABLE V
SCALE BALANCE

<u>Materials</u>	<u>Quantity</u>	<u>Approximate Cost</u>
metric mass weights	1 set	school
English mass weights (if possible)	1 set	school
1/2" Dymo vinyl embossing tape	35 cm.	\$1.27 per roll
1/16" x 650" glossy transparency tape	30 cm.	\$1.50 per roll
Brailier	1	see Table I
medium size sewing needle	1	\$.05
scissors	1	school
Exacto razor blade knife	1	school
standard torsion pan balance with pendulum arm	1	school
Total Cost:		\$.60

Approximate Construction Time: 20 - 30 minutes

taped, soldered, or glued to the back of the pendulum scale in the lower central part of the balance. This needle should extend above the scale with the eye of the needle on top and situated at the center of the scale where the pendulum indicates an equilibrium position. (refer to Plate VII) This will be used as a reference point in order to find out how much mass should be added or removed.

Next, the gram scale of the torsion arm is marked off in intervals of five tenths of a gram, as seen in Plate VIII. This is done by taking the 1/16" transparency tape and aligning it over the corresponding printed marks on the scale. The face of the scale should first be wiped clean with a cloth dampened with acetone. As in the case of the clock timer, the tape can be easily cut by scoring it with the Exacto knife. In this way, the metal slide at the top of the torsion arm will register a reading with an accuracy of five tenths of a gram. Braille labels can then be made and placed on the face of the torsion arm which say "gr. .5", indicating the units and the subdivisional marks. Also, the values of each mass weight in the set can be embossed on Dymo tape and wrapped around the weight. (presented in Plate IX) The 10 gram weights are too small for a label to fit. This is usually the smallest weight needed for this type of balance, so it does not matter if it is not labeled. The student can easily remember that the unmarked weight has a mass of ten grams. The added weight of the small vinyl label will effect the accuracy at the most by less than a tenth of a gram, which is well within the intended accuracy.

Analysis

The pan balance is one of the simplest items to alter for the use of the blind student. The operation that takes the most time is cleaning and labeling the mass weights. Usually, the student quickly learns how to find

PLATE VII: An expanded sketch of the pendulum scale on the pan balance is shown. Note the position of the reference needle taped behind the equilibrium position.

PLATE VII

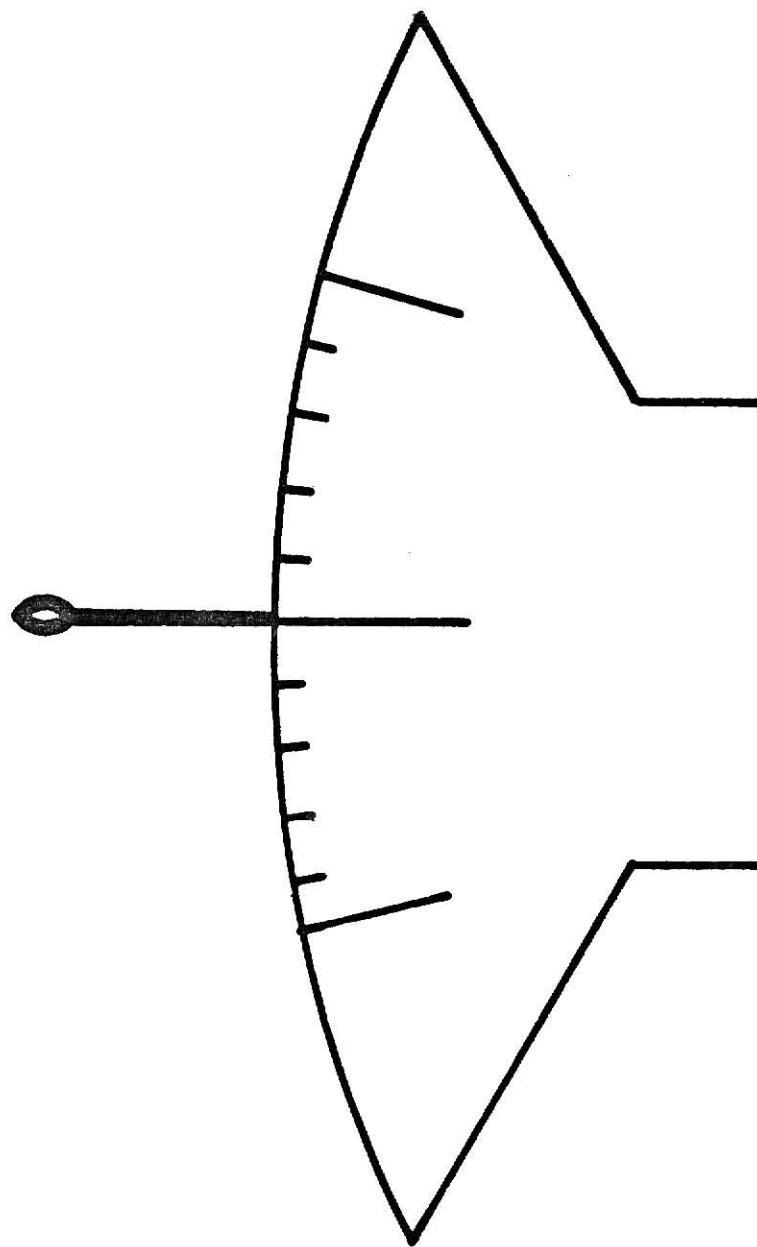


PLATE VIII: A close-up view of the gram scale on the
torsion arm of the pan balance is presented
clearly showing the altered face.

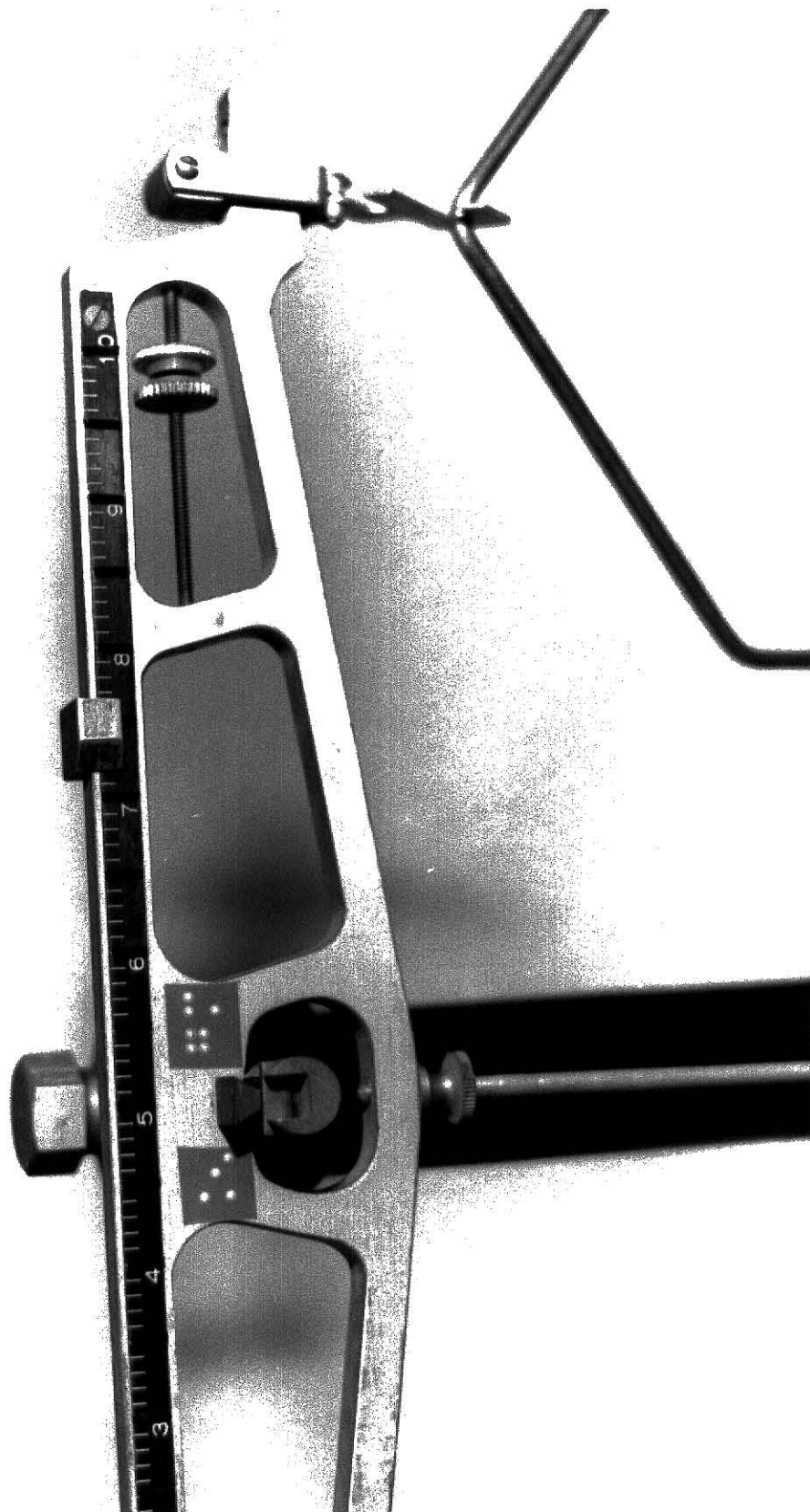
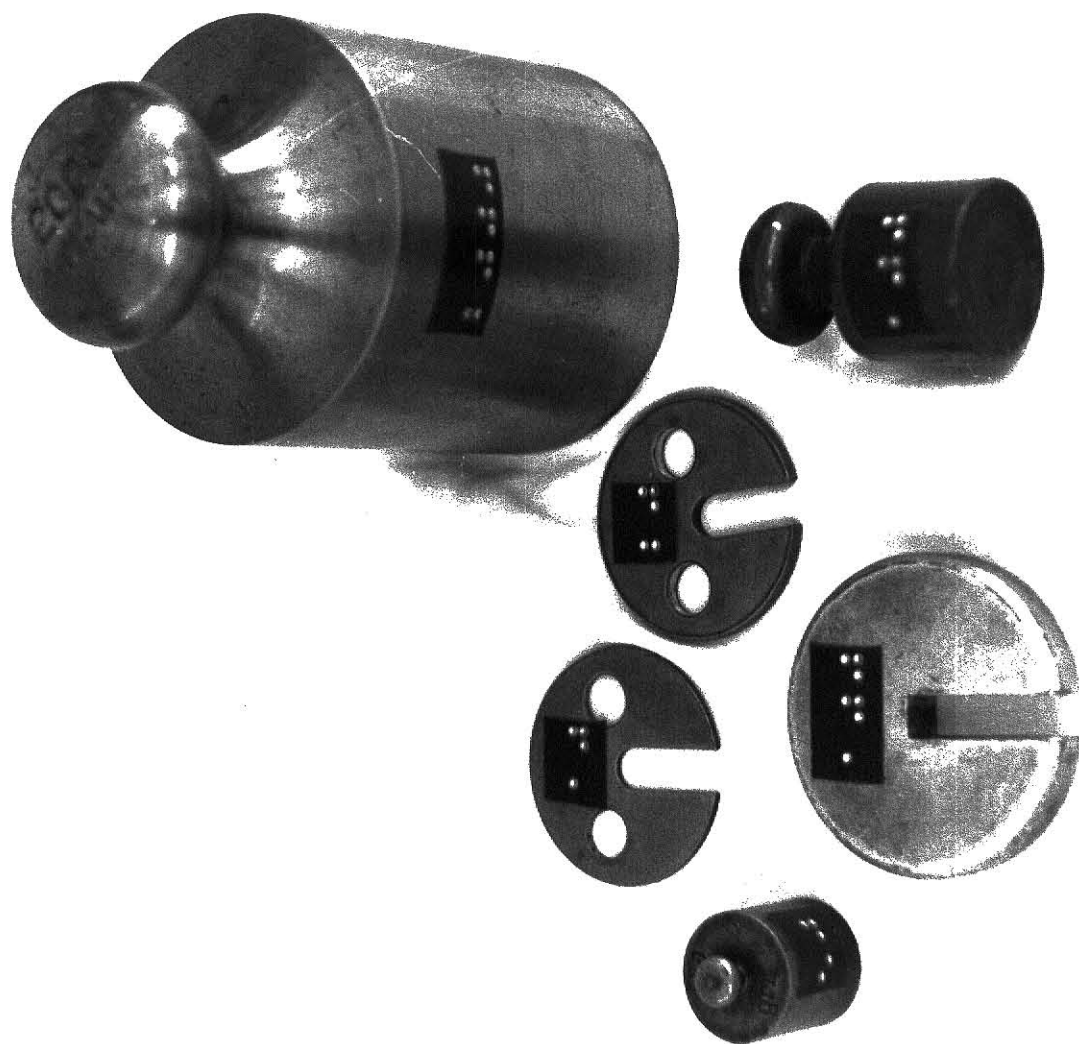


PLATE IX: A sample collection of altered mass weights
is shown.

PLATE IX



the equilibrium point of balance by lining up the pendulum arm and the reference needle with his forefinger and thumb, then releasing them to feel which direction the pendulum swings from equilibrium. This gives the proper indication as to how much mass he should add or detract.

Most scales available in the catalog are of the spring variety, ranging from \$7.00 to \$15.00 in price.²⁷ First, it is doubtful that any of these are as accurate as the altered pan balance. Secondly, it is unlikely that there are even many metric scales on the market yet. This method certainly requires more time to determine the mass of an object compared to using a spring scale. Even so, it requires little effort to alter and operate the pan balance, and most students find it easy to manipulate the masses and determine the weight of a particular object. Actually, the time required for a visually impaired person to operate the pan balance is about the same as that needed for a sighted person.

It is very helpful if mass weights with English units can be supplied with this balance. They are of a great aid in showing the relationship between this particular system and the metric system.

F. Graph Board

Design

A piece of ceiling tile, described in Table VI, makes an excellent graph board because of its size and lightweight characteristics as well as the accurately drilled holes. The tile can be notched on the edge to indicate various rows and columns of holes. A rubber band can be used for the horizontal and vertical axes by stretching it around the tile and situating it into the notches. In this way, the axes are readily movable in case a student wishes to work within a certain quadrant. If permanent axes are desired, the rubber bands or a length of string can be glued at

TABLE VI. Quantity and price list of materials needed to construct the graph board are shown, including the approximate time of construction.

TABLE VI
GRAPH BOARD

<u>Materials</u>	<u>Quantity</u>	<u>Approximate Cost</u>
string	4 ft.	school
large rubber bands	4 - 8	school
golf tees	12	\$.02 apiece
1' x 1' ceiling tile with evenly spaced holes	1	\$.50 to \$1.00
Exacto razor blade knife	1	school
Total Cost:		\$1.50

Approximate Construction Time: 10 - 15 minutes per board

each end of the board. It may be necessary to leave the string along the surface of the board unglued so that it does not interfere with placing the pegs in the holes. Then the points are plotted by the student, a line curve can be produced by looping a string around each peg in a continuous connection. (see Plate X)

Another variation of this is a 1' x 1' piece of peg board mounted on two pieces of 1" x 1" boards like a miniature work bench. It may be easier to find the materials necessary for this compared to the particular type of ceiling tile described here.

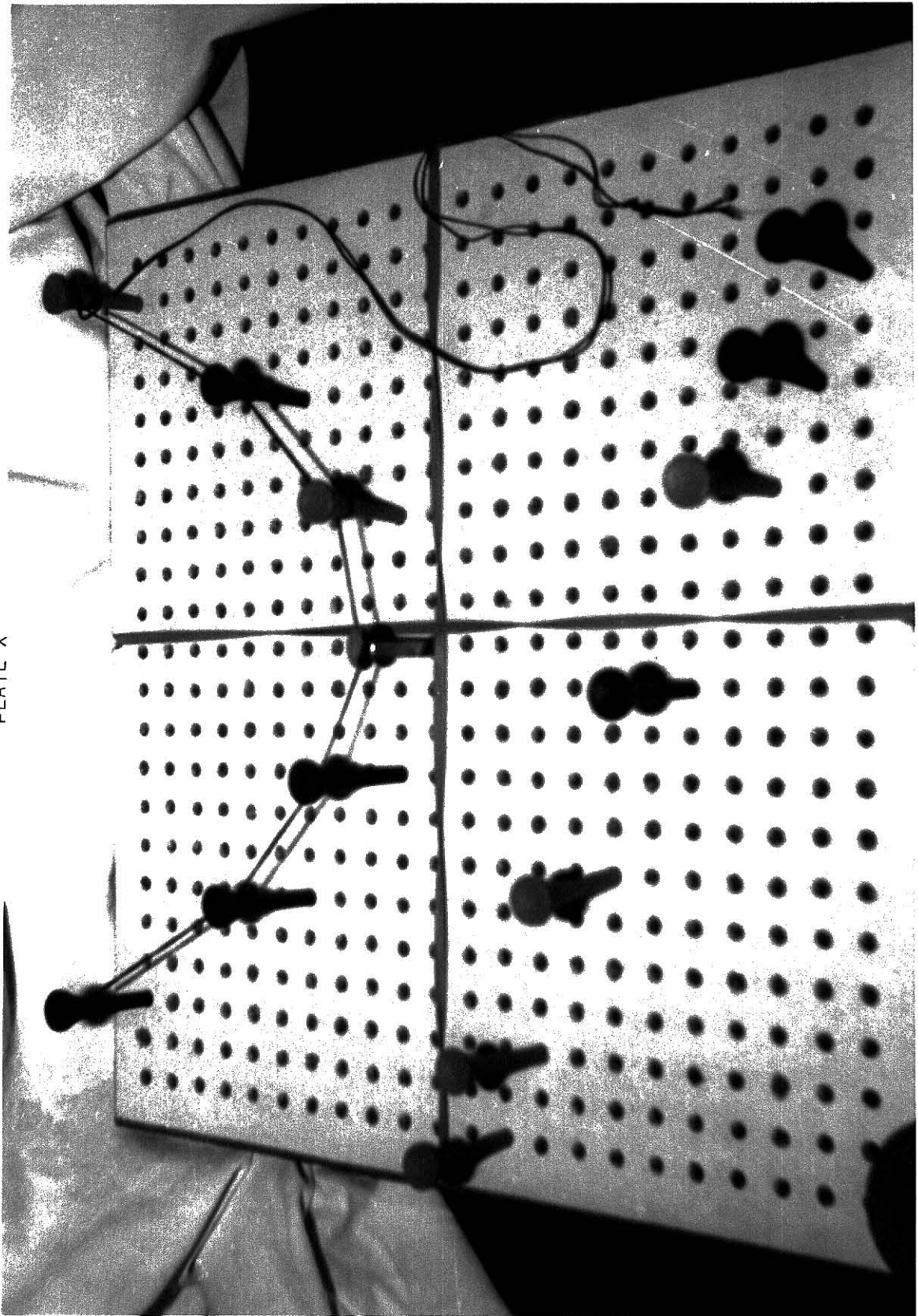
Analysis

The ceiling tile graph board is a very practical and inexpensive method for visually handicapped students to employ. The board used in most institutions are large 2' x 2' boards with a rubber inlay. It is fairly heavy and awkward to carry around. Since only one graph can be made at a time, the ceiling tile offers a better utilization of time. This is because four or five boards can be carried about with ease and used for a set of problems one right after another. Thus, because of size and weight, the other type of board must be cleared after each problem. It is only feasible to have one in a person's possession. The cost is also relatively high for the larger board.

The long golf tees provide a more outstanding picture of the graph compared to the thumbtacks, which are used on the larger board. By wrapping the string around the top of the "points", the curve is elevated in such a way so as to give the student a clear indication of the graphical interpretation of the problem at hand. The student can represent a problem on this board in the same amount of time, if not less, compared to that needed for the larger "thumbtack" board. After some practice for a blind

PLATE X: A view of the ceiling tile graph board is
presented depicting a sample curve.

PLATE X



person, graphing can be done in about the same amount of time as needed for a sighted person.

Even though the peg board method was not tested in this project, it is felt that this may be more useful than the tile method not only because of the availability of materials, but also because of the durability of the board. Most ceiling tile shatters pretty easily and, by inserting the golf tees very many times, the holes become worn. Perhaps the peg board would offer more stability and long-term use.

G. Volume Cubes

Design

Solid cubes come in handy to help a visually handicapped person to tactilely perceive volume and the three-dimensional world. Those cubes are also useful in comparing the English system with the metric system. In this project, the following cubes are used: cubic half foot, cubic decimeter, cubic inch, cubic half inch, and cubic centimeter. (see Plate XI) The larger cubes can be made of cardboard using a pattern similar to that in Plate XII. By using a wide adhesive tape to seal the edges, a sturdy cube is the result.

For the smaller ones, aluminum or plexiglass cubes may be cut from sheets of the material in the school shop department. These can then be labeled with the transcribed Dymo tapes written as "cu. in." and so on. The cubic half inch and cubic centimeter are too small to have a label attached to one of the faces. Therefore, these must be identified when presented to the student.

Analysis

The items described here are in keeping with the teaching aids generally used in educating the blind. These special students perceive

PLATE XI: The collection of volume cubes is shown which can be used in the comparison of the two measurement systems.

PLATE XI

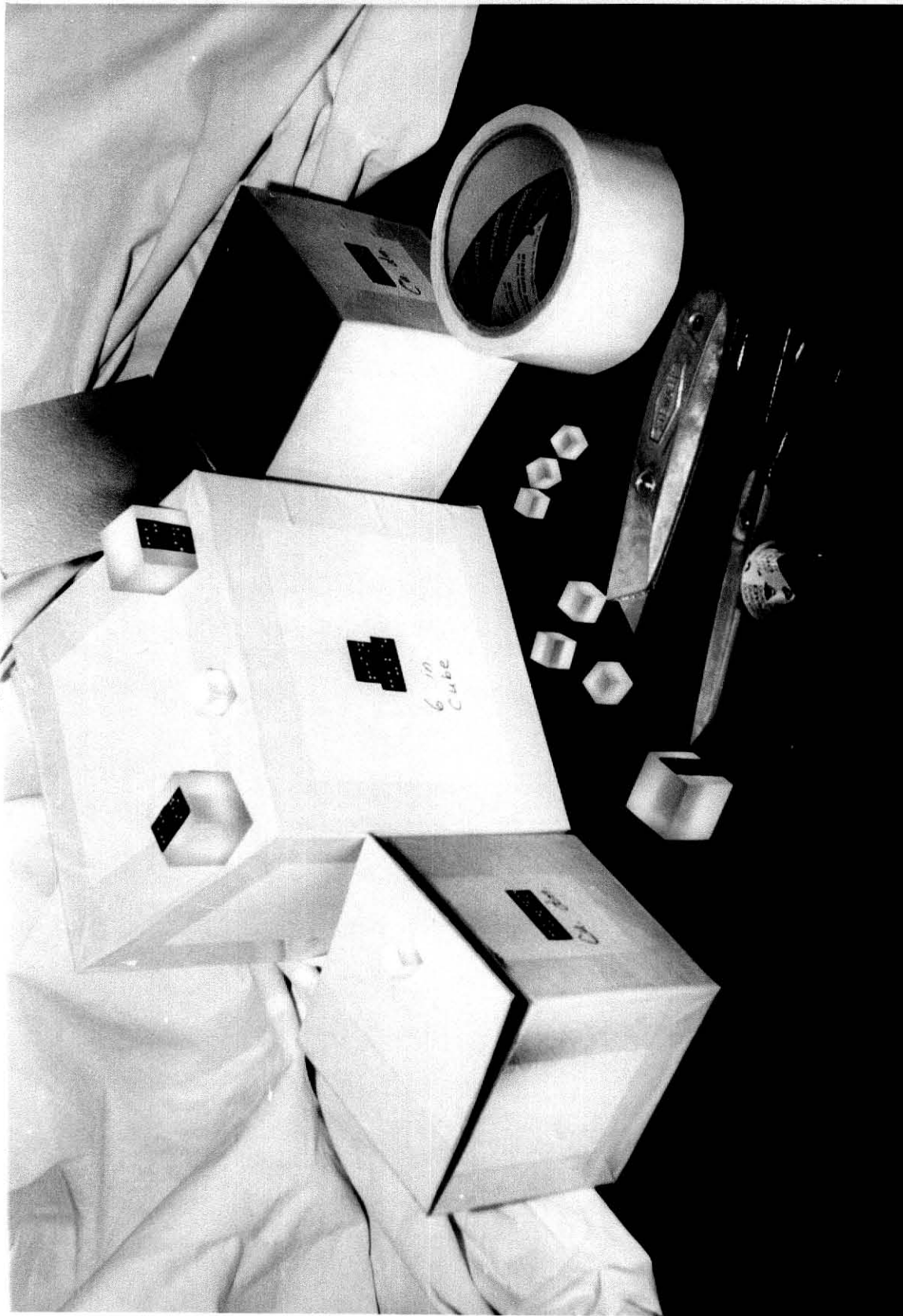
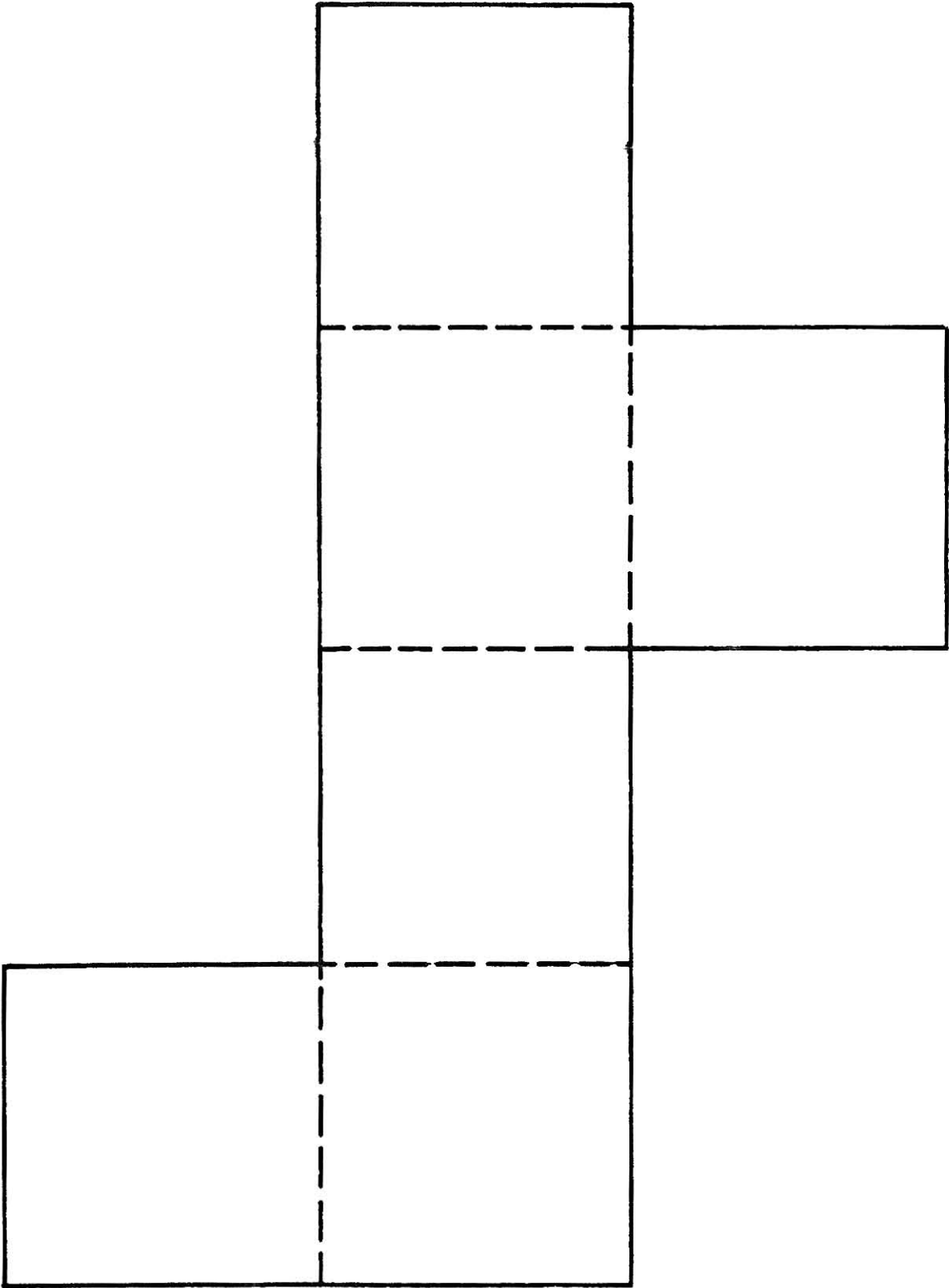


PLATE XII: The basic pattern is given which is used to
construct the cardboard volumetric cubes.

PLATE XII



most physical objects through the sense of touch. The concept of volume is easily taught with the use of the cubes in this project. This part is best presented after the concepts of length and weight. In this way, the student can measure the lengths of the cubes and compare the two systems of volume measurement: cubic centimeters and cubic inches.

Also, if it is possible, the cubic decimeter cube can be made to be waterproof and weighed in order to prepare it for an extended check on the metric system. The student can set the container on the pan balance and fill it with water, keeping track of how much is put in. By doing this, he can check to see if it holds one liter of water, as it should, and if it weighs one kilogram. Of course, the concept of density should be touched on a little here so that the student understands the reason why one liter of water alone will be a mass of one kilogram.

These cubes are quite inexpensive to make and take relatively little time to construct, as noted in Table VII. Also, they are invaluable in helping the visually handicapped person "see" how the concept of volume is derived. They especially help relate units of length, cubic centimeters or cc, to units of volume, milliliters or ml.

H. Photo Detector

Design

Table VIII presents the components needed to construct the photo detector circuit. The device described here is a hybrid of sorts which is based on the idea of a resonant circuit. It was not totally developed or assembled by the author, even though he could have put it together. The staff from any high school electronics shop will be able to follow the desired schematic shown in Plate XIII and assemble the components into an electronic light detector. The parts are joined and soldered so that there

TABLE VII. Quantity and price list of materials needed to construct the volumetric cubes are shown, including the approximate time of construction.

TABLE VII
VOLUME CUBES

<u>Materials</u>	<u>Quantity</u>	<u>Approximate Cost</u>
poster board or mat board	3' x 4' sheet	\$.75 to \$1.00
1/2" Dymo vinyl embossing tape	15 cm.	\$1.27 per roll
scissors	1	school
Braille	1	see Table 1
Exacto razor blade knife	1	school
wide (2 in.) thin adhesive tape	1 roll	\$1.50 to \$2.00
aluminum or plexiglass	(see discussion)	school
		Total Cost: \$2.50

Approximate Construction Time: 30 minutes per cube

TABLE VIII. Quantity and price list of materials needed to construct the photo detector circuit are shown, including the approximate time of construction.

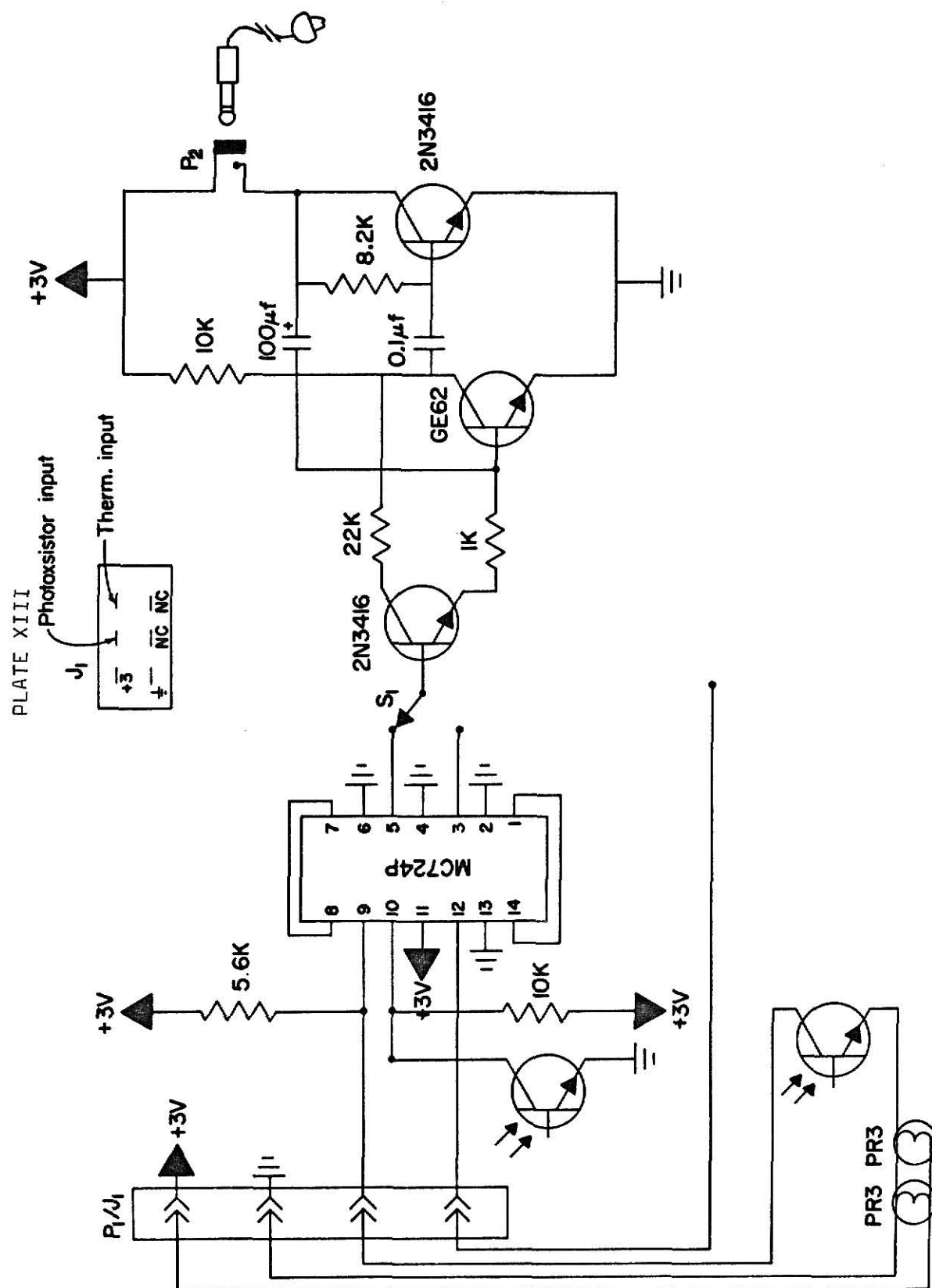
TABLE VIII
PHOTO DETECTOR

<u>Materials</u>	<u>Quantity</u>	<u>Approximate Cost</u>
miniature earphone	1	\$1.50
miniature earphone jack	1	\$.50
2N3416 transistor	2	\$.63 each
Ge 62 transistor	1	\$1.00
100 microfarad capacitor	1	\$1.00
.1 microfarad capacitor	1	\$.55
MC724P IC chip	1	\$1.25
PR3 flashlight lamp bulbs	2	\$.25 each
10 Kiloohm resistor (.5 Watt)	2	\$.20 each
22 Kiloohm resistor (.5 Watt)	1	\$.20
1 Kiloohm resistor (.5 Watt)	1	\$.20
5.6 Kiloohm resistor (.5 Watt)	1	\$.20
8.2 Kiloohm resistor (.5 Watt)	1	\$.20
4 conductor cable	15 ft.	\$1.50
2 conductor cable	3 ft.	\$.25
female binding posts	2	\$1.00 each
SPDT single pole, single throw switch	1	\$1.25
6 pin female Jones connector	1	\$2.00
6 pin male Jones connector	1	\$2.00
FPT100 Archer Phototransistor*	2	\$.79 each
Bud box metal container	1	\$1.50
3 volt, 1 amp capacity DC power supply	1	school
Total Cost:		\$21.25

Approximate Construction Time: 6 - 8 hours

*This inexpensive, wide range phototransistor is readily available at Radio Shack.

PLATE XIII: A schematic diagram is presented showing
the circuit design for the photo detector.



will be a firm connection. Next, the circuit is inserted into a metal Bud box for protection from the outside environment.

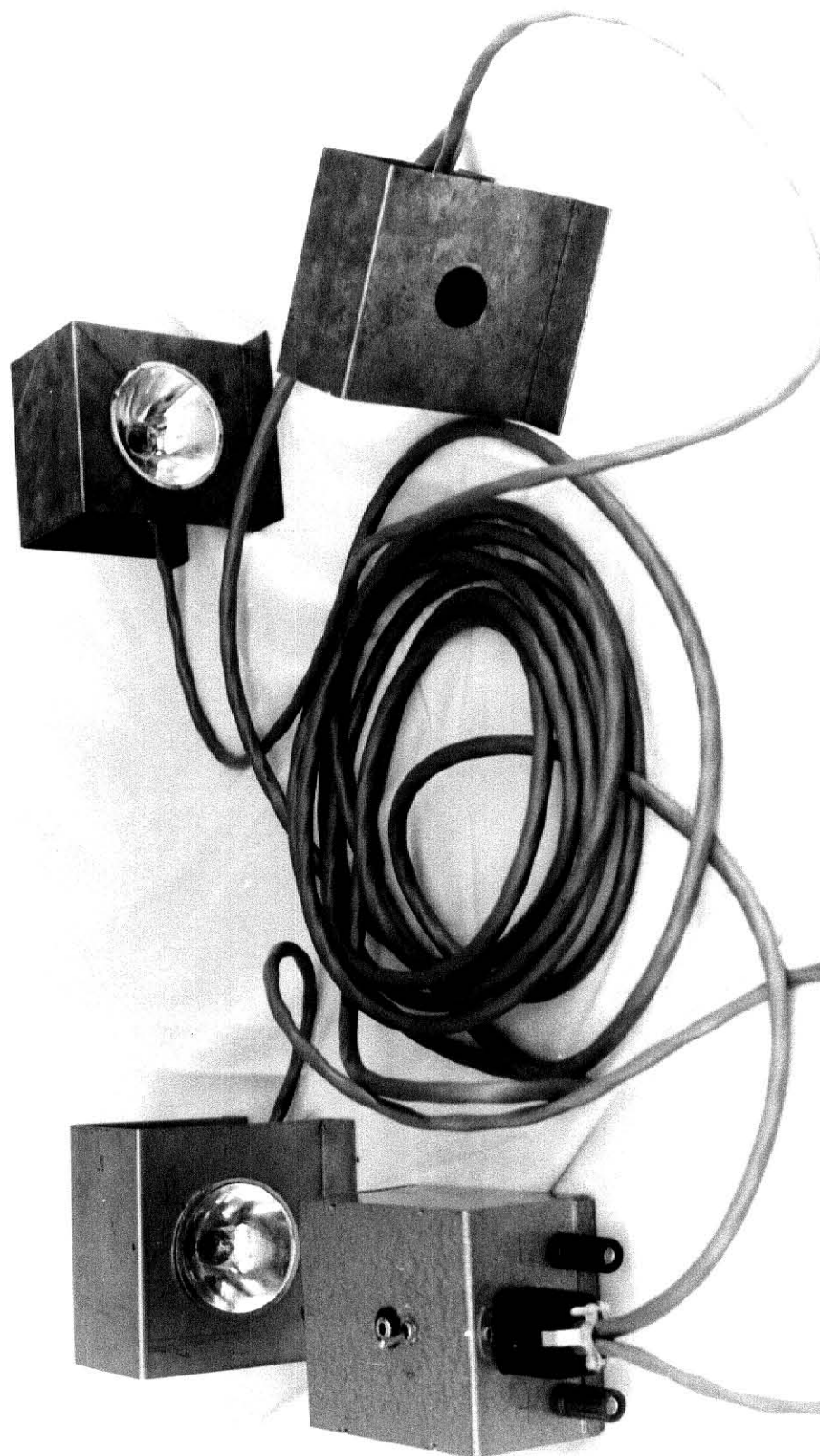
The circuit is particularly designed so that there are two sets of light source and photo cell. The long cable wire shown in Plate XIV is necessary in that the two sets be separated for use as an "on-off" switch. In other words, as is exemplified later in the discussion of the air car experiment (Chapter III), one set can be placed at one end of an air track while the other is placed at the opposite end. With this arrangement, the clock can be started when the bleep is heard on one end and stopped when the sound is heard again, this time coming from the other end. The setup need not always be used in this manner as shown in the discussion of the pendulum experiment in Chapter III. Nevertheless, it is convenient to have it made with a dual set of detectors for the instances when they are needed.

The circuit is designed so that when the light source is directed on-to the photo cell, the audible sound is blotted out. In this way, when the light beam is broken, a bleep is heard in the ear plug speaker. The sound is loud enough for the ear phone to be taken from the ear and placed nearby the person operating the equipment. In this way others are able to hear the intonations also.

It is necessary to maintain a close balance between 2.5 volts and 1 ampere in order for the circuit to behave properly. It was found that if the voltage exceeds this value, the sound becomes a constant hum, and when the light beam is broken, only the pitch of the hum varies. This constant audible sound can become very distracting and bothersome. The high current is necessary to operate the flashlight lamps. The electronic circuit is of course designed to protect the components from such a high amperage.

PLATE XIV: An overall view of the photo detector apparatus is shown. Note the basic unit on the left in which the electronic circuit is contained.

PLATE XIV



The power supply can be obtained in any Heathkit electronic display commonly found in many public high schools. Or, it may be made from a fairly constant 6 volt battery source hooked in circuit with a rheostat to adjust the proper potential and current flow. It is necessary to have as much of a nonvariable power supply as possible. A 6 volt battery is necessary because, when the power source is connected into the circuit, the overall potential drops.

Analysis

This particular device is the most costly and most complicated tool presented in this work. It is also the most crucial piece of equipment needed for totally blind students to perform experiments dealing with motion. The cost is actually not a complication here because, if money can be saved by designing the other instruments discussed previously, then funds are available for such a photo detecting device. Actually, in retrospect, the cost is very reasonable considering the value and versatility of this apparatus.

However, one may not want to take the time required to build this tool. If this is the case, there are other alternatives possible in order to obtain such an apparatus. If the Heathkit Jr. 36 equipment is accessible to the instructor, there are several simple circuits that can be devised. One is the metronome circuit²⁸ which is used as a bridge circuit. A photo resistor takes the place of the variable potentiometer, and the circuit is connected into the speaker.

Another setup in the Heathkit Jr. 36 is the light sensing alarm circuit.²⁹ This one was not tested to see if it would work as was the previously mentioned circuit. Even so, it is a logical possibility.

Still another variation can be found in the Thornton Catalog³⁰ of

modular electronics equipment. If the APS-101 amplifier power supply is available in the classroom, which may be the case in some schools, the photo cell accessories can be arranged in a simple manner to set up an amplified oscillator circuit. The PHC-100 photocell is perhaps the best choice in this case. This is said because of previous contact with this equipment not related to this particular field of work. Equipment is quite expensive in this case, with a cost in the vicinity of \$120 with the power supply and \$35 without.

The particular device used in this project performs very well. It is the key to the success of the two experiments discussed in depth later. The earplug speaker is convenient for individual work. It creates an atmosphere which enables other classroom activity to be carried on undisturbed. Also, the electronic circuit is fairly well protected. In the event that an overload is produced, the lamps act as a fuse and burn out. This happened once during a demonstration.

CHAPTER III

PROCEDURE AND RESULTS OF THE FOUR WEEK PRACTICUM

This section is an account of how the materials previously described were used in an actual classroom situation. Along with this is a summary of the following: students' backgrounds and capabilities, results and analysis of the experimental work, and the testing procedure. The purpose of this part is to verify the practical aspect of this endeavor and to give an indication of what to look for when these materials and ideas are used in other classroom situations.

A. The People

Robert Johnson has worked at the Kansas State School for the Visually Handicapped for over fifteen years. He has taught everything from English and physical education to mathematics and science. At present, he is the mathematics and physical science instructor for the junior and senior high students. Thus, an opportunity existed to visit the mathematics class which the four general science students attended. Since the level of science instruction depends upon the background in mathematics, it was fruitful to observe and help the people in this subject for a few days so that their degree of understanding could be determined. Mr. Johnson was willing and eager to help in any way to see that this endeavor would be a success. He even assisted in discovering the graph board method discussed in section II-F.

Student #1, a freshman, has been totally blind from birth. His mathematics abilities extend to the realms of algebra, dealing with factoring, solving simultaneous equations, and the like. He is somewhat

scientifically inclined and enjoys doing laboratory work. Students #2 and #3, both freshmen, are at the same level in mathematics. They are not as advanced as the other student mentioned, but they are fairly proficient with the four basic operations of math and have a workable knowledge of fractions and decimals. They, too, have been totally blind from birth. All three of these students have excellent tactile abilities and read Secondary (advanced) Braille very well. Student #2 is exceptional when it comes to speed reading. Even so, she has the most difficulty in making mental connections between successive laboratory events and has a hard time remembering basic techniques. All of the students can use a standard typewriter quite well. One of the most important physical aspects of these people is the fact that none of them have multiple handicaps. An additional handicap would have complicated the testing of the equipment and methods in the work presented here. Finally, each of them is truly dedicated to learning, as mentioned before, and there was never a time when their attention span was lost to the extent of having to put disciplinary action into effect.

Student #4 is presently a sophomore. For being partially sighted, he can see rather well. For this reason, he has been sent to regular public schools in the past. Due to his partial loss of hearing and his lack of motivation, he is presently attending classes at the Kansas State School for the Visually Handicapped. Student #4 was able to work for two weeks with this project in the general science class in which he was also enrolled. He left for home two weeks before the conclusion of school and was unable to finish with the rest of the group. Even so, the time which he spent in class provided some valuable information. Because of his ability to see, a comparison of measurement times and accuracies could be

made between the partially sighted and the sightless using the same equipment.

This research, of course, cannot be considered to be a truly analytical work since statistical analysis is difficult, and questionable, when based on the accomplishments of only three blind and one partially sighted student. However, the observations here provided feedback about the feasibility and suitability of the equipment for teaching blind students.

B. Procedure and Analysis

The schedule for the five week practicum is shown in Table IX. Three days were spent just getting to know the students. Attempts were successfully made to learn about their family background and history, and to discover their capabilities in mathematics. Time was spent helping each student individually with homework and discussing particular interests and goals. On April 24, a small presentation and laboratory situation to investigate the properties of sound waves and tuning forks was taught by the author. Although this topic is not covered in the research, it was a good opportunity to help the students prepare for the next four weeks by learning how the class would be handled and what would be expected of them.

Tuesday, April 29, was the actual beginning of the project at the institution. During that particular week, time was spent orienting the student to the design and general use of the clock timer, the pan balance, and the meter measuring rule. With each apparatus, the student was given a certain object or situation to measure. In the case of the clock timer, reflex speed, as well as being able to read the clock's face, was emphasized and practiced by timing various events. The student was asked to accurately measure the time lapse between two raps on a bell. Not knowing when the second noise would take place made them alert and created

TABLE IX. A calendar is shown depicting the general outline of events and accomplishments during the practicum session.

TABLE IX
PRACTICUM SCHEDULE

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
April 21 Visit and get acquainted	April 22 Not present	April 23 Visit and get acquainted	April 24 Visit and get acquainted	April 25 Not present
April 28 No school	April 29 Introduction to the clock timer	April 30 Introduction to the pan balance	May 1 Introduction to the meter rulers	May 2 Review and practice session
May 5 Metric vs. English systems weight	May 6 Metric vs. English systems length	May 7 Metric vs. English system: volume cubes	May 8 Metric vs. English system: volume review	May 9 Written and practical test
May 12 Not present	May 13 Review test and intro- duction to pendulum	May 14 Data taken for pendulum	May 15 Data taken for pendulum and discuss reports	May 16 Review and collect reports
May 19 Introduction to velocity and air track	May 20 Data taken for velocity measurements	May 21 No class	May 22 Data taken and reports finished in class	May 23 Braille embossing method

a situation similar to the timing of the motion of an air car later in the four week session. Their reflex ability was excellent and significantly sharpened through practice. (see Plate XV)

After an introduction to the balance was presented, an object was given to the student to be weighed. The technique stressed was making an estimate as close to the object's mass as possible, then working from there. Because they cannot aid their comparison with the use of sight, this concept was difficult to grasp for some of the students. Student #2, in particular, had problems with remembering this procedure. She would start by randomly picking any mass weight and go from there to balance the scale. The other students caught on more rapidly and tended to better remember this process for later applications.

The students gained a workable knowledge of measurement with the meter sticks very quickly. They were asked to measure the length and width of the desk top using as much accuracy as possible. After a few attempts, they quickly learned how to accomplish this task with speed. Finally, the last day of this week was spent using the meter stick, timer and balance to work out any difficulties and to acquire a greater sense of competence in using them. (see Plate XVI)

The activities during the second complete week were designed to fulfill two purposes. One was to present an experimental analysis of the differences between the metric and English measurement systems. This laboratory approach of introducing the two systems for the first time is even essential for sighted people. In this way, the students can get a practical knowledge of how they compare and how to convert from one to the other. In the same way, the visually handicapped students methodically determined conversion factors by making concrete observations. In many

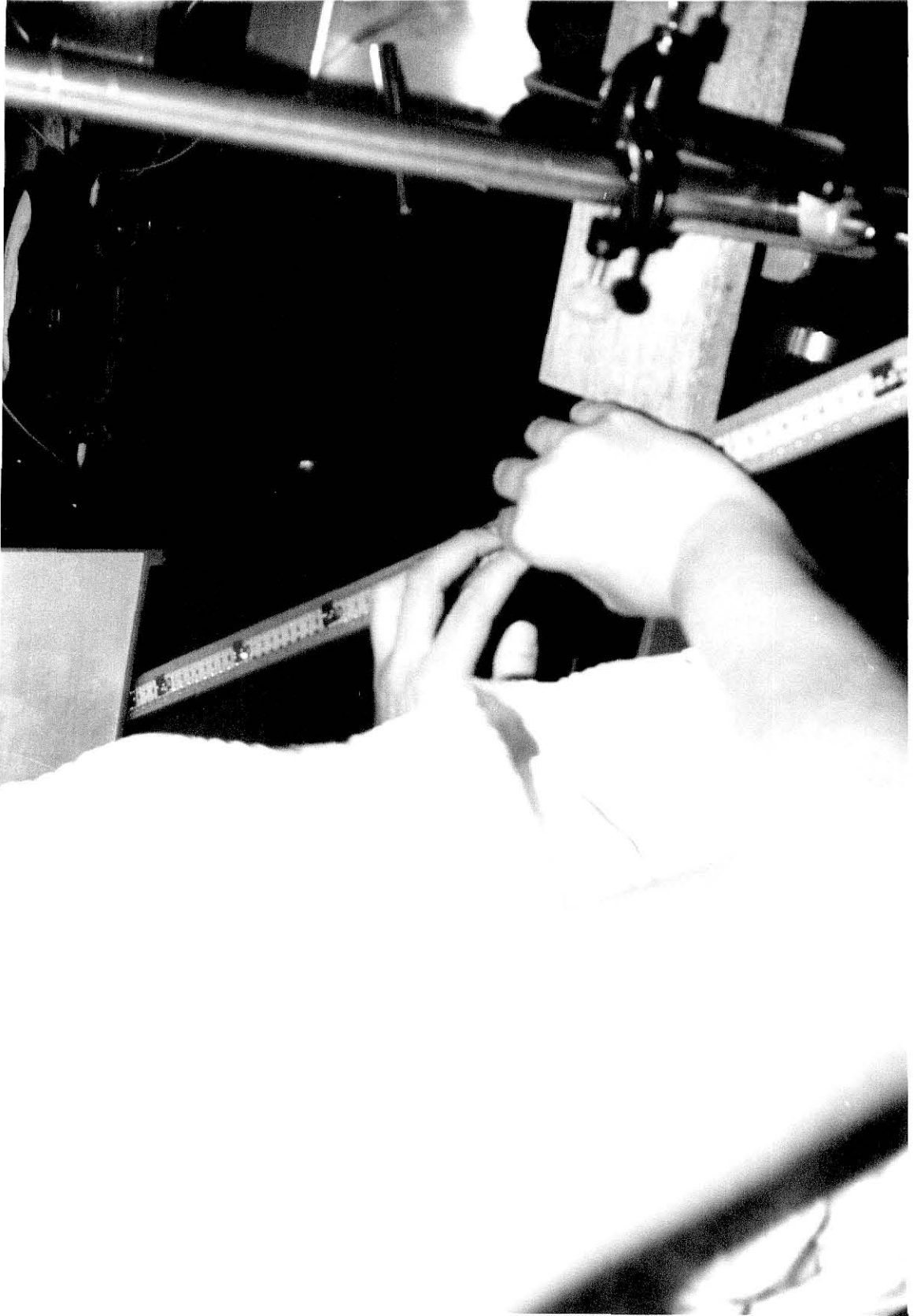
PLATE XV: A student is shown using the clock timer.

PLATE XV



PLATE XVI: A student is shown reading the metric-
scaled meter ruler.

PLATE XVI



institutions, the blind student merely memorizes a system of charts dealing with converting English units to metric units and vice versa. The students working with this project were very excited about having a chance to verify the facts which they had memorized, and then mostly forgotten, in the past. The second purpose of this particular week was to give the people an opportunity to practice further on using the equipment in order to gain proficiency. In this way, they were able to prepare for the practical quiz at the end of the second week, and also prepare to incorporate their knowledge in the experiments to come.

In comparing metric and English weights, each student was asked to find the mass, in grams, of a pound and an ounce. They used their previous experience of operating the pan balance to determine the mass of pound and ounce weights. From this information, they were able to find the proper conversion factors from one system to the other. Similarly, the students were to discover the number of inches in a decimeter and meter, and how many centimeters in an inch, foot, and yard. Again, they were able to set up a series of conversions for the two systems due to their practical experience.

The third day consisted of deriving volume units from the approach of using the concepts of length and the three-dimensional world. For instance, they measured and compared the sides of each volume cube in order to grasp an understanding of how much space a cubic inch or a cubic foot occupies. Then, the connection between metric mass, length, and volume was made. Before this could be done, a short discussion of density was held and the density of water was particularly emphasized. From this, they quickly discovered that one cubic centimeter of water is the same as one milliliter, and it has a mass of one gram. The students found this

fascinating. The next day was even more interesting to the students because, in the laboratory, they were to fill the decimeter cube with water, weigh it, and see if the results agreed with the hypothesis made beforehand. It was a good opportunity to check their recall abilities from the previous day. Also, the volume syringes were introduced for the first time on this day. By using the two 60 cc. syringes, one marked in metrics and the other in English units, they were able to compare the two systems. The 60 cc. metric syringe was the one primarily used to fill the decimeter cube. At this time, the author observed that, due to the error and the time factors, the syringes were not very practical for measuring large volumes. A review was also held to tie together all important points of the last two weeks.

Actually, the most important aspect which was emphasized during the second week was the relative sizes and measurements in qualitatively comparing the two systems, such as one inch being larger than one centimeter and so on. On Friday, a written and practical test was given covering all previous work in the class. A more detailed explanation of the homework assignments and tests is given in the next section.

In the third week, applications of the use of equipment were undertaken in the simple pendulum experiment. Because of some complications, unrelated to the project, the exercise was not started until Tuesday. The entire hour was spent reviewing parts of reading material concerning the pendulum found in their physical science book.³¹ Potential and kinetic energy were discussed along with the ideas dealing with harmonic motion, such as, period and amplitude. The procedure of the experiment was explained, and an introduction of the equipment was given at the end of the hour. This phase was very important because visually handicapped students need to have

an idea of the manner in which things are going to move before they study any effects on the motion. So, each student spent a few minutes just swinging the pendulum back and forth to see how it would react. Also, the idea of how to find the period of motion was explained so that it would take little preparation time to figure out how to go about the experiment the next day. As was hoped, it did not take long before they were well on their way when the next class period came around.

This particular experiment was chosen mainly because it incorporates the use of the pan balance, clock timer, and the meter ruler. All measurements were done in metric units for simplicity. The objective of this endeavor was to help the student investigate which factor, or factors, affect the period of a pendulum in a qualitative manner: length of string, weight of the plumb, or amplitude of swing. The class, as a whole, decided which measurements were to be kept constant and which one was to be the variable. A discussion was also held to decide which variables would actually affect the period according to their understanding of the situation.

One of the people found the mass of the tin bucket which was suspended by a length of string from a cross bar connected to two ring stands. The mass was changed by adding various disc shaped mass weights so that the different trials consisted of 50, 100, and 150 grams. The length was also varied from 20 to 80 centimeters in steps of 20 centimeters, while the mass was held constant at 50 grams. This was measured by placing the meter ruler at the desired length and adjusting the string to raise or lower the pail. The amplitude was varied from a small to medium to a large swing. The author's assistance was needed because, even though the student could initiate the swing, it was difficult at times to figure out how far back the pail was to be pulled. When the mass was varied, the amplitude was kept at

a medium swing and the length was kept at 60 centimeters.

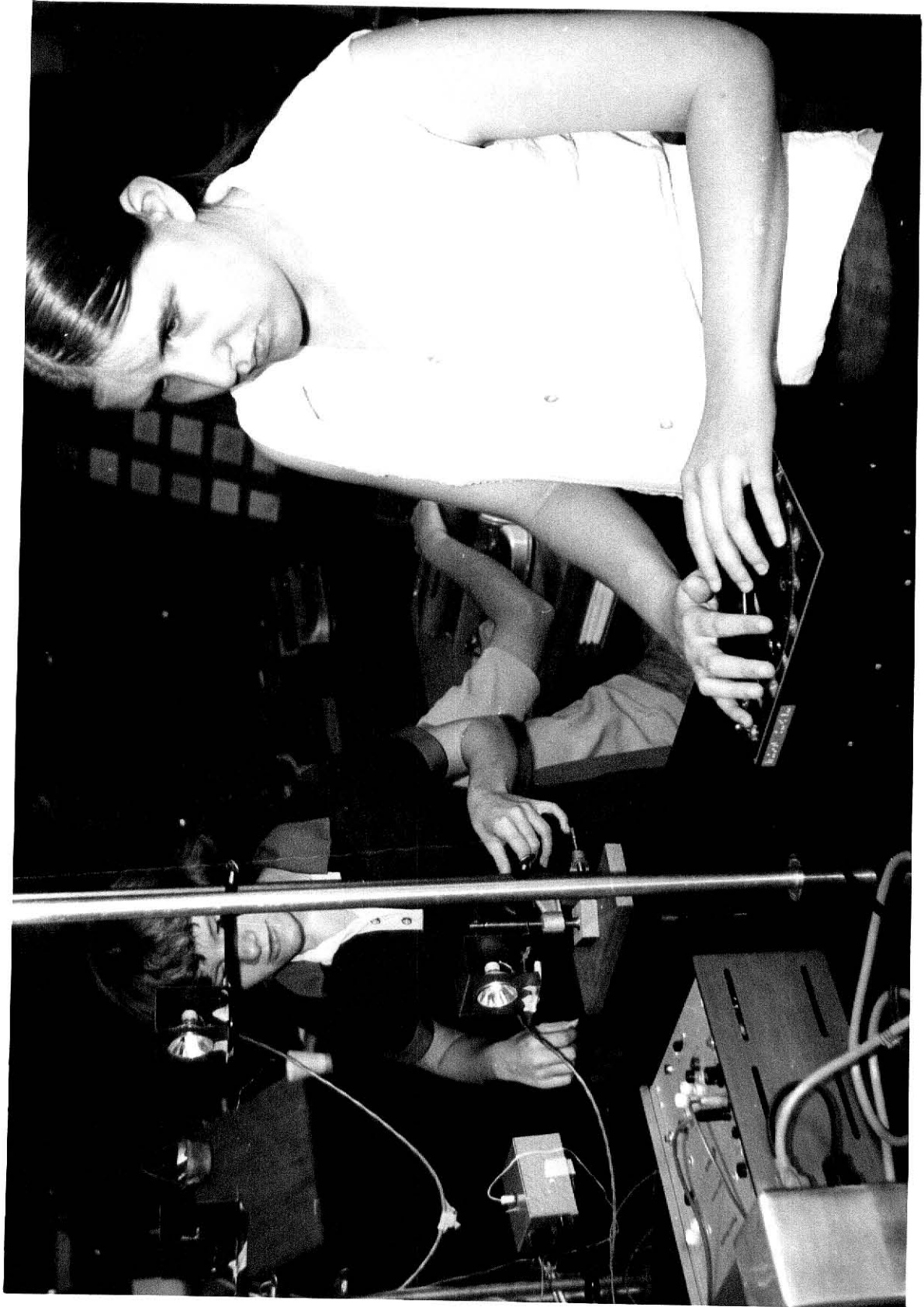
The period of swing was determined by listening for sound impulses produced from the light detector apparatus, and measuring the time interval between forty of them. As seen in Plate XVII, both light sources were utilized by being set up in a vertical fashion on two ring stands. In this way, the source and detectors were not only kept in line so that the device would operate properly, but also, the top half could be used for the shorter lengths of string while the bottom detector could be used for the longer pendulum tests. This saved a few problems in adjusting the detectors so many times. Nevertheless, even though the student could measure the right length for the various trials, there was still some difficulty in aligning the source and detector with the pendulum so that the pail would break the light beam at its static equilibrium point. Therefore, assistance was also needed here in order to properly adjust this part of the setup.

The students were instructed to take two trials of each situation so that an average could be calculated. Data was taken by one student while another operated the timer. The third one initiated the pendulum swing and counted forty beeps caused by the breaking of the light beam. (see Plate XVII) Since the pail breaks the beam twice during each periodic motion, twenty periods were timed. Thus, a good average time for one period could be calculated. The degree of error could have been decreased some by having only one student count the sound impulses and operate the clock at the same time. However, due to the complexity of the operations, some complications would have resulted. The deviation of the readings from the expected results was surprisingly low, and the data was quite accurate and consistent.

After a certain amount of data was taken, the students switched roles

PLATE XVII: The three students are present in the background of the setup for the pendulum experiment. Note the positions of the photo detectors and pendulum "pail".

PLATE XVII



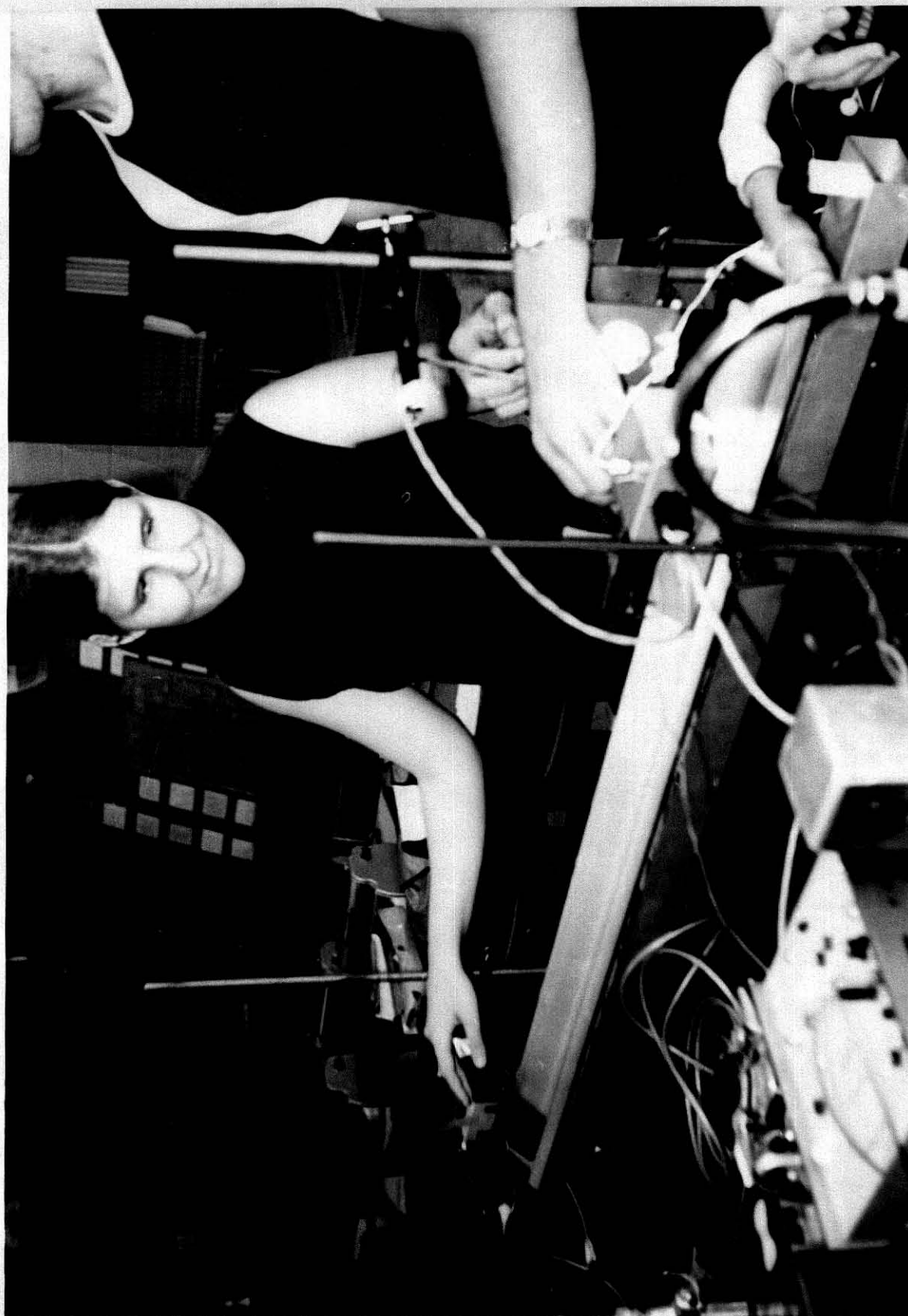
so that each of them could work with all aspects of the experiment. Two days were needed to collect all of the data. At the end of that period, copies of the data were given to each student for their report. Since the level of math of the two girls was fairly low, the required mathematical operations were kept at the arithmetic level, (e.g., finding averages, etc.). The mathematical level is one of the main reasons for dealing only with a qualitative analysis of the exercise. Another reason is that most junior high science courses rarely deal with many quantitative results. Even so, Student #1 was able to see the square relationship between length and period. His observation indicates both the precision of the results and his level of competence. The reports were due the next day, Friday, which was also the time when the data was discussed in full. Actually, none of the students had time to finish their reports until the following Monday.

In a similar fashion, the final week of the practicum was devoted to a second experiment dealing with the aspects of the "frictionless" motion of an air car. The objective of this exercise was again to use various measuring devices in a practical situation. Also, the purpose was to introduce and calculate various motion-related quantities such as average velocity, momentum, and kinetic energy. This time, the laboratory work was more quantitative in nature than the previous one.

Preceding the experiment, time was taken out to discuss the ideas of constant and changing velocity, momentum, and the energy of motion. Also, an introduction of the setup was given. As before, each student was allowed to start a car in motion and "watch" the manner in which it moves and reverses direction at each end. As can be seen in Plate XVIII, the equipment was set up so that a light source and a detector were placed at each end of a 120 centimeter air track. The distance between sources was measured

PLATE XVIII: Two students are shown starting a trial run to eventually find the linear average velocity of the car.

PLATE XVIII

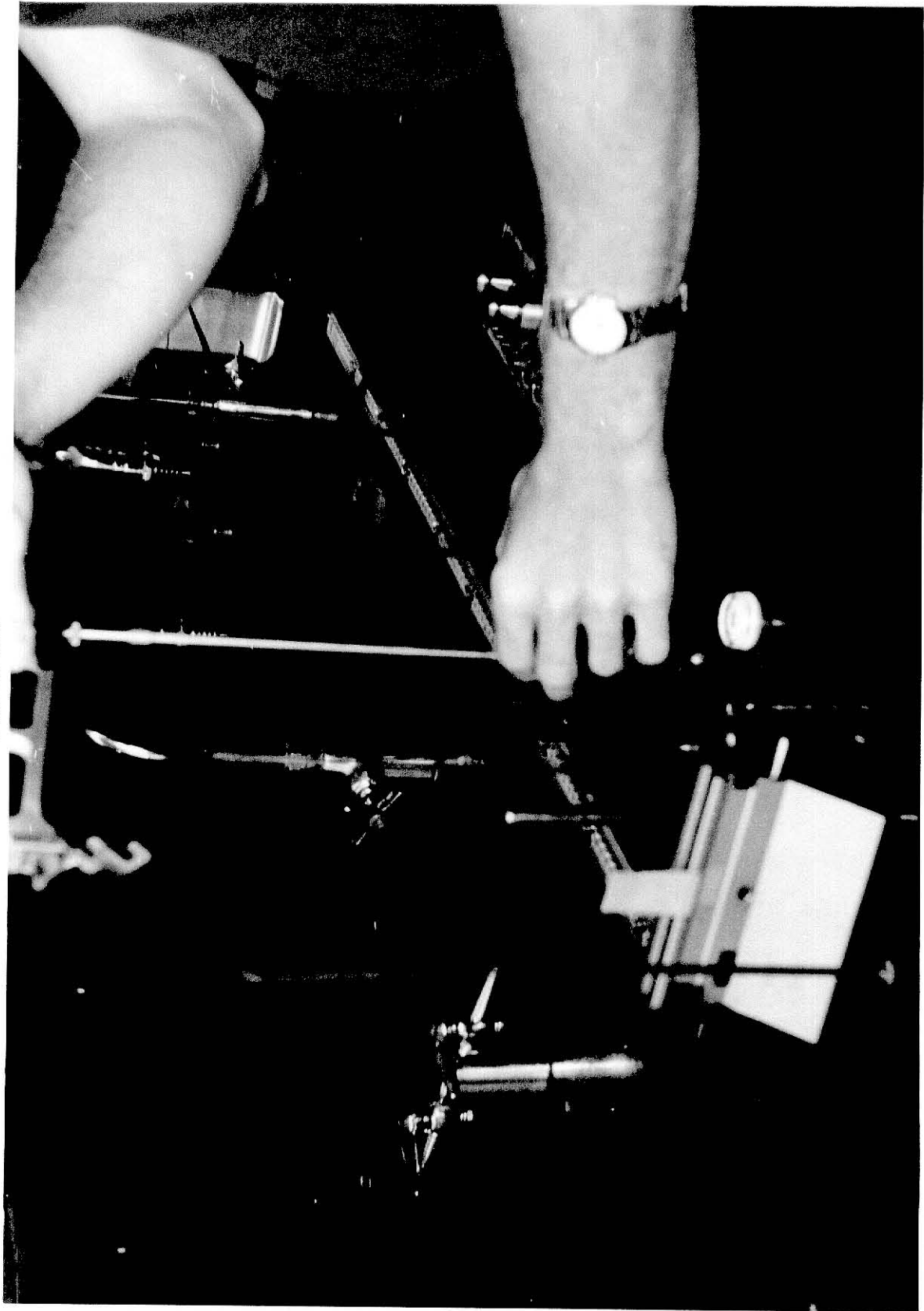


by a student using the Braille meter ruler and was kept at a constant 100 centimeters. The car was first weighed by using the pan balance. (see Plate XIX) This information was incorporated later when the momentum and kinetic energy were to be found. The car was started by one student and another, using the Braille clock, timed the interval between two audio impulse signals caused from a small cardboard flag of the air car breaking the light beam. The third student recorded the results of each trial on a Brailler. Again, it took two full class periods in order to collect data for some slow, medium, and fast velocities. During this time, too, the student took the opportunity to switch roles in order to experience the procedure of the entire experiment. All readings had to be kept separate because, with each start, the car was given a different push force, thus creating a different average velocity. Therefore, no averages were found for several trial readings. For each reading, however, the students were asked to calculate the average velocity, momentum, and kinetic energy of the moving car. This time, in an effort to develop a proper method for writing a presentation of experimental procedure, data and analysis, the report was written during the Thursday class period as a group. It was also a good opportunity for the author to assist with some of the mathematics. Thus, the multiplication computations were done as a class, so that immediate feedback could be given to guide them in the right direction. The reports were collected, reviewed, and returned on Friday.

The last day of the work at the institution was also the last day of the spring session. Thus, nothing of a scientific nature was presented during that class period. However, because the students were so enthralled with the techniques of making permanent, vinyl, Braille labels, they were shown how to do it. In their opinion, this is perhaps the most important

PLATE XIX: A student is shown finding the mass of the air car before beginning the air car experiment.

PLATE XIX



and memorable piece of information they received throughout the entire session. They realized how they would be able to label books, records, tools, and so on without having to get a special embossing device. Thus, their undivided attention was kept until the end of the period, regardless of what day it was.

C. Homework Assignments and Tests

Throughout the entire four week program, two homework assignments, two laboratory reports, and one test was required of the students. All of the instructions, comments, and student work were written in Braille. This created a great opportunity for the author to learn the advanced system of words, partial words, and contractions in the Grade II level of Braille. Let it be a reminder, here, that this need not be the procedure followed by a public school instructor. Oral instructions and comments are easier to issue, and a student's report typed with a standard typewriter is more simple to read. Copies of the assignments were quickly made by putting two to three sheets of Braille paper in the Brailler and transcribing the characters in the normal fashion. If numerical solutions were requested, they were kept well within the mathematical abilities of the two girls. Student #1 still had a challenge in computations even though they were held at a fairly simple level. All assignments were handed in at the required time and promptly graded.

Grades consisted mainly of a comparison of the number correct with the total number possible. As will be seen later, arbitrary numbers were given to the various problems and required assignments. Actually, the total number grade received at the very end was disregarded by Mr. Johnson in terms of an achievement record. The grade was based upon the effort, accomplishment, and enthusiasm of each student according to his or her capabilities.

Mr. Johnson knew much more about these aspects of their character than did the author of this paper. Nevertheless, the number grade was useful in determining the extent to which each student was accomplishing to a previously set goal. In this sense, all students did rather well for their level in school. Both Mr. Johnson and the students believed that the standard of achievement was not set too low. However, the required reading assignments were perhaps a little too few.

The first assignment was to read about length and weight in their science book.³² This assignment was given during the first week. It primarily concerned itself with giving an explanation of those various quantities and the relationship between the metric and English measurement systems. The following homework assignment was requested at the beginning of the second week:

Answer the following questions utilizing the information obtained in the laboratory exercises:

1. How many centimeters are in one inch? (2.54 or 2.5)
 2. How many centimeters are in one foot? (30.5)
 3. How many centimeters are in one yard? (91.5)
 4. How many inches are in one foot? (12)
 5. How many feet are in one inch? ($1/12$ or .08)
 6. How many inches are in one centimeter? (.39 or .4)
 7. How many inches are in one decimeter? (3.9 or 4.0)
 8. How many grams are in one ounce? (28.4)
 9. How many grams are in one pound? (453.6)
 10. How many pounds are in one kilogram? (2.2)
- Bonus: How many yards are in one meter? (1.09 or 1.1)

One can see that most of the questions can be answered by using a direct result from the laboratory. However, another purpose is brought to mind when questions four and five are compared. The simple answer from number four must be used in an abstract way in order to solve problem five, since there is no feasible way to measure an inch in terms of feet by using a ruler. This introduces the technique of reciprocating the previous answer and seeing how it still represents a comparison between the two units. In

other words, there are twelve inches in a foot or one-twelfth of a foot in an inch. Questions six and ten are of the same nature. The bonus question is interesting because one must first break the question into two parts: how many inches in a yard and how many inches in a meter. Then these two figures are divided to get 1.09 yards per meter. No one solved this one correctly even though each person tried.

The questions were worth two points apiece. The primary grading criteria were the correct numerical answer at least to the nearest five tenths (except for the bonus), showing the proper position of the decimal point, and showing the mathematical procedure for getting the answer. All students did rather well with grades ranging from 15 to 17 points. This was a good exercise to get them involved in both a practical and an abstract experience with metric and English conversion. It also gave some indication as to how the students could deal with abstraction.

The following is a copy of the quiz given on Friday of the second week:

Written (see Plate XX)

When answering each question, do not use abbreviations, such as, cm., ml. Show all work and indicate the correct units for each numerical answer.

1. Using the correct prefix, what is 10 grams called? (one decagram)
2. If I had .01 liter, what would it be called, using the correct prefix? (one centiliter)
3. Is a decimeter larger or smaller than a foot? (smaller)
4. Is 2 pounds heavier or lighter than 2 kilograms? (lighter)
5. 2,000 cc of water is how many liters of water? (2 liters)
6. How many kilograms does 2,000 cc of water weight? (2 kilograms)
7. How many grams does 30 milliliters of Oak wood weigh? Oak has a density of .8 grams per cc. (24 grams)

Practical

1. Measure the length and width of the given object to the nearest .5 cm. (33.0 x 16.5 centimeters sq.)
2. Weigh the given object to the nearest gram. (25 grams)
3. Time the given event to the nearest tenth of a second. (17.0 seconds)

As can be seen, the first couple questions test their understanding of

PLATE XX: Students are shown taking the written part of
the quiz at their Brailers.



PLATE XX

prefixes in the metric system. The next ones deal primarily with qualitative relationships between the two systems. The last ones have to do with the relationships between various metric units of measurement and the concept of density. All numerical answers were asked to be accurate to the nearest tenth, except for the practical section. Also, each question was worth two points.

The three practical problems were given to show some indication as to how competent and accurate they could be while using the prepared measuring tools dealing with length, weight, and time. Each student was given a steel ball to weigh, a rectangular piece of wood to measure length and width, and 1 17-second interval on a wristwatch to measure. The latter was achieved by announcing the beginning and stopping point and having the student listen to the commands. This question concerning the timer not only tested the ability of the students, but also their reaction time, which was a certain factor in coming close to a 17 second reading or not. Again, each question was worth two points.

The grading was based on numerical accuracy, proper decimal point position, correct prefix or word, and showing the arithmetic and proper units for numerical answers. The students again did well with scores ranging from 13 to 19 points. A lot of the difficulties occurred in the last three questions of the written part, indicating a lack of understanding due to a possible short and inadequate treatment of these particular topics.

The next week dealt primarily with pendulum motion, so a reading assignment was given on Monday from the students' textbook.³³ The assignment dealt with forms of energy and an example discussion of the pendulum. Four questions at the end of the chapter were assigned to be handed in by Wednesday of that same week. The following list is an example of two of

the questions:

1. Explain what kind of energy a car has at the top of a hill and as it is rolling down the hill. Why?
2. What kind of energy does a pendulum have at the top of the swing, during the swing, and at the bottom of that swing? Why?

These questions gave the students a general working knowledge of the two types of energy and a foundation for understanding the motion of a pendulum. The questions were graded in class and were worth two points apiece. The scores were not recorded because they were so low due to the poor understanding of the material. It is felt that more time definitely needs to be spent on the topic of energy because of the importance of the concepts and their wide usage. Nevertheless, the small introduction somewhat aided the students' discovery of the cause of motion of a pendulum.

Finally, two laboratory reports, one each for the pendulum and velocity experiments, were required. The following is the basic format which was suggested and discussed before either of the two reports were assigned:

Objective or Purpose -- a couple of sentences
 Procedure -- a brief paragraph dealing with basic techniques
 Data -- usually taken in class on a separate piece of paper
 Calculations -- mathematical work showing the general method of getting numerical answers
 Conclusion and Questions -- data analysis and discussion along with any questions assigned which deal with the experiment

Again, the entire report, in each case, was written in Braille. The first write-up was done at home over the weekend after the third week's experiment. There was a special question assigned to this work which asked, "What would you alter if your Grandfather clock was running slow -- the pendulum weight, length, or amplitude?" Most students were quick to answer this correctly by transferring practical observations to a theoretical problem. This was a good opportunity to see how well the students could organize and present information in written form without much intervention

from the instructor. As a result, the reports were somewhat vague and incomplete. The scores ranges from 6 to 9 out of a possible 10 points. This actually was a marvelous accomplishment for the three people in the class because it was the first laboratory report they had ever written.

The reading material for the activities during the fourth week was again found in the textbook.³⁴ The sections assigned dealt with the concepts of motion and Newton's laws. In the discussion, the ideas of instantaneous velocity, average velocity, acceleration, and momentum were dealt with. No special questions concerning the experiment were required from the book or after the work was finished in the laboratory.

The second experimental write-up was done using the same format as was used for the first. This time, it was completed in class under the strict guidance of the instructor. By doing this, the students were able to almost identically copy the information in the proper form as the instructor dictated the various ideas and observations. Each student then had an example of a complete and orderly laboratory report. Because it was a class effort, this one was not graded. It was given directly back to the students for a later reference if and when they are required to write another such report in a future science class. The opinion of the author is that visually handicapped students should be required to write laboratory reports in science classes. It provides a means for them to have a good system of organizing experimental experiences and keeping a reference of previous classroom activities. Again, it would be advisable for the public school instructor to have the people type their reports using a standard typewriter so that it is less cumbersome to read.

CHAPTER IV

SUMMARY AND CONCLUSION

It is not within the scope of this report to list detailed statistical findings. However, the following general observations and conclusions seem pertinent.

Much of the success of this project is due to the enthusiasm and interest of the students during the practicum session. All were eager to learn in a laboratory situation. According to the critiques written by the students and Mr. Johnson, they were impressed with the smooth operation of the entire session. Most of all, they enjoyed learning new ideas in a way different from the methods used previously. Because of this, they portrayed no sign of disciplinary problems.

The homework and quiz grades reveal that there was a good understanding of the material presented. All three students appeared to be at approximately the same emotional level of stability due to the near equal performance in most instances. Student #2 was somewhat lacking in this respect, which may have been the cause of some inability to retain concepts and techniques from one day to the next.

With practice, the students were able to use the instruments quite efficiently and with speed. Hence, with daily use and practice, it is felt that many blind students at this level could use the altered equipment as rapidly and as accurately as a sighted person. One major observation related to this is that much individual attention is needed in order for each student to initially grasp the basic concepts involved in using these items. This fact may tax the time of a public high school instructor. He or she may find it somewhat difficult to continually divide his or her attention

between the regular class and the special handicapped student.

It can be emphasized again that the instruments altered in this project are useful in other fields of study and can be used by people with sight. The latter is proven by the fact that Student #4, as well as Mr. Johnson and the author, was able to use the same equipment to measure the same things with similar accuracy. It can also be concluded that Braille-reading students can perform general physics laboratory experiments dealing with motion when using the equipment designed in this project. Results of the experiments show this, especially the pendulum experiment. The error in the results taken by the students was within 25% of the expected outcome.

This project is by no means an end to the work that must be done in this field. It is only an introduction and a beginning of ideas which can unfold in all directions. It is the challenge, now, of public school instructors to be stimulated to continue this work. It only takes a little time, creativity, and heart to develop a way for blind students to learn about the physical world around them. The motivation must come from someone in order for them to realize that their limitations are only fantasies of the mind.

APPENDIX

This section is devoted to giving a brief description of other ideas which can be developed and employed in the science classroom. First of all, other types of altered equipment will be discussed, and then a suggestion of related experiments will be given.

The hot plate shown in Plate XXI was designed but not used in the practicum session due to the lack of time. This basic technique can be used for any instrument which uses a scaled dial for a variable quantity such as potentiometers and other electrical apparatus.

For large volume measurement, graduated cylinders can be altered for use by a blind student. A cork can be used as a float inside the container. A piece of string can be attached to the cork and extended to the outside of the cylinder. The scale on the graduate is reversed, when marked in Braille, so that the pointer needle attached to the other end of the string can indicate the proper volume. When the container is filled, the cork floats, allowing the needle to descend. Weights probably should be used to insure proper stabilization of the cork and the pointer needle. This method was not attempted in this study, also due to the lack of time.

Theoretically, a thermometer can be made using the photo detector circuit. By replacing the photo cell with a linear thermistor probe and a frequency generator, the circuit will produce a resonance at the correct temperature reading. This also was not accomplished in this project though attempts were made at doing so. Further investigation into the problem is needed before anything else can be said concerning the topic. If accomplished, though, a thermometer with an accuracy of .5 degrees will be available to the blind student. This is the same accuracy as any standard

PLATE XXI: A close-up view of the altered hot plate is shown. Note the wire pointer which indicates the degree of heat as dial is turned.

PLATE XXI



mercury thermometer.

Experiments related to this work can also be tried in the classroom even though they were not attempted in this project. Archimedes Principle and density can be studied using the Braille graduated cylinder. Pressure, volume, and temperature relationships can be studied as well as the heat of fusion and vaporization. Light intensity can be studied using the photo cell circuit, since the intensity of the audible sound varies with the distance from the light source.

Other experiments related to the air car equipment are average linear acceleration, conservation, laws of motion and energy and collision effects. Also, the motion of a spring pendulum, as well as other harmonic motion experiments, can be studied using the photo detector circuit. Actually, the list of possibilities is limitless.

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INEXPENSIVE SCIENCE MATERIALS

FOR THE INSTRUCTION

OF THE VISUALLY HANDICAPPED

by

JAMES A. BAUGHMAN, JR.

B.A., Benedictine College, 1973

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Physics

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1975

Basic measurement instruments already existing in a typical public high school science laboratory were altered for visually handicapped students' use. The alterations are inexpensive, simple, and not time-consuming in construction. Materials for construction are found in most common department stores. Instruments consisted of a meter ruler, pan balance, volumetric syringes, clock timer, and other related devices. A four week practicum was spent with three totally blind General Science high school freshmen. The time was used to test the efficiency, simplicity and usefulness of the home-made devices. Highlights of the practicum were laboratory discoveries of the comparison between the metric and English measurement systems. Two general physics experiments dealing with the simple pendulum and linear average velocity were included to present a practical opportunity to use the instruments. From tests and homework results, the author supports the finding that sightless Braille-reading students are capable of comprehending and handling a laboratory situation at a general physics level. Further development of other related ideas is suggested and left to the reader's creative imagination.